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Natural Resource Program Center

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Natural Resource Report NPS/CUPN/NRR—2011/XXX

ON THE COVER
(Clockwise starting at top-left) Portable Ozone Monitoring Station at CHCH in 2010, patch of common milkweed plants at MACA in 2010 and a foliar injury sampling site at ABLI in 2008.
Photographs by: Johnathan Jernigan

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Contents

Page

Background and Objectives 11
Issues Being Addressed and Rationale for Monitoring 12
Ozone Effects *12*
Factors Affecting Plant Response to Ozone *14*
Computing Exposure Indices *14*
Thresholds for Exposure Indices *15*
Established Methods Used by this Protocol *15*
Brief Description of the CUPN 15
Historical Development of Ozone Concentration Monitoring within the CUPN 16
Historical Development of Foliar Injury Monitoring within the CUPN 19
Measurable Objectives 20
Sampling Designs 21
Sampling Design Overview - Ozone Concentration 21
Sampling Design Overview - Foliar Injury Assessments 21
Site and Species Selection 22
Ozone Sample Frequency and Replication 23
Foliar Injury Sample Frequency and Replication 23
General Sampling Schedule 23
Field Methods 11
Preparations for Ozone Sampling 11
Preparations for Foliar Injury Sampling 12
Sampling Methods – Ozone Concentration 12
Reasons for Choosing this Method Rather than Others *12*
Sampling Methods – Foliar Injury Assessments 13
Voucher Specimens *13*
Photography of Voucher Specimens *14*
Reasons for Choosing this Method Rather than Others *16*
Data Management 16
Overview of Database Design 16
Data Processing 16
Data Archiving 17
Metadata Procedures 17
Analysis and Reporting 17
Data Analysis 17
Reporting 18
Personnel Requirements and Training 19
Roles and Responsibilities 19
Qualifications and Training 19
Operational Requirements 19
Ozone Field Schedule 19
Foliar Injury Field Schedule 20
Combined Ozone and Foliar Injury Annual Workload 20
Facility and Equipment Needs 21
Startup and Monitoring Costs 21

Procedure for Revising the Protocol and Archiving Previous Protocol Versions 22
References 23
Acknowledgments 24
Standard Operating Procedure (SOP) #OC1: Ozone Concentration - Training of Field Personnel 26
Standard Operating Procedure (SOP) #OC2: Ozone Concentration - Pre-Sampling 27
General Site Visit Preparation 28
Scheduling Site Visits with Host Parks 29
Preparing a POMS for Use in the Upcoming Season 29
Preparing to Install or Remove a POMS 29
POMS II Components 29
POMS III Components 30
Pre-trip Checklist 30
Standard Operating Procedure (SOP) #OC3: Ozone Concentration – Establishment and Location of Sampling Sites 32
Establishment of Sampling Sites 32
Site Selection Criteria 33
Standard Operating Procedure (SOP) #OC4: Ozone Concentration - Removing, Installing and Servicing a Portable Ozone Monitoring Station 35
Assembly and Disassembly of a Second Generation POMS (POMS II) 35
POMS II Assembly 35
POMS II Disassembly 38
Assembly/Disassembly of a Third Generation POMS (POMS III) 40
Biweekly Maintenance Visits: Servicing an Installed Second or Third Generation POMS (POMS II or POMS III) 42
POMS II Checklist 42
POMS III Checklist 44
Notes on Modes and Commands Used by the Campbell Scientific Datalogger in a POMS II 46
Modes 47
Flags 48
Standard Operating Procedure (SOP) #OC5: Ozone Concentration - Post-Sampling 49
Closing out a trip to move a Portable Ozone Monitoring Station (POMS) 49
Storage of a POMS 49
Standard Operating Procedure (SOP) #OC6: Ozone Concentration - Data Management 50
Introduction 50
Data Validation 50
Database Administration 52
Data Maintenance 52
Data Organization 52
Data Security and Integrity 53
Version Control 53
Data Logs and Backups 53
Data Availability 53
Literature Cited 53
Standard Operating Procedure (SOP) #OC7: Ozone Concentration - Data Analysis 54
Data Flow 54
Data Analysis 54
NAAQS and Cumulative Exposure Indices 56

Time Series and Diurnal Plots *58*
Standard Operating Procedure (SOP) #OC8: Ozone Concentration - Reporting 59
Report Format 59
General59
Tables 60
Figures 60
Pictures *60*
Report Outline *60*
Review Procedure 61
Internal Review *61*
Park Review *62*
External Review *62*
Distribution Procedure 62
Identifying Stakeholders *62*
Distributing Reports *62*
Literature Cited 63
Standard Operating Procedure (SOP) #OC9: Ozone Concentration - Revising the Protocol 64
Procedures 64
Standard Operating Procedure (SOP) #FoIn1: Foliar Injury - Training of Field Personnel 66
Standard Operating Procedure (SOP) #FoIn2: Foliar Injury - Pre-Sampling 67
USFS Workshop/Certification and NPS-ARD Online Training 67
General Site Visit Preparation 68
Standard Operating Procedure (SOP) #FoIn3: Foliar Injury - Establishment and Location of Sampling Sites 69
Establishment of Sampling Sites 69
Standard Operating Procedure (SOP) #FoIn4: Foliar Injury - Sampling 70
Foliar Injury Sampling Procedure 70
Standard Operating Procedure (SOP) #FoIn5: Foliar Injury - Post-Sampling 76
Standard Operating Procedure (SOP) #FoIn6: Foliar Injury – Data Management 77
Introduction 77
Data Entry, Verification, Validation. 78
Database Administration 78
Data Maintenance *78*
Data Organization *78*
Data Security and Integrity *79*
Version Control *79*
Data Logs and Backups *79*
Data Availability 80
Literature Cited 80
Standard Operating Procedure (SOP) #FoIn7: Foliar Injury - Data Analysis 81
Data Flow and Data Analysis 81
Standard Operating Procedure (SOP) #FoIn8: Foliar Injury - Reporting 83
Report Format ..... **Error! Bookmark not defined.**
General ***Error! Bookmark not defined.***
Tables ***Error! Bookmark not defined.***
Figures ***Error! Bookmark not defined.***
Pictures ..... ***Error! Bookmark not defined.***
Report Outline ..... ***Error! Bookmark not defined.***
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Distribution Procedure ..... **Error! Bookmark not defined.**
Identifying Stakeholders ..... ***Error! Bookmark not defined.***
Distributing Reports ..... ***Error! Bookmark not defined.***
Literature Cited ..... **Error! Bookmark not defined.**
Standard Operating Procedure (SOP) #FoIn9: Foliar Injury - Revising the Protocol 84

Background and Objectives

Ground level (tropospheric) ozone is a secondary pollutant, meaning that ozone is not directly emitted by sources, but is created through chemical reactions between primary pollutants that are emitted directly from sources such as power plants, automobiles and factories (Great Smoky Mountains National Park 2006). The U.S. Environmental Protection Agency (EPA) maintains that ozone is "Good up high, bad nearby" (EPA 2003). This is because, up high (in the stratosphere), the ozone layer protects Earth from ultraviolet radiation. Down low (in the troposphere), however, higher concentrations of ozone are undesirable since breathing ozone is harmful to humans.

Figure 1. Foliar injury on spreading dogbane. Photo was copied from Kohut (2007).

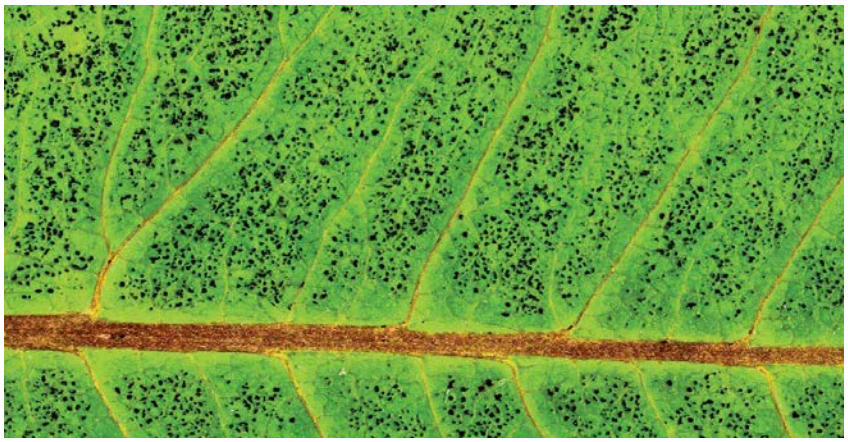

Figure 2 – Close-up of ozone injury on common milkweed. Image downloaded from the USFS website http://nrs.fs.fed.us/fia/topics/ozone/default.asp.

Ozone also damages plants and crops (EPA 2003). An example of an ozone-injured plant leaf is shown in Figure 1. The image was copied from Kohut (2007). Figure 2 shows a close-up of foliar injury on common milkweed (downloaded from the United States Forest Service (USFS) website). Each of the small spots on the leaves is ozone injury. In comparison, the leaf shown in Figure 3 (downloaded from http://www.geo.sunysb.edu/bad-ozone/index.html) also exhibits ozone injury, but, on the sweet gum leaf, injury manifests itself as something that looks more like fall color. So, the appearance of ozone injury varies amongst species.

Figure 3 – Ozone injury on a sweet gum leaf. Note the uninjured portion of the second leaf in the upper-right section of the image. That portion of the second leaf was shaded by the first leaf. Image downloaded from http://www.geo.sunysb.edu/bad-ozone/index.html.

Sensitivity to ozone also varies amongst species (Rose and Coulston 2009) and runs the gamut from not being sensitive at all to being very sensitive. For example, black cherry (*Prunus serotina*) and several blackberry species (*Rubus spp.*) are sensitive to ozone while white oak (*Quercus alba*) is not (Smith et al 2007).

The objective of this protocol is to provide the Cumberland Piedmont Network (CUPN) and its parks with ozone concentration and injury data. The data collected will primarily address two questions: are ozone concentrations high enough to cause injury to plants and is that injury occurring? Ancillary issues, such as whether ozone concentrations are high enough to violate human health standards, will also be explored.

This protocol is divided into two sets of sampling designs and methodologies. The first set of designs/methodologies provides ozone concentration data in CUPN parks using established methods. The SOPs for this set of designs/methodologies use the prefix "OC". The second set provides foliar injury data (with the validity of its data being supported using voucher specimens) in CUPN parks using established methods. The SOPs for this set of designs/methodologies use the prefix "FoIn". When these two data sets are collected over multiple years, correlation between ozone concentration and severity of foliar injury may be explored. The NPS and policymakers may use this information to prescribe actions that may, at the least, reduce ozone injury to plants.

Issues Being Addressed and Rationale for Monitoring

Ozone is formed through chemical reactions between nitrogen oxides and volatile organic compounds (both of which are emitted by anthropogenic sources such as automobiles, power plants and factories). Volatile organic compounds are also emitted by plants (Ray 2004). The chemical reactions are catalyzed by sunlight, resulting in generally higher concentrations of ozone during summer.

Ozone Effects

Ray (2004) lists several ways that ozone negatively affects human health. What follows is a verbatim list of the effects listed by Ray (2004).

- Acute respiratory problems, such as
    - Aggravation of asthma

    - Temporary decreases in lung capacity in some adults
    - Inflammation of lung tissue
- Impairment of the body's immune system

Vegetation is also negatively affected by ozone. Extensive research (such as exposing plants to various concentrations of ozone in gas chambers and observing the plants' responses) has shown that ozone causes the stipple shown in Figure 1 as well as the other effects listed in the overview (Negra et al 2009). Several species have been examined and it has been determined that different species (and even different individuals within the same species) have different tolerances to ozone. That is, some species are generally more able than others to withstand higher ozone exposure.

While many studies of plant response to ozone have been undertaken in controlled laboratory settings, plant response has also been studied in natural settings. Ray (2004) notes that these studies have shown that foliar injury occurs at levels well below EPA's air quality standard. In addition, Ray (2004) notes that studies have documented foliar injury in national parks. Even some of CUPN's assessments (conducted using the draft version of this protocol) in 2008 and 2009, have shown that foliar injury is occurring in CUPN parks (Jernigan et al 2009 and Jernigan et al 2010).

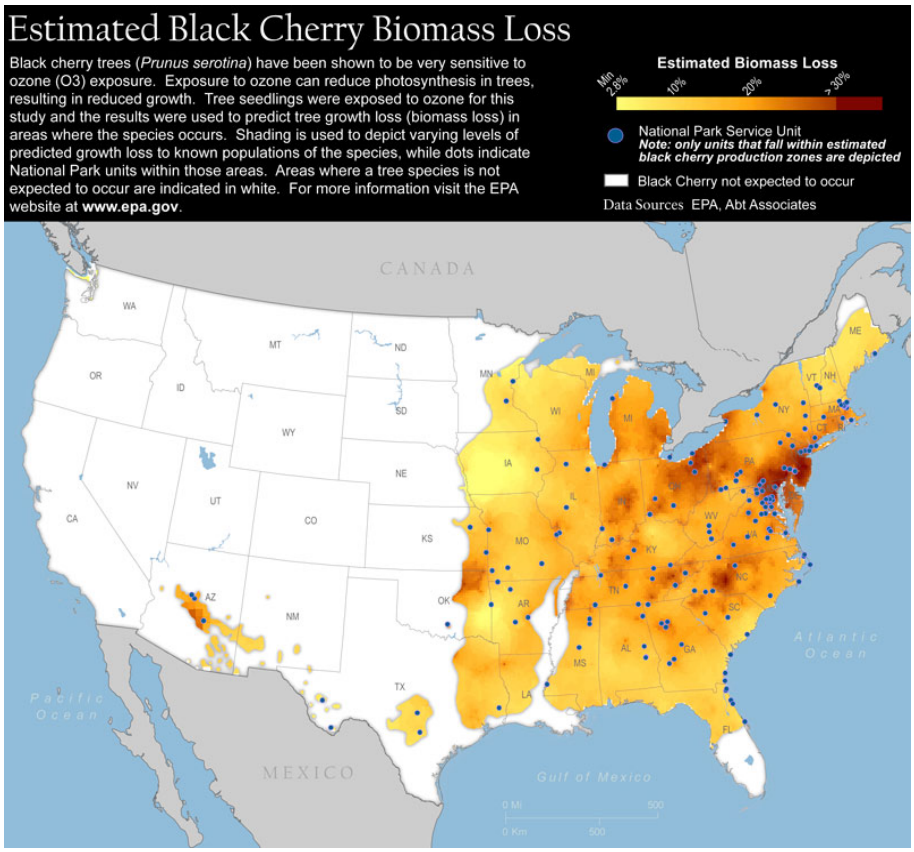

Figure 4 – Map showing loss of black cherry in forests as a result of ozone injury. Image downloaded from http://www.nature.nps.gov/air/aqbasics/TreeGrowth/index.cfm.

Ray (2004) states that ozone enters leaf stomata and oxidizes plant tissue. This exposure results in changes to biochemical and physiological processes. Ray (2004) also states that severe cases of foliar injury can lead to growth effects to particular plants and that long-term exposure to such plants can lead to shifts in species composition wherein more sensitive species are replaced by less sensitive species. For example, note the black cherry decline shown in Figure 4 (downloaded from http://www.nature.nps.gov/air/aqbasics/TreeGrowth/index.cfm). Grantz (2009) further indicates that the exact nature of changes in species composition is reliant not only on ozone concentration but also on other complicating factors.

Factors Affecting Plant Response to Ozone

Simply having sensitive plants in the presence of high levels of ozone does not guarantee that those plants will be damaged by ozone. There are conditions under which sensitive plants may not be significantly affected even with high ozone exposure. This is a consequence of the need for ozone gas to enter the interior of the leaf through the stomata. If environmental conditions are not favorable for gas exchange, foliar injury is less likely to occur. Two conditions that lead to a decrease in gas exchange are high air temperature and drought. Plants in hot and dry (low soil moisture) conditions may close their stomata, resulting in less ozone within the leaf interior and, therefore, less exposure of the plant to ozone (Kohut 2005).

Conversely, ozone injury can be exacerbated under certain conditions. For example, if moisture availability is above average when ozone concentration is only average, injury to a plant can be similar to injury under average moisture availability and above average ozone concentration. Ray (2004) lists the following as factors that can enhance the risk of ozone injury:

- Existence of sensitive species
- Ozone concentrations high enough to cause injury
- Environmental conditions that support plant respiration

Computing Exposure Indices

Ray (2004) notes that to quantify the likelihood that a plant will be damaged by ozone, indices have been developed (the SUM06, W126 and N100). In the past, the CUPN has used the SUM06. However, the EPA is considering the strengthening of its secondary standard (whose purpose is to be protective of plants and natural ecosystems). That strengthened standard will be based upon the W126. As such, the CUPN will begin using the W126 statistic when analyzing ozone and foliar injury data. Ray (2004) defines the W126 as "a cumulative index that is calculated as the maximum running 90-day sum of the 0800-2000 weighted hourly ozone concentrations, where a sigmoidal weighting function is used to give increasing significance (weights between 0 and 1) to concentrations of ozone greater than 0.04 ppm, and no weight to concentrations below 0.04 ppm."

The W126 may be computed using only values from 8 AM to 8 PM (the hourly values reported for 8 AM to 7 PM, inclusively). It may also be computed using all data available, including nighttime data. The W126 over a given period of time is defined by the equation

where c_i is the hourly ozone concentration expressed in ppb and n is the number of hours with valid ozone measurements. The equation is based on the information in the presentation found at http://www.epa.gov/ttn/analysis/docs/W126_Steps%20to%20Calculate_revised_Mar9.pdf. Frequently, the W126 is computed for each possible 3 consecutive month period in the growing season and the largest of those values is taken as the W126 for the season. We will also compute the W126 simply by computing the summation above for the entire growing season. The CUPN will compute these W126 values for its annual reports by following the guidelines posted at http://www.epa.gov/ttn/analysis/w126.htm. However, we will not, in general, be able to compute a 3-year average of the W126 since we will only be collecting ozone concentration data for one year at a time.

Thresholds for Exposure Indices

Ray (2004) also provides estimates for W126 threshold values above which effects to plant health can be expected. Ray's W126 estimates include accompanying N100 thresholds. Those N100 statistics will not be considered by the CUPN since the EPA's proposed secondary standard is based only upon the W126 (see http://www.epa.gov/groundlevelozone/fr/20100119.pdf for more information). Ray's W126 thresholds are:

	W126	N100
Highly Sensitive Species	5.9 ppm-hr	6
Moderately Sensitive Species	23.8 ppm-hr	51
Low Sensitivity	66.6 ppm-hr	135

In 2010, the EPA proposed that the secondary standard no longer be the same as the primary standard. According to NPS-AIR (2010), that standard would prescribe a W126 value between 7 and 15 ppm-hours. The EPA is also proposing a method for computing the W126 that would be based on a 3-year average rather than an annual value. Since at each park the CUPN will only measure ozone for one year at a time, the CUPN will only be able to compute annual W126 values. Further discussion of ozone, ozone exposure indices and foliar injury may be found in U.S. Forest Service et al (2010).

Established Methods Used by this Protocol

The literature available on ozone and foliar injury is myriad. A comprehensive review of this literature is beyond the scope of this proposal. As such, the authors will primarily discuss only those documents which are directly influential to our sampling designs and methods. Those are Kohut (2007), Ray (2004) and the USFS' standard operating procedure for conducting foliar injury surveys (USFS 2005). Our ozone monitoring SOPs are based upon the work by Ray. Our foliar injury sampling SOPs are based upon the USFS protocol and are influenced by the Kohut protocol.

Brief Description of the CUPN

The Cumberland Piedmont Network (CUPN) is part of the NPS Inventory and Monitoring Program. The CUPN contains parks with a varying mix of natural and cultural resources. It is comprised of the fourteen parks listed in Table 1. Park abbreviations as used throughout this

protocol are also listed in Table 1. Figure 5 is a map showing the locations of the fourteen parks (Leibfreid et al 2005).

Table 1 – List of CUPN parks and their abbreviations.

Park Name	Abreviation
Abraham Lincoln Birthplace National Historic Site	ABLI
Carl Sandburg Home National Historic Park	CARL
Chickamauga & Chattanooga National Military Park	CHCH
Cowpens National Battlefield	COWP
Cumberland Gap National Historical Park	CUGA
Fort Donelson National Battlefield	FODO
Guilford Courthouse National Military Park	GUCO
King's Mountain National Military Park	KIMO
Little River Canyon National Preserve	LIRI
Mammoth Cave National Park	MACA
Ninety-Six National Historic Site	NISI
Russell Cave National Monument	RUCA
Shiloh National Military Park	SHIL
Stones River National Battlefield	STRI

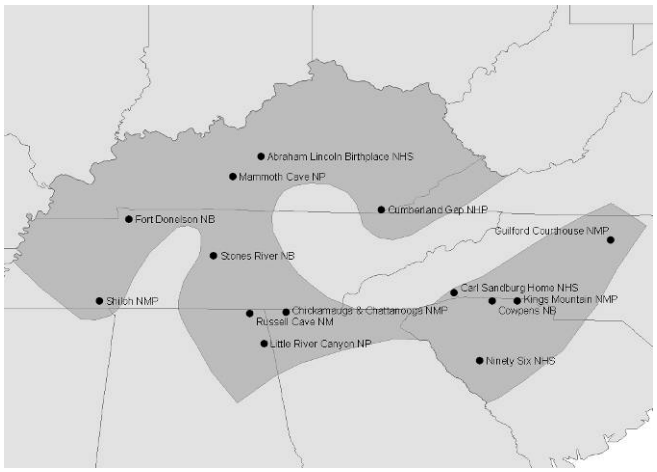

Figure 5. NPS units that make up the CUPN.

Sampling in Cultural and Historical Parks

All of CUPN's parks have significant cultural resources, and, for many of those parks, cultural and historical preservation is the primary objective. Ozone is nevertheless a concern at those parks. The NPS maintains cultural landscapes just as it preserves and protects natural ecosystems, and ozone can cause damage to plants that are part of a cultural landscape. For more information on cultural landscapes and NPS efforts to maintain them, see http://www.cr.nps.gov/hps/tps/briefs/brief36.htm.

Management at most cultural and historical parks is concerned with acid rain since it can dissolve historic structures such as limestone grave markers, buildings and monuments. Most of these parks do not have the resources to monitor acid rain or its causes (pollutants consisting primarily of sulfur and nitrogen compounds). Ozone is a good surrogate for nitrogen compounds. Since "clean" air masses generally don't contain excessive amounts of ozone, it can be assumed that if ozone is low then it is likely that nitrogen compounds will be as well (assuming that ozone is not reacting with other precursor emissions and being consumed). So, in

order to lower ozone concentrations, nitrogen compounds must be lowered. That is, efforts to lower ozone should result in less acidic rainfall thereby reducing impacts to structures in historic and cultural parks.

Historical Development of Ozone Concentration Monitoring within the CUPN

There were two parks in the Cumberland Piedmont Network with ozone monitors in operation prior to the implementation of its Vital Signs Monitoring program: COWP and MACA. Prior to 2004, no extensive sampling of ozone had taken place on the remaining twelve parks. In 2004, pilot studies were initiated by the CUPN. During that year, only ozone concentration sampling (no foliar injury sampling) was completed. Two methodologies were used: passive ozone samplers (Figure 6) were used for most of the summer at each of the fourteen parks and a modified version of a Portable Ozone Monitoring Station (POMS) was used for a few weeks each at LIRI and RUCA. A POMS is shown in Figure 7. At most of the parks, multiple passive sites were used primarily to assess spatial variance in ozone concentrations and to explore the correlation between ozone concentration and elevation. In 2005, 2004's passive monitoring was continued (with a few deletions/additions of sampling sites), but the intensity of POMS sampling was greatly increased. Two dedicated POMS units (each of which included air temperature and relative humidity sensors) were rotated amongst a total of eleven CUPN sites (one of these eleven was a non-NPS site that was very near to a CUPN park). For most sites, the POMS was collocated with a passive sampler.

Table 2. Ozone monitoring history for the CUPN. Values in parentheses indicate the number of monitoring units in the park.

Park	Year 2004	Year 2005	Year 2006	Year 2007
ABLI	Passive (2)	Passive (3) POMS (1)	POMS (1)	POMS (1)
CARL	Passive (2)	Passive (1) POMS (1)	--	--
CHCH	Passive (2)	Passive (2) POMS (1)	--	--
COWP	Passive (2) Continuous (1)	Continuous (1)	Continuous (1)	Continuous (1)
CUGA	Passive (2)	Passive (3) POMS (1)	POMS (1)	POMS (1)
FODO	Passive (1)	Passive (2) POMS (1)	--	--
GUCO	Passive (1)	--	--	--
KIMO	Passive (1)	POMS (1)	--	--
LIRI	Passive (2) POMS (1)	Passive (1)	--	--
MACA	Passive (9) POMS (2) Continuous (1)	Passive (8) POMS (1) Continuous (1)	Continuous (1)	Continuous (1)
NISI	Passive (1)	Passive (1) POMS (1)	--	--
RUCA	Passive (1) POMS (1)	Passive (1)	--	--
SHIL	Passive (1)	Passive (2) POMS (1)	--	--
STRI	Passive (2)	Passive (2) POMS (1)	--	--

Remaining in place for three weeks at each site, the POMS measured diurnal variability that could not be detected using the passive devices. The POMS data were also used to "double-

check" the data from the passive devices. The passive units were dropped beginning in 2006, but POMS sampling in ABLI and CUGA was continued by NPS-ARD in both 2006 and 2007. A summary of the sampling completed from 2004 to 2007 within the CUPN is presented in Table 2.

In 2008, the CUPN began implementation of the draft version of this protocol. That draft version stated that ozone sampling would occur at two parks per year using one POMS. So, a POMS would be at a site only for part of the ozone season and data for the remainder of the ozone season would need to be estimated. This estimation would be based upon a mathematical model derived from the observed relationship between the POMS data and data from the "best" nearby state-operated monitor. Identification of the "best" monitor was to be based upon regression analysis of the POMS data and state-operated monitor data (the site with the best R-squared would be considered the "best" site). This approach has been abandoned in favor of collecting data for the entire ozone season at each park, thereby necessitating the use of two POMS units per year rather than only one.

Figure 6. Passive sampler at MACA.

The CUPN did not take delivery of its own POMS until 2009. So, in 2008, the CUPN could not sample for ozone at its target parks for that year (namely ABLI, CUGA and MACA). Fortunately, CUGA was running a POMS that was and continues to be on loan from NPS-ARD, and MACA, in partnership with NPS-ARD, maintains its own monitoring station. In 2009, the CUPN used its POMS to sample at FODO and SHIL. In May 2010, the CUPN was able to borrow a second POMS that was in the possession of the Inventory and Monitoring Program's Gulf Coast Network and sample for nearly the entire ozone season at each of two parks (CHCH and STRI).

Figure 7. POMS located at MACA. This POMS was maintained by MACA and funded by NPS-ARD.

Historical Development of Foliar Injury Monitoring within the CUPN

Prior to 2006, the CUPN had made no attempt to do any sort of foliar injury assessment. Foliar injury assessments had been completed on MACA in 1985 and 1986, but these assessments were part of a short-term study and were not part of long-term monitoring activities (McCune et al 1987).

Figure 8 – Tree climber (circled) during the 2006 Kohut pilot assessment at MACA.

In early 2006, NPS-ARD worked with Dr. Robert Kohut from Cornell University to initiate some pilot foliar assessments as designed by Dr. Kohut [see Kohut (2005) for specifics on sampling

designs and methodologies]. CUPN and MACA staff (along with staff from other parks and networks) participated in conference calls with NPS-ARD personnel and Dr. Kohut to discuss these pilot assessments. It was decided that, with the help of Dr. Kohut, three CUPN parks (COWP, CUGA, and MACA) would participate in the pilot assessments. Through the collaborative efforts of CUPN staff, park staff, and Dr. Kohut, foliar injury sampling was completed in the summer of 2006. One of Kohut's sampling designs (the one attempted by the CUPN during the pilot) required that branches be removed for examination from the crowns of very large trees. In Figure 8, note the tree climber near the top of a very tall tree.

No foliar assessments were completed in 2007. MACA staff intended to conduct injury surveys, but drought conditions suggested the absence of ozone injury symptoms, and it was informally decided that no surveys would be conducted. It should be noted that, when monitoring as prescribed by this protocol, parks should be sampled without regard to the drought index at the time when sampling is to be completed. In 2007, this protocol had not been officially implemented.

Figure 9 – Sammi Jo Eubank (CUPN staff) examining a sweet gum tree for foliar injury using USFS methods.

In 2008, the CUPN began implementation of the draft version of this protocol. Specifics of the foliar injury sampling designs and methods are discussed in more detail later in this narrative. In 2008, parks sampled were ABLI, CUGA and MACA. COWP, FODO, MACA and SHIL were sampled in 2009 while 2010 sampling consisted of CHCH, MACA and STRI. Figure 9 shows CUPN staff during 2009 foliar injury sampling at FODO.

Measurable Objectives

The objective of the CUPN ozone and foliar injury protocol is to measure ozone exposure in each of the fourteen CUPN parks (about two per year), and ascertain the presence/absence of foliar injury at select sites within those parks where ozone concentration data are being collected.

The specific **monitoring questions** that will be addressed by this protocol include:

1. What is the cumulative ozone exposure in CUPN parks during a typical April-October growing period?
2. What is the trend in cumulative ozone exposure in CUPN parks across time (years)?
3. At select CUPN parks in any given year, is foliar injury occurring?
4. What are the trends in foliar injury occurrence and severity?

The specific **monitoring objectives** that will be addressed in this protocol include:
1. Determine the cumulative ozone exposure levels for at least two CUPN parks per year.
2. In at least two CUPN parks per year, use established biomonitoring methodologies to detect the presence/absence (and, if present, to quantify the amount and severity) of foliar injury.

Sampling Designs

Sampling Design Overview - Ozone Concentration

Ozone sampling with a POMS will take place at two parks per year as shown in Table 4. Data are collected hourly. One POMS will be stationed at each of the two parks to run through the entire growing season, thereby allowing the computation of a W126 (and a SUM06) for each park. 8-hour averages will also be computed for comparison to the current National Ambient Air Quality Standard (NAAQS) for ozone. The current NAAQS may be found at http://www.epa.gov/air/criteria.html. Other analyses will also be conducted using the data and the results presented in annual and 5-year reports.

MACA and COWP currently have continuous monitors near park boundaries. Operation at MACA is expected to continue (there are no plans to discontinue the site) while operation at COWP is expected to continue through at least 2014 (South Carolina Bureau of Air Quality 2010). Both sites use EPA-certified equivalent methods. Equivalent methods are defined in Title 40 Part 53 of the Code of Federal Regulations which may be found at http://ecfr.gpoaccess.gov. For a list of equivalent methods, see United States EPA (2010). The COWP site is run by the state of South Carolina while MACA's site is run by the NPS. Lastly, recall that CUGA has a dedicated POMS on loan from NPS-ARD that is being maintained by CUGA staff. How long that POMS will remain at CUGA is unknown.

So, by either the CUPN and/or some other organization, ozone concentration data will be collected in COWP, MACA and two other parks. For the remaining parks, the CUPN will use data from off-park sites. Generally, these sites are state-operated and use primary standards or equivalent methods. Data from these sites will be used to suggest what ozone concentrations are like within a park. For example, state-operated sites around a park experiencing high levels of exposure would suggest that the park is also experiencing high levels of exposure. Exposure indices from state-operated sites that surround a park will be presented in annual reports to suggest the level of exposure in that park.

Sampling Design Overview - Foliar Injury Assessments

Foliar injury assessments will be completed for two or three CUPN parks per year as detailed in Table 4. CUPN staff will generally complete foliar injury assessments in parks where ozone sampling is taking place. Foliar injury sampling should be conducted between late-July and mid-

August as directed by the USFS. The USFS provides specific date ranges for each year. For more detail on the timing of foliar injury assessments, please see SOP #FoIn4.

All sites throughout the CUPN cannot be sampled each year since the CUPN does not have the resources to conduct foliar assessments at each of its fourteen parks each year. However, staff at parks for which CUPN staff is not scheduled to collect foliar injury data may discretionarily perform injury assessments provided that crew leaders have participated in USFS foliar injury training and the guidelines presented in this protocol are followed.

Site and Species Selection – Ozone Concentration and Foliar Injury Assessments

POMS site selection criteria are adopted from Ray (2004) and foliar injury site selection criteria are adopted from USFS (2008) and Kohut (2007). For both ozone and foliar injury, non-randomly selected sampling locations are chosen by the project lead in consultation with park management and park natural resources staff based upon accessibility, known sensitive species distributions and minimal interference with maintenance and/or visitor activities. Open sites are required (at least one acre). Other general rules for choosing sampling locations address topographic elevation and distance from acute sources of ozone precursor emissions (such as parking lots). Whenever possible, one foliar injury site at each park should be collocated with that park's POMS. Whenever possible, the pool of sites should also provide spatial coverage of the park as well as cover multiple elevations, soil types, aspects, steepness, soil disturbance, etc.

Table 3 Ozone sensitive species in CUPN parks as of 2006 (NPSpecies and Porter 2003).

Scientific Name	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Ailanthus altissima		X	X	X	X	X	X	X	X	X		X		X
Apios americana		X	X	X	X	X	X	X	X	X	X		X	X
Apocynum androsaemifolium		X							X					
Apocynum cannabinum	X	X	X	X	X	X	X	X	X	X	X			X
Artemisia ludoviciana						X				X				
Asclepias exaltata					X					X				X
Asclepias incarnata		X			X	X		X		X				X
Asclepias syriaca		X	X		X	X	X			X		X		X
Aster acuminatus					X				X					
Aster macrophyllus		X		X						X				
Cercis canadensis	X		X	X	X	X	X	X	X	X	X	X	X	X
Clematis virginiana	X	X	X		X	X	X		X	X		X	X	X
Corylus americana	X	X			X	X	X	X	X	X			X	X
Eupatorium rugosum (Ageratina altissima)	X		X		X	X		X	X	X	X	X	X	X
Fraxinus americana	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fraxinus pennsylvanica	X		X		X	X		X	X	X	X		X	X
Gaylussacia baccata		X		X	X	X	X	X		X				
Liquidambar styraciflua	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Liriodendron tulipifera	X	X	X	X	X	X	X	X	X	X	X	X	X	
Lyonia ligustrina		X	X		X			X	X			X		
Parthenocissus quinquefolia	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Philadelphus coronarius				X										
Pinus rigida		X			X		X							
Pinus taeda			X	X		X	X	X	X	X	X	X	X	
Pinus virginiana	X	X	X	X	X	X	X	X	X	X		X	X	
Platanus occidentalis	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Prunus serotina	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Prunus virginiana			X		X					X				
Rhus copallinum	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Robinia pseudoacacia	X	X	X		X	X	X	X	X	X		X	X	X
Rubus allegheniensis			X		X					X				
Rubus canadensis					X									
Rubus cuneifolius					X	X	X							
Rudbeckia laciniata	X		X		X	X		X	X	X				
Sambucus canadensis	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sambucus racemosa					X									
Sassafras albidum	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Solidago altissima		X		X	X	X		X	X	X				X
Verbesina occidentalis			X	X	X	X		X	X	X	X			
Vitis labrusca	X		X	X	X			X		X				X

Table 3 lists sensitive plant species within each of the CUPN parks. Generally, samplers may choose from amongst the entire list of sensitive plant species, but the use of species common amongst CUPN parks is encouraged. The USFS gives preference to the following plant species in the southeast (species in bold are preferred by the CUPN and should be searched for at each park):

- **Blackberry**
- **Common milkweed**
- Black cherry
- Yellow poplar
- White ash
- Sassafras
- Spreading dogbane
- Big leaf aster
- Sweetgum
- Pin cherry

For more specific guidelines on site selection, see SOP #OC3 and SOP #FoIn3.

Ozone Sample Frequency and Replication

Every year, two parks will be sampled using a portable ozone monitoring station for the entire growing season. COWP and MACA will not be sampled since each of these two parks has its own ozone monitor. Should either park lose its ozone monitor, the CUPN will begin monitoring at that park with a POMS. This addition of a park for POMS sampling would necessitate changing from the 6-year cycle shown in Table 4 to a 7-year cycle that would be determined at the time of the change.

Foliar Injury Sample Frequency and Replication

Foliar injury assessments will generally be conducted only at the two parks where POMS sampling is taking place. The exceptions to this rule are MACA and COWP. Since MACA and COWP have long-term ozone monitors already in place that are operated by non-CUPN organizations, a POMS will not be installed at those two parks. Therefore, during years when foliar injury sampling is conducted at these two parks, it will take place in parallel with ozone/foliar injury sampling at two (or three) other parks (as shown in Table 4). In addition to the scheduled CUPN assessments, park-level natural resource managers and park management may opt to conduct additional foliar injury assessments at their parks. These additional sampling events are not shown in Table 4. Lastly, the foliar injury schedule may be enhanced in the future to include monitoring at some parks and sites by the CUPN vegetation monitoring crews.

Foliar injury assessments will likely take place at multiple, non-randomly distributed sites on any given CUPN park. When these sites are pooled, the data may provide good information on how sensitive species are responding to the current year's ozone concentrations.

General Sampling Schedule

Since three parks are sampled for the first two years of a cycle and two parks are sampled each year for the subsequent four years, it will take six years to sample each of the fourteen parks. At the end of the six year period, the sampling cycle will repeat itself. The proposed sampling schedule is shown in Table 4. Parks will be said to be "active" in any given year if they are being sampled for ozone concentration or foliar injury.

Table 4. Proposed CUPN sampling schedule of on-park POMS ozone concentration (OC) monitoring and foliar injury (FoIn) assessments. (*) next to a park abbreviation indicates that ozone concentration data

are currently collected each year by an organization other than the CUPN. (**) indicates that the CUPN is currently providing some of the funding for the CUGA site, but that funding may be pulled in the future.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
ABLI	OC, FoIn	--	--	--	--	--
CUGA**	FoIn	--	--	--	--	--
MACA*	FoIn	FoIn	FoIn	FoIn	FoIn	FoIn
FODO	--	OC, FoIn	--	--	--	--
SHIL	--	OC, FoIn	--	--	--	--
COWP*	--	FoIn	--	--	--	--
CHCH	--	--	OC, FoIn	--	--	--
STRI	--	--	OC, FoIn	--	--	--
LIRI	--	--	--	OC, FoIn	--	--
RUCA	--	--	--	OC, FoIn	--	--
CARL	--	--	--	--	OC, FoIn	--
GUCO	--	--	--	--	OC, FoIn	--
KIMO	--	--	--	--	--	OC, FoIn
NISI	--	--	--	--	--	OC, FoIn

Field Methods

Preparations for Ozone Sampling

Prior to taking a POMS to a park, that POMS should be set up at the CUPN office within MACA. The POMS should be allowed to run as if it were at its scheduled park to verify that all components are in working order. This setup and verification will usually be handled by the project lead with the assistance of the NPS monitoring support contractor. The project lead will work with the monitoring support contractor to address any deficiencies discovered. The project lead will then work with the destination park's staff to choose a site for the POMS and schedule installation. Lastly, the project lead should work with the destination park's staff to determine who will be responsible for biweekly maintenance of the POMS.

Once the POMS is installed and operational, biweekly maintenance visits are necessary. This can easily be accomplished by one crew member (frequently staff from the host park) although, for safety reasons, two members may be necessary. Since the individual is trained by the project lead at the time of the installation, the crew member should be well-equipped to perform the maintenance visit. The following items need be taken to the site for maintenance visits:

- Field forms (which can be obtained from the NPS Monitoring Support Contractor)
- Any keys necessary for accessing the POMS enclosures
- Writing tool
- As necessary, keys to any gates that are passed through en route

It is also recommended that the crew member takes a cell phone so that the project lead or the NPS monitoring support contractor can be called in the event that problems are discovered. More details on preparation are available in SOP #OC2 "Pre-Sampling".

During the off-season, both POMS in CUPN's possession will be stored in CUPN facilities at MACA. At the end of each season, the ozone analyzers that are used with those POMS will be shipped to the NPS monitoring support contractor for servicing and calibration.

Preparations for Foliar Injury Sampling

In general, foliar injury sampling events will be scheduled by the project leader in collaboration with CUPN and park staff sometime in the month of July. Specific sampling schedules may be slightly adjusted to account for inclement weather, personnel workloads, etc. Sampling order and routes to parks/sites will be finalized at least one or two days beforehand in order to maximize efficiency and minimize travel times. If at all possible, site accessibility should be verified by appropriate park personnel.

Lists of pre-trip activities are provided (SOP #FoIn2 "Pre-Sampling"). The crew leader must check each item on the lists, particularly the supplies list (which includes items such as field forms), at least one week before sampling, in case supplies are needed, and again the day before the trip for final details.

Frequently, the crew leader will be assisted by individuals who have not participated in the USFS training. Minimal training is provided to these inexperienced crew members prior to the sampling event. This is acceptable since the crew leader will make the final call on all plants that show any form of injury. Inexperienced crew members are trusted to know when a plant has no injury of any sort on it and the crew leader will accept that designation without closer inspection. However, any plant that has any sort of injury on it will be inspected by the crew leader. The number of inexperienced crew members participating will be kept to a minimum.

Sampling Methods – Ozone Concentration

Ozone data are collected using a POMS that is located in the park. A POMS consists of the following components:

- Power supply (solar array, batteries, battery enclosure, and power distribution system)
- Instrumentation (ozone analyzer, GPS and meteorological instruments)
- Control system (datalogger, relay panel, and satellite uplink module)
- Mechanicals (mounting system, security system, tripod, enclosures and lightning protection system)

Particular components of a POMS will likely change over time as dictated by NPS-ARD and the NPS monitoring support contractor. For example, as technologies improve, the ozone analyzer that is currently in use will likely be replaced with an updated model. The CUPN will adopt these methodological changes as prescribed by NPS-ARD and the NPS monitoring support contractor. For this reason, particular methodologies are not discussed in this document. Information on current and historic methodologies is available from either the NPS monitoring support contractor, NPS-ARD or the CUPN ozone and foliar injury project lead.

Reasons for Choosing this Method Rather than Others

There are several advantages to using a POMS. With a POMS, data collection is automated and data are uploaded via satellite. This approach streamlines data collection, largely eliminates the need for data entry from data forms to a database, and significantly improves data quality since the possibility of human error is largely removed. Additionally, since the data are continuous, hourly measurements, the user obtains detailed information on ozone cycles and dynamics that would not be available if some other method (such as passive sampling) was used. Lastly, since

the unit is solar powered, it is not necessary to have any power source nearby, greatly increasing the number of sites where a POMS could be located. This solar power feature also makes the initial installation much easier, since the power needed/provided is low-voltage so that the individual performing the setup and disassembly need only minimal training (when compared to the training needed for tapping into standard, "on-the-grid" power sources).

For more information on EPA-certified methods, POMS and passive samplers, see NPS-ARD's ozone monitoring protocol (Ray 2004).

Sampling Methods – Foliar Injury Assessments

Methodologies for foliar injury assessments have been adopted from those used by the USFS in their protocol (see USFS 2005). Essentially, the USFS visually inspects plant leaves from the target species while walking around the site. Any injury observed is noted on a field form. With the exception of a voucher specimen for each species when injury is found, no leaves are removed from the sampled plants. Typically, the assessment takes a crew of two or three people between one and two hours to complete. Usually after plants have been surveyed, the center of that site is mapped using a GPS and a site sketch is drawn that shows the position of target plants/patches within that site as well as significant proximal landmarks (cities, roads, power lines, etc.). Other site-level abiotic data are also collected.

As samplers sweep a site, two types of data are collected on each plant sampled. The first datum is referred to as "injury amount." This parameter defines how widespread ozone injury is on a particular plant. The parameter can range from no damage on the plant anywhere up to the entire plant showing some level of foliar injury. The next parameter collected is referred to as "injury severity." This parameter is a measure of how badly a plant is injured on any given leaf. Samplers are instructed to select and collect data on a leaf with an injury level that is "typical" of the entire plant. Parameter values can range from no injury on a typical leaf to as much as the entirety of a typical leaf shows damage. These estimates are based only upon parts of the plant that are exposed to sunlight since ozone injury will generally not occur on shaded parts of leaves (as shown in Figure 3).

While there is no minimum number of plants per species at any given site, samplers *should* select sites that contain at least ten plants per species. The USFS protocol calls for at least two species with thirty plants each. Also, the maximum number of individual plants examined for each species is thirty.

Voucher Specimens

One voucher specimen (a specimen is considered to be three leaves) is collected for each species that is evaluated at a site. The USFS protocol explicitly stipulates that voucher specimens should show obvious signs of ozone injury whenever possible. That is, voucher specimens should be collected only when injury is suspected. Leaves should not be collected that do not show signs of ozone injury. Three leaves per species are placed in a plant press and, after the leaves have properly dried (according to the USFS protocol, at least 36 hours after being placed in the press), the vouchers are sent to USFS personnel in a centralized laboratory/office. The vouchers are then examined by a regional expert to determine if the injury observed is ozone injury. The purpose of the vouchers is to determine whether or not samplers in the field are correctly

identifying ozone injury on plants. This verification is necessary since ozone injury is similar in appearance to other types of leaf injury.

Some of the data that are collected in the field for each voucher aid in characterizing the nature of ozone injury at the site. The injury location datum, for example, is an estimate of the age of injured leaves on plants at the site (mostly younger leaves, mostly mid-aged and older leaves, or no distinct age class). The second datum, injury type, estimates how much of the injury on injured leaves is ozone injury (most of the injury is stipple, most of the injury is not stipple, or it is difficult to tell how much of the injury is stipple).

Voucher specimens should be brought/sent to the CUPN office at MACA. Upon receipt at the CUPN office, the specimens are sorted by park, packaged using blotter paper and cardboard, and then sent to the USFS for inspection. Upon completion of the inspection, the USFS will return the specimens to the CUPN office at MACA. Vouchers are then photographed and catalog/accession numbers are obtained from the originating park. All voucher information (including catalog/accession numbers) is entered into ICMS (includes digitally attaching the photo to the ICMS record). See subsequent section, "Data Management", for more information about ICMS. Next, NPS labels are printed using ICMS info just entered. Specimens are then curated by laminating the voucher together with its NPS label. Lastly, the ICMS records are mailed to the originating park and vouchers are sent to the park's chosen repository.

The park's chosen repository could be located at that park or some other park (frequently the curatorial facilities at MACA). Also, the CUPN allows parks to have their voucher specimens discarded after analysis. However, that option (discarding of the specimens) is strongly discouraged. Retaining specimens is the most desirable action since future studies (both related and unrelated to the study of ozone and its effects) may be able to use the specimens. However, the CUPN recognizes that the originating park has the authority to determine the fate of its specimens and will abide their decision. The CUPN will not discard specimens unless instructed to do so by the originating park. In any of case, procedures from the NPS museum handbook will be followed for discarding, processing, pressing, preserving and shipping of voucher specimens.

Photography of Voucher Specimens

All voucher specimens (upper and lower sides) are photographed. Photographs of voucher specimens, henceforth referred to as photographic vouchers, are not required by the USFS protocol.

There are a number of reasons why these photographic vouchers will be useful to the CUPN. First, "handling" of these photographs will not damage them. Second, as a result of the ability to copy digital photographs, it will be possible for multiple parties (for example, the CUPN office and the originating park) to retain vouchers. Third, photographic leaf vouchers are a valuable training and presentation tool. Photographic leaf vouchers will show varying levels of ozone injury mixed with other forms of injury. Photographic vouchers can easily be compiled and a wide variety of injury levels/mixes be illustrated. Fourth, archival procedures for digital photographs are simpler than those for specimens, making it relatively easy for the CUPN to build and maintain an archive of digital photographs. And fifth, photographic vouchers can be quickly and easily distributed to interested non-NPS parties.

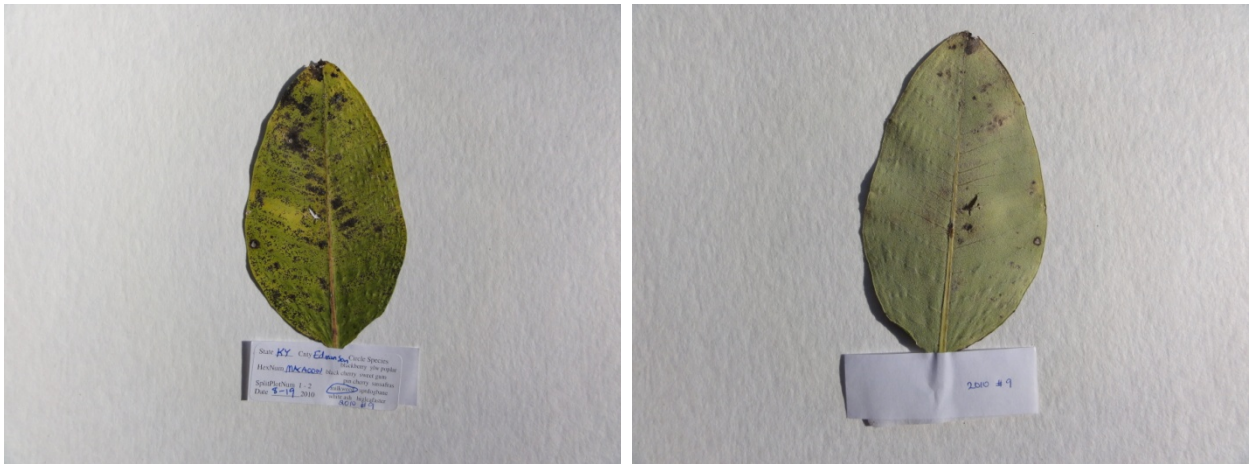

Figure 10 – Photographs showing the upper (abaxial) and lower (adaxial) side of a common milkweed specimen. NPS photographs by Brenda Wells (CUPN staff).

Figure 11 – Photographic voucher showing all three leaves of which the voucher consists. The leftmost photograph shows the abaxial side of the leaves while the rightmost photograph shows the adaxial side of the leaves. These common milkweed leaves were collected from MACA in 2010. NPS photographs by Brenda Wells (CUPN staff).

Standardized procedures will be followed when photographing voucher specimens. Some of the particular rules for photography include:

- Photographs are taken from a fixed distance
- Photographs are taken using a standardized set of camera settings
- Photographs are taken using a standardized background
- Petiole labels are shown in the photographs, so that information shown on the label is in the photograph with the leaf
- Petiole labels are numbered on both their front and back sides, allowing the adaxial side of a leaf to be matched to its abaxial side

- Photographs are taken inside under artificial lighting and not outside where light intensity and quality can fluctuate greatly over time

More specific rules for voucher photography may be provided in later versions of this protocol. Also, all specimen and photographic vouchers will be cataloged in the Interior Collections Management System (ICMS).

Reasons for Choosing this Method Rather than Others

The USFS approach is easy to execute provided that the sampler is properly trained. Tree climbing is not necessary and a crew with only a few members can sample a park. Sampling a site also takes very little time, usually as little as a couple of hours. The USFS program examines sites across the U.S. and uses established/accepted methods. The CUPN is also able to rely on the USFS to provide training and data archival.

The only significant difficulty associated with the approach is that, in some of the CUPN parks, it can be difficult to find an ideal site. Early successional stands of plants can be rare as can suitable meadows.

Data Management

Overview of Database Design

This protocol will produce two main types of data: 1) ozone concentration data; 2) foliar injury data.

Ozone concentration data will be generated by three sources: 1) on-park continuous monitors (COWP, MACA); 2) on-park portable ozone monitors (two active parks per year); and 3) off-park continuous monitors (usually EPA-certified state-operated monitors). For on-park ozone data, the CUPN plans to participate in the database management system maintained by the NPS ARD. For selected off-park monitors, the CUPN anticipates that the project lead will poll and retrieve those data from the central databases maintained by EPA.

Foliar injury data will be entered into a relational MSAcess database utilizing the Natural Resource Database Template (NRDT), which includes an established set of core tables and fields developed by the Inventory and Monitoring Program (NPS 2006). Foliar injury data will also be provided to the US Forest Service FIA program for entry/import into their database. See SOP #FoIn 6 “Data Management” for a list of fields and descriptions.

Data Processing

Data from ozone monitors are automatically uploaded by the NPS monitoring support contractor via satellite. There are no field forms, other than documents used for equipment maintenance and calibration. Once data are uploaded, the NPS monitoring support contractor performs various validation procedures that meet EPA requirements and are fully described in SOP #OC6 “Data Management”.

Foliar injury data will be entered from hardcopy field forms into the electronic database by CUPN data managers. Immediately following data entry, a verification step will be conducted

by data managers to check for hardcopy-to-electronic transcribing errors. During data entry, some validation checks (those incorporated in database design) will occur, such as limiting values to allowable ranges. In addition, a final validation overview will be performed by the project lead to capture any further inconsistencies that were not resolved during data entry.

Data Archiving

According to ARD procedures, there will be a monthly/quarterly submittal of final validated regulatory data to the EPA's AQS database. These data include hourly average ambient air quality and meteorological data, precision data from ozone analyzer precision checks, and accuracy data from audit reports on ozone analyzers.

Final data sets for foliar injury will be archived by CUPN locally with all supporting documentation, including documentation of data files, data management procedures, hardcopy field forms, and quality assurance data. Multiple copies of datasets will be stored, and care will be taken that all copies are updated simultaneously when additional material is added. Datasets destined for archiving will be stored locally within an object-oriented file structure established on the CUPN file server. Incremental or differential tape backups of all project databases on the server are regularly conducted. Backup copies of the data are maintained in a secure alternate location. Currently, GIS files are maintained and archived separately by the GIS specialist.

Metadata Procedures

All ozone geospatial data will be documented with appropriate Federal Geographic Data Committee (FGDC) and NPS metadata standards. ArcCatalog (i.e., geospatial data) records destined for upload to the Integrated Resource Management Applications site (IRMA) will be edited with the NPS Metadata Tools and Editor prior to upload.

Analysis and Reporting

Data Analysis

The monitoring questions and subsequent analysis of the supporting data address issues related to status and trends in ozone concentration/exposure, foliar injury, and the interrelationship between the two. Monitoring questions will be addressed using a combination of summary and descriptive statistics, graphic analysis, and multivariate comparative and correlative analysis.

For hourly ozone data from a POMS or state-operated site, cumulative ozone exposures (such as the seasonal SUM06, the seasonal W126 and the highest consecutive 3-month W126) will be computed for each growing season. POMS data will be presented as a time series and analyzed for diurnal patterns.

Foliar injury data consist of injury amount (how much of the total plant shows any level of ozone injury) and injury severity (on average, how much of the plant's leaf surfaces show ozone injury). These data are recorded as indices from zero to five, with zero meaning there is no injury up to five meaning that nearly all of the plant or leaf surface shows injury. In annual reports, these data will be presented in various tables without statistical analysis. In 6-year reports, summary statistics will be computed for these indices to determine the severity of damage at the site level for each species sampled as well as for all plants sampled (by pooling all species data from the site). Similar statistics will also be computed at the park level by pooling

all of the site data. It should be noted, however, that since sites were not randomly selected, these pooled site-data (which can be loosely considered park-level data) do not necessarily spatially characterize ozone injury as it is occurring across the park. Nevertheless, these park-level data are informative in discussing conditions as they occurred amongst the pooled sites.

Relationships between ozone exposure indices and foliar injury data will be explored in annual reports simply through a discussion in the text. Drought severity indices will also be considered. For example, for a site and year when ozone concentrations are low and very little foliar injury is discovered, it will be explained that this is the expected finding especially since (let's suppose) the drought severity index was near zero (neither an excessively wet year nor an excessively dry year). In the 6-year reports, correlation analysis will be performed on the pooled set of these same data.

The development of basic queries and summary reports in MS Access will be utilized to automate and thus streamline the data analysis and reporting workload, as appropriate. In consultation with the project leader, the data manager will develop queries (and accompanying summary reports) that will address basic statistical questions. It is anticipated the results of these queries will be relied upon heavily for annual reporting.

In instances where the statistical questions become increasingly complex, data will need to be exported out of the relational MS Access database to commercial off-the-shelf statistical packages for higher level statistical analyses (i.e., t-tests and ANOVA). In general, these data will be formatted based on parameters provided by the data analyst.

Reporting

There will be two main categories of reports. The first is an annual status report. The second is a multiple year (~6) that will be used to explore long-term trends and correlation between ozone exposure and foliar injury data. Reports will follow the NPS Natural Resource Data Series format.

In an effort to disseminate findings in a timely manner, annual reports should be completed by November of the year following data collection. A brief (2-3 paragraphs) summary of sampling activities, preliminary results, and any public interest highlights that occurred during each federal fiscal year will be written by October 15 of the following fiscal year for inclusion in the CUPN Monitoring Program's Annual Administrative Report. Fiscal years begin in October and end in September.

Annual summary reports *may* be used to supplement annual reports. These "Resource Briefs" are intended for park-level managers that are interested only in key findings of the monitoring and do not have the time to read through the details contained in the annual reports. As of this writing, the CUPN has not yet decided whether to implement the use of annual summary reports with its protocols.

Personnel Requirements and Training

Roles and Responsibilities

Implementation of this protocol requires a team of staff members working cooperatively. Leading the team is an overall project leader who oversees and directs project operations. The project leader is the principal scientist for implementing this monitoring protocol and is supervised by the MACA Air Quality Specialist with program oversight by the CUPN coordinators. The project leader will be responsible for obtaining park permits, installation/removal of POMS, training park personnel to maintain POMS, participating in foliar injury training, conducting foliar injury surveys, filing trip reports, data entry, data verification, data validation, data summary, analysis, and reporting.

The CUPN coordinators are responsible for ensuring that staff members receive appropriate training for foliar injury identification and data management. A combination of trained CUPN and park staff will be responsible for data collection, data recording, post-sampling equipment inspection and storage, and shipping/receiving of sampling materials. Data entry is the responsibility of the project lead with assiatance from data managers as needed. Data management will be shared responsibilities among the project leader, data managers, park staff, the NPS monitoring support contractor, and Air Resource Division contacts. For the foliar injury component, the data managers are ultimately responsible for ensuring that adequate QA/QC procedures are built into the database management system. The data managers, project leader, and park staff are jointly responsible for ensuring data handling procedures are followed.

Voucher specimens resulting from foliar injury surveys will be handled by the CUPN biologist/curatorial specialist. He/she will be responsible for photographing and shipment of specimens to USFS. When specimens are returned, he/she will be responsible for cataloging of specimens and photographic vouchers in ICMS according to park instructions.

Qualifications and Training

To ensure data quality, all staff should be knowledgeable on the tasks for which they are responsible. In particular, new crew leaders should be thoroughly familiar with SOP #OC4 and SOP #FoIn4 and should be given hands-on training by the project leader, or a designee, for each of the items detailed therein. Further, foliar injury crew leaders must participate in USFS training or pass pre-season USFS exams to be certified to collect foliar injury data. Pre-sampling "training and handling preparation" meetings should be held as necessary to review sampling procedures, components and assembly/disassembly steps for a POMS, and assessment of foliar injury symptoms. See SOP #OC1 and SOP #FoIn1 for further training guidelines.

Operational Requirements

Ozone Field Schedule

POMS installations and removals require one person (usually the project lead) and limited assistance from the host park for equipment setup and equipment disassembly. The amount of time that setup and disassembly of equipment requires depends upon which of the two POMS is being setup or disassembled. The smallest POMS takes only about an hour for either installation or removal. The larger unit takes about 3 hours to install and about 2 hours to remove. These

time estimates do not include transit times. Since two parks are sampled each year (and to increase efficiency), installations or removals at both parks are completed in one trip. Both POMS will fit into a pickup truck for the trip. This does, however, necessitate at least one overnight stay.

Ozone sampling requires one person (although two people may be necessary for safety reasons) to make biweekly, fifteen minute POMS maintenance visits throughout the ozone season. Maintenance visits usually take only about fifteen minutes at the site, but travel time can be significant if the site is located far from the park's offices. Transit time to a POMS will vary amongst parks, but should generally take between .25 and 1 hour. Additional time should be allowed for repairs of malfunctioning equipment. Past experience with these monitors has shown that the units rarely malfunction and, when a problem does occur, it is generally easy to fix. In most cases, maintenance visits are handled by park staff since they are on-park and travel times for centralized CUPN staff would be too long.

Approximate time requirements for each of the activities just discussed are summarized below.

CUPN costs for ozone monitoring equipment (POMS) beginning-of-the-season setup and end-of-the-season takedown:
(1 person) X (1 setup+1 takedown) X (1-3 hour for setup or takedown + to-and-from transit time from park office + travel from centralized CUPN office + travel times between the two parks)

Park costs for ozone monitoring equipment (POMS) maintenance visits annually:
(1 or 2 people) X (2 parks) X (16 maintenance visits) X (0.25 hours + to-and-from transit time)

Foliar Injury Field Schedule

Foliar injury assessments are generally handled by centralized CUPN staff with help from park personnel.

CUPN costs for foliar injury assessments annually:
(2 members of CUPN staff+1 member of park staff) X (2 parks) X (1 set of assessments per park) X (8 hours for assessments and travel time to/from/between sites)+(travel time to first park and from last park)+(two overnight stays for 2 members of CUPN staff)

Combined Ozone and Foliar Injury Annual Workload

Time must also be used for obtaining park permits, completing Investigator's Annual Reports, and participating in scheduling calls and training sessions (about 5 days for the project leader GS-11). Data entry, verification, editing, validation, archival, and metadata procedures are estimated to require approximately 3 office-days per year (2 days for data manager GS-9 and 1 day for project leader GS-11). Data analysis is estimated to take approximately 6 office-days per year (5 days for project leader GS-11 and 1 day for a data manager GS-9). Producing the five-year status report is estimated to consume 5 office-days per year (4 days for project leader, and ½ day each for a data manager and GIS specialist GS-11). Annual status reports are anticipated to require about 4 days from the project lead. Processing of voucher specimens takes about 2 days per year (all for the data manager GS-9). Therefore, all data management, analysis, and reporting activities are estimated to involve a total of 25 office-days per year. Table 5 summarizes task/personnel assignments.

Table 5 – Proposed workload distribution for ozone and foliar injury monitoring. Abbreviations are: PL=Project Lead, NPS-MSC=NPS Monitoring Support Contractor, PP=Park Personnel, TPP=Trained Park Personnel, T-CUPN-S=Trained CUPN Staff, CUPN BIO-CUR=CUPN Biological/Curatorial Specialist, GIS=Geographic Information System specialist, and DM=Data Manager.

Task	Ozone Concentration Personnel	Foliar Injury Personnel
Park Permits	PL	PL
Annual POMS Maintenance	PL+NPS-MSC	--
POMS Installation and Removal	PL+PP	--
Weekly POMS Maintenance	TPP	--
Training	PL+TPP	PL+TPP
Data Collection (Field Work)	--	PL+TPP+T-CUPN-S
Processing Voucher Specimens	--	CUPN BIO-CUR
Filing Field Forms	PL+TPP+NPS-MSC	DM+TPP
Data Entry	NPS-MSC	PL+DM
Data Verification and Validation	NPS-MSC	PL+DM
Data Summary	PL	PL
Data Analysis	PL+DM	PL+DM
Data Management	NPS-MSC	PL+DM
Reporting	PL+DM+NPS-MSC+GIS	PL+GIS

Facility and Equipment Needs

Ozone sampling does not require special facilities beyond normal office space and equipment storage needs. However, foliar injury sampling, in addition to office space and equipment storage needs, requires storage for voucher specimens. There are two types of vouchers: specimen vouchers and photographic vouchers. Specimen vouchers must be stored in specialized storage cabinets and in accordance with guidelines as set forth in the NPS museum handbook. Photographs will be digital and will be archived on the CUPN server, also in accordance with guidelines as set forth in the NPS museum handbook. The NPS museum handbook is available at http://www.nps.gov/history/museum/publications/handbook.html.

SOP #OC2 and SOP #FoIn2 contain lists of field equipment needs.

Startup and Monitoring Costs

Startup costs for implementing this protocol consisted primarily of the cost of purchasing one POMS unit. The cost to the CUPN of that POMS was $18,000.

Personnel expenses for field work are based on personnel/time requirements as estimated in the previous section “Field Schedule and Annual Workload.” As detailed in that section, ozone and foliar injury monitoring is estimated to require a minimum total of 25 field-days to implement across the CUPN. Based on FY 2011 personnel costs, annual CUPN personnel expenses for 25 workdays are estimated to be $8,000. Additionally, annual travel expenses are about $800.

Perennial supplies and equipment costs should be minimal, since the equipment that is needed is non-perishable and does not need to be replenished (with the exception of archival materials, field notebooks and pens/pencils). The only significant perennial supplies and equipment costs

are POMS operational costs paid to the NPS monitoring support contractor. The cost to the CUPN for the ozone season is about $6,500 per POMS. This perennial fee covers data collection, data validation, data archival, technical support, and replacement of malfunctioning equipment. The remaining costs are paid for by NPS-ARD. The CUPN is providing this partial funding for two POMS, totaling $13,000 per year. When totaled with the perennial costs in the paragraph above, the total annual cost for monitoring is about $21,800.

Procedure for Revising the Protocol and Archiving Previous Protocol Versions

No protocol can be expected to remain unchanged over the long term. We anticipate the foundation, the logic and rationale of program design, to remain as written over the term of the program. However, there will come a time when program logistics, such as sample locations, cost estimates, methods, and reporting criteria may require updating. Careful documentation of changes to the protocol are essential when people, in the future, examine data trends, for example, to know exactly under what conditions the data were gathered. All ozone monitoring data will be entered into a database, which contains a field that denotes the protocol version under which the data were collected. Each protocol version will be properly archived to ensure future retrieval.

The rationale for dividing a sampling protocol into a Protocol Narrative with supporting SOPs is based on the following:

- The Protocol Narrative is a general overview of the protocol that gives the history and justification for performing the work as well as sampling methods. It does not contain all methodological details which are found in the accompanying SOPs. The Protocol Narrative is changed only if major revisions are necessary.
- The SOPs, in contrast, are specific detailed instructions for performing given tasks and are expected to be revised more frequently than the Protocol Narrative.
- When an SOP is revised, in most cases, it will not require modification to the Protocol Narrative, unless it affects the Narrative direction or rationale.
- All electronic versions of the Protocol Narrative and SOPs will be archived on the network server in the CUPN protocol folder under the Vital Signs project folder for Ozone. Revised versions of the protocol will be posted to the NPS I&M protocol database and CUPN websites.

Steps for changing the Protocol Narrative or SOPs are detailed in SOP #9 (both OC and FoIn) “Revising the Protocol”. The Protocol Narrative and each SOP contains a Revision History Log that will be filled out each time the Protocol Narrative or an SOP is changed.

Protocol Narrative Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

References

Grantz, D.A. *Review of NPS Document: "A Protocol for Monitoring Ozone and Foliar Injury Throughout the Cumberland Piedmont Network"*. University of California at Riverside, Riverside, California. 2009.

Great Smoky Mountains National Park. *Great Smoky Mountains National Park Folio #2: Air Quality*. Brochure. Great Smoky Mountains National Park and the National Park Service, Gatlinburg, Tennessee. 2006.

Jernigan, J. W., B. Carson, and T. Leibfreid. *Ozone and foliar injury report for Cumberland Piedmont Network parks: Annual report 2008.* Natural Resource Data Series NPS/CUPN/NRDS—2009/012. National Park Service, Fort Collins, Colorado. 2009.

Jernigan, J. W., B. Carson, and T. Leibfreid. *Ozone and foliar injury report for the Cumberland Piedmont Network Parks consisting of Cowpens NB, Fort Donelson NB, Mammoth Cave NP and Shiloh NMP: Annual report 2009*. Natural Resource Data Series NPS/CUPN/NRDS—2010/110. National Park Service, Fort Collins, Colorado. 2010.

Kohut, Robert. *Handbook for Assessment of Foliar Ozone Injury on Vegetation in the National Parks*. Boyce Thompson Institute, Cornell University, Ithaca, New York. 2005.

Kohut, Robert. *Handbook for Assessment of Foliar Ozone Injury on Vegetation in the National Parks. 2nd Edition*. Boyce Thompson Institute, Cornell University, Ithaca, New York. 2007.

Leibfreid, T. R., R.L. Woodman and S.C. Thomas. *Vital Signs Monitoring Plan for the Cumberland Piedmont Network and Mammoth Cave National Park Prototype Monitoring Program: July 2005*. National Park Service, Mammoth Cave, Kentucky. 2005.

McCune, Bruce, C.L. Cloonan, and T.V. Armentano. *Foliar Injury, Tree Growth and Mortality, and Lichen Studies in Mammoth Cave National Park.* Holcomb Research Institute, Butler University, Indianapolis, Indiana, USA. 1987.

National Park Service, Air Resources Division (NPS-AIR). *Air quality in national parks: 2009 annual performance and progress report*. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado. 2010.

NPS, Washington Support Office, Inventory and Monitoring Program. 2006. Natural Resource Database Template Revised Documentation. National Park Service. Fort Collins, CO.

Negra, Christine, E. Geczi, S. Gopal and C. Sweedo. *Indicators of Ecological Effects of Air Quality*. The H. John Heinz III Center For Science, Economics and the Environment, Washington, D.C. 2009.

Porter, Ellen. *Ozone Sensitive Plant Species on National Park Service and U.S. Fish and Wildlife Service Lands: Results of a June 24-25, 2003 Workshop. Baltimore, Maryland.* Air Resources Division, Research and Monitoring Branch, National Park Service, Lakewood, Colorado, USA. 2003.

Ray, John D. *Ozone Monitoring Protocol: Guidance on Selecting and Conducting Ozone Monitoring.* Air Resources Division, Research and Monitoring Branch, National Park Service, Lakewood, Colorado, USA. 2004.

Rose, Anita K. and J. W. Coulston. *Ozone Injury Across the Southern United States, 2002-06*. Gen. Tech. Rep. SRS-118. U.S. Department of Agriculture Forest Service, Southern Research Station, Asheville, North Carolina. 2009.

Smith, Gretchen C., W.D. Smith and J.W. Coulston. *Ozone Bioindicator Sampling and Estimation*. Gen Tech. Rep. NRS-20. U.S. Department of Agriculture, Forest Service, Northern Research Station, Newton Square, Pennsylvania. 2007.

South Carolina Bureau of Air Quality. *State of South Carolina: Network Description and Ambient Air Network Monitoring Plan Calendar Year 2011*. South Carolina Department of Health and Environmental Control (DHEC), South Carolina. 2010.

United States Environmental Protection Agency (EPA). *List Of Designated Reference and Equivalent Methods*. Human Exposure and Atmospheric Sciences Division, Research Triangle Park, North Carolina. 2010.

United States Environmental Protection Agency (EPA). *Ozone: Good Up High, Bad Nearby*. Brochure. Office of Air and Radiation, Washington D.C. 2003.

United States Forest Service (USFS). *Phase 3 Field Guide – Section 9. Ozone Bioindicator Plants (east).* 2008.

United States Forest Service (USFS), National Park Service, and U.S. Fish and Wildlife Service. *Federal land managers' air quality related values work group (FLAG): phase I report—revised (2010).* Natural Resource Report NPS/NRPC/NRR—2010/232. National Park Service, Denver, Colorado. 2010.

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A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #OC1: Ozone Concentration - Training of Field Personnel

Version 1.0 (November 2011)

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Implementation of this protocol requires an overall project leader and additional staff as outlined in the Table 6. The project leader oversees and directs project operations, including training of personnel. Crews may consist of one crew leader and at least one crew member. The crew leader has ozone sampling techniques expertise and is responsible for team tasks. The crew member has varied and less expertise (frequently no expertise), and is responsible for assisting the crew leader (as during installations/removals by helping unload/load system components from the pickup truck). No pre-training of crew members is necessary provided they are assigned only menial tasks such as filling out field forms.

Table 6 – Personnel requirements for POMS activities.

Task	Personnel required
POMS setup/removal	1 crew leader (typically the project lead) and one person from the host park
POMS weekly maintenance	For each POMS, 1 crew leader
POMS repairs	1 crew leader or 1 crew member. Or, if the individual performing weekly maintenance visits has the skill set necessary, that individual can perform the repairs.

To effectively work with a POMS, new crew leaders should be thoroughly familiar with the relevant section of SOP #OC4 which deals with installing/servicing/removing a POMS. New crew leaders should be given hands-on training by the project leader (or an experienced crew member designated by the project lead) for the relevant activities detailed in that SOP. The overall project leader should be a permanent staff member and should review any relevant Job Hazard Analyses with new crew leaders.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #OC2: Ozone Concentration - Pre-Sampling

Version 1.0 (November 2011)

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It must be noted that the NPS requires research/collecting permits be obtained before any field work can commence. So, each year and for each park, the project lead must submit an application through the NPS Research Permit and Reporting System https://science.nature.nps.gov/research/ac/ResearchIndex. A travel authorization should also be completed prior to departure when overnight stays are needed.

This SOP describes tasks to be performed prior to site visits. This SOP gives procedures for:

- General site visit preparation
- Scheduling site visits with host parks
- Preparing a POMS for use in the upcoming season
- Preparing to install or remove a POMS

The CUPN is currently using two versions of a POMS: second (POMS II) and third (POMS III) generation systems. The POMS II (Figure 12) is an early design by the Monitoring Support Contractor and is very similar to the unit that was used by the CUPN during its 2005 pilot study. The POMS II, while relatively compact, is still fairly large. The CUPN restarted its usage of the POMS II during the 2010 sampling season. The unit that we have is on loan from the Gulf Coast Network and NPS-ARD. The POMS III (Figure 13) was designed by the Monitoring Support Contractor specifically for the CUPN's use. The CUPN began using the POMS III in 2009. The POMS III is considerably smaller than the POMS II, thereby making transport, assembly and disassembly much easier. Preparation differs slightly depending upon whether a POMS II or POMS III is being utilized. Throughout the rest of the protocol, the term "POMS" is used to refer to both the POMS II and the POMS III.

Figure 12 – POMS II near CUPN's MACA office being prepared for its 2010 deployment at STRI.

Figure 13 – POMS III at SHIL during the 2009 sampling season.

General Site Visit Preparation

1. **Acquire an NPS research/collecting permit.** The crew should carry a photocopy of the permit while in the field.
2. **Obtain travel authorization.**
3. **Review copies of field data forms from recent sampling events to identify any unique conditions or hazards that may be encountered.**
4. **Prior knowledge of POMS setup and disassembly procedures is necessary for efficient site setup.** Project crew leaders and crew members should be trained and refreshed (SOP #OC1 "Training of Field Personnel") as necessary.
5. **A POMS installation crew will need to access the site at which the POMS will be installed.** To locate a particular site, it may be sufficient to arrange for personnel at the host

park to escort the installation crew to the site. Otherwise, the crew leader will need to obtain directions to the site.

Scheduling Site Visits with Host Parks

Site visits should be scheduled with host parks regardless of whether park assistance is needed. Usually (for installation visits) it is necessary to have personnel from the host park escort installation person(s). Preferably, the escort would consist of any personnel (such as primary and backup operators) that are likely to service the POMS during its residence at the host park. If these personnel are on-site during the setup, they will gain familiarity with the system by having seen it installed by the crew – one or two people with more detailed knowledge of the system. Regardless of whether park personnel are present during the installation, once setup is complete, the setup crew must train the host park's personnel (those who will be servicing the POMS throughout the season) on how to maintain the POMS. The site visit should be scheduled at least a couple of weeks prior to the time of the visit.

Preparing a POMS for Use in the Upcoming Season

At times outside the ozone season, the POMS will be stored at a designated location at Mammoth Cave National Park. Storage in this location will make the POMS readily accessible for preseason preparations. The project lead will be responsible for most of the preseason preparation. The project lead is generally responsible for:

1. Assembling and testing the POMS (see SOP #OC4 for installation instructions) near the CUPN's MACA office prior to installation at a park.
2. Sending/receiving instrumentation and analyzers to/from the NPS Monitoring Support Contractor for/after calibration/refurbishing/replacement. This also includes storage modules (small memory devices used to store POMS data in the event of datalogger and/or satellite failure).
3. Any other activities that need to be completed at the CUPN's storage location.

There are also some tasks that need to be undertaken by the NPS Monitoring Support Contractor. These include:

1. Annual calibration of any meteorological equipment associated with the POMS (POMS II only).
2. Annual calibration of the ozone analyzer.
3. Helping to ensure that the satellite and GPS transmitters are functioning properly.
4. Supplying replacement parts as needed.

Preparing to Install or Remove a POMS

Prior to installation at the destination park, the POMS must be disassembled.

POMS II Components

A POMS II should be disassembled into the list of parts shown below.

1. Battery case (contains two batteries and power distribution panel)
2. Solar panels with power cabling that attaches to the power distribution panel in (1)
3. Tower's tripod base

4. Tower mast with two enclosures attached (one enclosure houses the datalogger and the other houses the ozone analyzer). There is also power cabling running from the datalogger enclosure to the power distribution panel in (1). This cabling remains attached and coiled with the tripod center pole.
5. Meteorological equipment and mounts including air temperature and relative humidity sensor, wind direction and wind speed sensor, solar radiation sensor and rainfall tipping gauge
6. Stakes for securing tower and padlocks/keys for battery case and two enclosures
7. Grounding rod and grounding wire (the grounding wire is attached to the tripod mast)
8. Lightning rod

POMS III Components

A POMS III consists of the parts listed below.

1. Tower
2. Instrumentation case
3. Whip antenna
4. Three (3) battery cases with one 12 volt battery in each case
5. Solar panel
6. Meteorological assembly (one unit with a combination of sensors included) that measures wind speed, wind direction, air temperature, relative humidity and atmospheric pressure
7. Stakes for securing tower to ground

Pre-trip Checklist

The steps for disassembling a POMS II and POMS III are provided in (SOP) #OC4: Ozone Concentration - Removing, Installing and Servicing a Portable Ozone Monitoring Station. The following steps should also be completed prior to departing for a destination park, regardless of whether the trip is for installation or removal of a POMS.

1. Know how to navigate to the park(s) to be visited. Obtain any necessary maps.
2. If necessary, make any necessary travel arrangements. This includes hotel reservations and completion of travel authorization.
3. Arrange to have a vehicle for the trip. An open-bed pickup truck (preferably 4-wheel drive, depending upon the site) is the best option.
4. Assemble the tools/supplies necessary. The minimum tool set should include:
   - ☐ a. Portable handheld GPS unit with spare fully charged batteries
   - ☐ b. Two pound hammer
   - ☐ c. Crow bar
   - ☐ d. Short planks and/or blocks of wood
   - ☐ e. Flat blade screwdriver
   - ☐ f. Wire stripper and crimping tool
   - ☐ g. Wire cutters
   - ☐ h. Campbell Scientific flat blade screwdriver (or a smaller, flat blade screwdriver as from a precision screwdriver set)
   - ☐ i. Phillips screwdriver
   - ☐ j. Adjustable wrench

- ☐ k. Rope or motorcycle ratchet strap to secure solar panels in bed of truck (POMS II only)
- ☐ l. Socket wrench
- ☐ m. Sockets
- ☐ n. Socket extension
- ☐ o. Arc joint pliers
- ☐ p. Electrical tape
- ☐ q. Extra locks/keys

5. Verify that the portable GPS unit (preferably handheld) is working properly.
6. Purchase supplies as necessary.
7. If this is an installation trip, the POMS will currently be assembled at the CUPN office. Disassemble and load POMS into the pickup truck.
8. Depart.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #OC3: Ozone Concentration – Establishment and Location of Sampling Sites

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This SOP explains the procedures used for establishing and locating ozone sampling locations. Ozone sampling is accomplished using Portable Ozone Monitoring Stations (POMS) as designed and manufactured by the NPS Monitoring Support Contractor.

Establishment of Sampling Sites

Sampling sites are based heavily upon those utilized during the developmental phase of this protocol which began in 2004. Ozone sampling was accomplished using passive samplers in 2004/2005 and two POMS in 2005. For each park, multiple passive sites were chosen to provide good spatial coverage and data from multiple elevations. The POMS sites were selected from amongst the passive monitoring sites. In 2004, only two sites were outfitted with a POMS (at LIRI and RUCA). Both of the 2004 sites were collocated with passive samplers. In 2005, POMS units were collocated with passive samplers for three weeks at each participating park, with only a couple of the POMS being located away from passive samplers.

From 2006 to present, passive collectors have not been used. During this time, the CUPN has used only POMS stations for on-park ozone sampling. This cessation of passive monitoring is due to the fact that the CUPN is not currently studying spatial variability in ozone across any given park. The CUPN also wishes to obtain more temporally detailed data from each site. It is the intent of the CUPN to select a location within a park that is representative in elevation and weather patterns of the park. Data from that monitor will be used to compute exposure indices such as the W126 and the SUM06.

A summary of POMS monitoring efforts from 2004 through present is shown in Table 7.

In future monitoring efforts, the CUPN intends to use a POMS on only twelve of the fourteen CUPN parks (all CUPN parks are shown in Figure 5 and Listed in Table 1). The two parks that will not be sampled with a POMS (COWP and MACA) are equipped with EPA-certified

equivalent methods. Should either of those parks lose their current monitors, it will be sampled with a POMS as are the other twelve parks. The sampling schedule for CUPN parks is presented in the protocol narrative (Table 4).

Table 7 – CUPN parks where POMS sampling has taken or is taking place.

Park	Site Name	Dates of Operation	Collocated with passive?	Used in future?
ABLI	Knob Creek High	2005	Yes	No
ABLI	Visitor Center	2006 – 2007	No	Yes
CARL	Granite Dome 14	2005	Yes	Yes
CHCH	Maintenance Area Field	2005	Yes	No
CUGA	Hensley Settlement	2006 – Present	No	Yes
CUGA	Lincoln Memorial University (off-park)	2005	No	No
CUGA	Pinnacles	2005	Yes	No
FODO	Visitor Center	2005	Yes	Yes
KIMO	Reservoir Hill	2005	Yes	Yes
LIRI	Rim – High	2004	Yes	Yes
MACA	Great Onyx Job Corps	2005	Yes	No
MACA	Great Onyx Meadow	2005	Yes	No
NISI	Bumble Bee Hill	2005	Yes	Yes
RUCA	Not named (but near Visitor Center)	2004	Yes	Yes
SHIL	Russian Tenant Field	2005	Yes	Yes
STRI	South Chicago Bottom Field	2005	Yes	No

Many of the sites listed in Table 7 will be used in the future. It should be noted, however, that, in Table 7, some parks have multiple sites and some parks (COWP and GUCO) were not sampled. A list all of the CUPN parks as well as anticipated sampling sites within each park is given in Table 8. At most parks, we anticipate utilizing the same locations as those used in 2005 (with the exception of ABLI and CUGA, where we will use the sampling sites that were used beginning in 2006). For GUCO, where no monitoring was completed in 2005, the site will be selected by CUPN staff in cooperation with park staff. Also note that, in 2010, sampling sites at CHCH and STRI were relocated due to park restrictions on site usage.

Table 8 – Anticipated POMS sites.

Park	Site Name
ABLI	Visitor Center
CARL	Granite Dome 14
CHCH	Lookout Mountain
COWP	--
CUGA	Hensley Settlement
FODO	Visitor Center
GUCO	----To Be Determined----
KIMO	Reservoir Hill
LIRI	Rim - High
MACA	--
NISI	Bumble Bee Hill
RUCA	Visitor Center
SHIL	Russian Tenant Field
STRI	Beasley Field

Site Selection Criteria

Generally, site selection criteria include(d) the following:

- Is the site elevation typical or average for the park?
- Is the site free of localized weather patterns (such as nighttime inversions that settle into valleys)?
- Is the site free of pollution sources that are not typical of the entire park?
- Is the site in an open field, free of high vegetation that could disrupt wind patterns around the POMS?
- Is the site easily accessed?
- Is the site secure?

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #OC4: Ozone Concentration - Removing, Installing and Servicing a Portable Ozone Monitoring Station

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Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP explains the procedures used for removal, installation, and servicing of portable ozone monitoring stations (POMS) that should be followed by all project crews during POMS removals/installations and service visits. Service visit information includes detailed procedures for data collection and maintenance of in-situ equipment.

Assembly and Disassembly of a Second Generation POMS (POMS II)

POMS II Assembly

The steps for assembling a POMS II are below. An assembled POMS II is shown in Figure 14.

1. **Open and secure the legs on the tower's tripod base.** To open the tripod legs, push outward on each of the tripod legs (it may be necessary to further loosen the bolts that prevent the legs from moving). Caution: be careful when pressing out on the tripod leg not to get fingers pinched by the parts that will move. If this approach is unsuccessful in getting the leg to open, it may be necessary to use a hammer to jar the leg into motion. Once the legs are fully open and the tripod is resting upright on the ground without wobbling, secure the bolts that prevent the legs from moving.
2. **Connect the tower's mast and secure the meteorological sensors and ozone intake on the tripod's upper portion.** The mast is a piece of conduit with male threads on its lower end. This piece of conduit threads into a female connector on the tripod base. Lay the tripod on the ground and insert mast. With at least two people and holding the mast above the enclosures, push the tower onto its feet, being careful not to pull the mast from the tripod base. With both sections of tower now standing upright, screw the mast into the tripod base. To screw in the mast, turn it clockwise by pressing against the datalogger and ozone analyzer enclosures. Continue to turn the mast until the two tower sections are snugly attached to one another. Next, on the top section of the tripod, move the meteorological sensor and ozone intake into position and tighten the u-bolts that secure them.

3. **Secure the tower and solar panels.** The tower is secured to the ground using short lengths of capped rebar. The feet of the tripod base have holes through which to drive these pieces of rebar. Drive one piece of rebar through each of these holes. The solar panel assembly is held in place simply by placing the battery case across the assembly's horizontal 2X4X6 (approximately) feet.
4. **Unwrap any loose cabling around the mast.** There should be a few cables loosely wrapped around the mast. These cables should be unwrapped for later use.
5. **Connect the GPS transmitter and the satellite whip antenna.** Each of these devices connects to the Orbcomm transmitter via a length of cable. These cables may be pulled into the datalogger enclosure through the cable port in the enclosure. Each device should be attached to the datalogger enclosure's solar shield by its magnetic base. Each of the devices has a unique connector so that it will plug into only one place on the Orbcomm transmitter.

Figure 14 – An assembled POMS II at STRI in 2010. Photograph by STRI staff.

6. **Mount the meteorological sensors and ozone intake onto the tower's mast or crossarm.** The sensors should be mounted as prescribed by the NPS Monitoring Support Contractor. On the POMS II in CUPN's possession, the sensors are mounted as shown in Figure 14. The sensors are mounted in the following order, moving from the lowest point on the mast to the highest point:
   a. Rain gauge that is mounted onto its own special mounting arm
   b. Air temperature/relative humidity probe
   c. Ozone intake
   d. Mounting arm with wind direction/speed and solar radiation sensors
      Note that the mounting arm for the wind and solar radiation sensors should be oriented along an approximate north/south axis.
7. **Attach the sensor wires to the datalogger's wiring panel.** Route the wiring for each of the sensors through the opening on the bottom of the enclosure. Wire the sensors into the wiring panel as instructed by the NPS Monitoring Support Contractor.

8. **Connect the ozone intake line to the ozone analyzer's ozone inlet.** Route the intake line through the opening on the bottom of the enclosure. Connect the intake line to the intake port on the back of the ozone analyzer.
9. **Install the grounding rod and attach the grounding wire to the grounding rod.** The grounding wire is secured to the grounding rod using a grounding nut. Drive the grounding rod into the ground, insert the grounding wire into the grounding nut and tighten the bolt. The grounding rod should be driven at least one foot into the ground. Be certain to drive the grounding rod in a location where it is unlikely that park personnel will inadvertently trip on it or scrape their leg. The opposite end of the grounding wire should be connected to the tripod base using its grounding lug.
10. **Connect the batteries to each other and the power distribution panel.** Recall that batteries will be "tied together" using shunts. Note also that on one of the batteries has no wires attached. It is to this battery that all wires should be connected. First, connect the negative lead and the negative shunt to the negative post on this battery. Then connect the positive lead and the positive shunt to the positive post on this battery.
11. **Connect the power cabling from the solar panels.** Because the solar panels are always active, the leads are always powered, even though they are not plugged into the power distribution panel. Therefore, use caution while handling these leads. The cabling must be run through the inlet on the battery case. Unscrew the cap that secures the cabling in the inlet and keeps the inlet weathertight. Run the cabling through this inlet cap and then through the inlet on the battery case. Screw the inlet cap over the inlet. Now the cabling may be attached to the power distribution panel. First, attach the negative lead to its connector on the power distribution panel. Lastly, attach the positive lead to its connector on the power distribution panel.
12. **Connect the power cabling to the datalogger.** This should be done at the power distribution panel that resides in the battery case. The cabling must be run through the inlet on the battery case. Unscrew the cap that secures the cabling in the inlet and keeps the inlet weathertight. Run the cabling through this inlet cap and then through the inlet on the battery case. Screw the inlet cap over the inlet. Now the cabling may be attached to the power distribution panel. First, attach the negative lead to its connection point on the power distribution panel. Then, attach the positive lead to its connector near the fuse panel.
13. **Power up the ozone analyzer.** This is accomplished by turning on the first bit on the Campbell Scientific datalogger. Key in "*6AD1" to turn the bit and analyzer on. More information on "bits" may be found in the subsequent section "Notes on Campbell Scientific Datalogger Modes and Commands".
14. **Fill each of the openings on the bottoms of the datalogger and ozone analyzer enclosures with plumber's putty to prevent insects and water from entering the enclosure.**
15. **Perform a calibration check of the rain gauge.**
16. **Perform a routine biweekly maintenance visit.** This will ensure that the POMS is working properly after it has been assembled on site. Performing this biweekly visit also allows for the training of new site operators while an actual maintenance visit is being performed. Inform the NPS Monitoring Support Contractor of any problems noted.
17. **Train site operators.** It is a good idea to run through an actual site visit (as in step 16), so that new site operators can see how to execute each of the steps detailed in the subsequent section "Biweekly Maintenance Visits: Servicing an Installed Second or Third Generation

POMS (POMS II or POMS III)". Having seen the steps carried out also makes the site operators more comfortable with operating the POMS.

18. **For newly established sites, use handheld GPS to get site coordinates.** Consult the owner's manual for the GPS device being used to find out how to take a waypoint with that GPS device. Use the UTM NAD83 coordinate system. Forward these coordinates to CUPN's GIS specialist upon return to the office.
19. **Take site photographs from each of the cardinal directions.** Take one good photograph of the POMS from each of the cardinal directions (north, east, south, and west). Additional, artistic photographs that may be useful in reports should also be taken. These should be JPEG formatted and medium resolution (800 X 600 pixels and normal image quality is sufficient). Upon return to the office, these photographs should be transferred to the CUPN's hard drive which undergoes tape-backup on a regular basis.
20. **Call the NPS Monitoring Support Contractor so installation at the site can be documented.** The contractor's phone number is printed on the maintenance field form.

POMS II Disassembly

The steps for disassembling a POMS II are as detailed below. They are essentially the reverse of the assembly with some steps at the end of the assembly process omitted.

1. **Perform a routine biweekly maintenance visit prior to disassembly of the POMS.** This will ensure that the POMS is working properly before it is removed from the current site. Fill out the field form. Inform the NPS Monitoring Support Contractor of any problems noted.
2. **Power down the ozone analyzer.** This is accomplished by turning the first bit off on the Campbell Scientific datalogger. Key "*6AD1" to turn the bit and analyzer off. Details on "bits" may be found in the subsequent section "Notes on Campbell Scientific Datalogger Modes and Commands".
3. **Disconnect the power cabling to the datalogger.** This should be done at the power distribution panel that resides in the battery case. First, detach the positive lead from its connector near the fuse panel. Then, detach the negative lead from its connection point on the power distribution panel. The cable can now be pulled out of the battery case. Unscrew the cap that holds the cable in place on the outside of the battery case and pull the cable out of that inlet. Replace the cap on the battery case so that it is not lost.
4. **Disconnect the power cabling from the solar panels.** First, detach the positive lead from its connector on the power distribution panel. Because the solar panels are still active, the leads are always powered, even though they are not plugged into the power distribution panel. Therefore, once the lead has been disconnected, be careful not to allow the lead to come in contact with metallic surfaces or there could be an electrical short. After the positive lead has been disconnected, it should have a couple of wraps of electrical tape placed around its exposed wires to prevent this shorting. Then, the positive lead may also be bent back on itself and taped to itself. The negative lead should now be disconnected from its connector on the power distribution panel. As in (2), the cabling should be pulled from the inlet in the side of the battery case.
5. **Disconnect the batteries from each other and the power distribution panel.** This is accomplished by disconnecting wires from the posts of one of the batteries. It should be noted that the batteries are "tied together" by a pair of wires (one wire runs between the positive posts on the batteries and one wire runs between the negative posts on the batteries

and those wires will be referred to as shunts). Note also that on one of the batteries will be a set of wires that run from the posts to the power distribution panel. It is from this battery with wires leading to the power distribution panel that the wires should be disconnected. First, disconnect the positive leads and then disconnect the negative leads. Note that the loose end of the shunt that runs from the other battery's positive post should taped with electrical tape to prevent electrical discharge. Replace the connecting bolts back onto the battery terminals so that those bolts are not misplaced.

6. **Unwire from the datalogger the signal/power lines running from the meteorological sensors.** Simply unscrew the lug on the datalogger's wiring panel and pull the wiring out. Be certain that only wiring to the sensor is being removed and not wiring from other system components. Pull the cabling out of the enclosure.
7. **Dismount the meteorological sensors from the mast.** Carefully dismount the sensors and place them in the cab of the pickup truck in such a way that they will not be damaged in transit.
8. **Detach the grounding wire from the grounding rod.** The grounding wire is secured to the grounding rod using a grounding nut. Simply loosen the bolt to allow the grounding wire to come out. Pull the grounding rod out of the ground and stow it in the bed of the pickup truck.
9. **Disconnect the GPS transmitter and the satellite whip antenna.** Each of these devices is connected to the Orbcomm transmitter via a length of cable. These cables may be disconnected at the Orbcomm and pulled through the cable port in the enclosure. The whip antenna may be stored in the bed of the truck, but the GPS transmitter is best stored in the datalogger enclosure.
10. **Wrap any loose cabling around the mast.** There will be a few cables hanging loosely from the mast of the tripod. These should be loosely wrapped around the mast to prevent them from wrapping around the tripod base in step 10.
11. **Remove any stakes that are holding the tower and solar panels down.** Typically, the tripod and solar panel assembly are secured to the ground using short lengths of capped rebar. Depending upon how deeply the stakes are driven into the ground, the stakes can either be pulled out by hand or it may be necessary to use a pry bar to pull them out.
12. **Disconnect the mast of the tripod from its base.** The mast of the tripod is a piece of conduit with male threads on its lower end. This piece of conduit threads into a female connector on the base of the tripod. To unscrew the mast of the tripod, turn it counter-clockwise by pressing against the datalogger and ozone analyzer enclosures. Continue to turn the mast of the tripod until a popping sound is heard. The mast and base of the tripod are now loose from one another. Using at least two people, lean the entire tripod onto its side. With the tripod resting on its side, pull the mast away from the tripod base.
13. **Collapse the legs on the tripod base and loosen the meteorological sensors and ozone intake on the mast.** To collapse one of the tripod legs, loosen the bolts that prevent it from moving. Then, push the leg toward the center of the tripod. Caution: be careful when pressing down on the tripod leg not to get fingers pinched by the parts that will move. If this approach is unsuccessful in getting the leg to collapse, it may be necessary to use a hammer to jar the leg into motion. Repeat for the remaining legs.
14. **Load all parts into a pickup truck.** Each of these parts should be carefully loaded into the bed of a pickup truck. Place the solar panel assembly next to the cab of the pickup truck (with the front of the panels against the cab) and secure it with either rope or a ratcheting

motorcycle strap that was passed through the cab of the truck. The solar panels should stand sideways and upright. Place the battery case against the back side of the solar panel array to help provide additional support. Behind the battery case, place the mast of the tripod with the top of the mast facing the tailgate of the truck. The mast should be secured to the bed of the pickup using rope or a motorcycle strap that was passed through the eyelets in the front of the pickup bed. All other parts should be placed in open places in the bed of the truck.

15. **Call the NPS Monitoring Support Contractor so the POMS' removal from the site can be documented.** The contractor's phone number is printed on the maintenance field form.

Assembly/Disassembly of a Third Generation POMS (POMS III)

The steps to assemble a POMS III are given below. To disassemble a POMS III, reverse these steps, excluding steps 15 through 17. An assembled POMS III is shown in Figure 15.

1. **Open the tower's tripod legs and lock them in place.** Align the holes on each of the legs with the holes on each pair of vertical plates at base of the mast. Insert the supplied pin through the holes to hold the legs in place.
2. **Hammer one piece of rebar into each of the tripod's feet.** Each piece of rebar has a hose clamp at the top to hold the tripod feet down. Adjust the location of the hose clamp to within about a decimeter of the top of the rebar and tighten down the hose clamp. Drive a piece of rebar through each hole in the feet of the tripod until the hose clamp is pressed firmly against the tripod foot.
3. **Attach the meteorological sensor pack/ozone intake to the top of the mast.** Simply slide the base of the pack over the top of the mast and tighten the wing bolts against the mast.
4. **Raise the telescoping section of the mast.** Lift up on the top section of the mast until the hole in the top section aligns with the hole in the lower section. Insert the pin that is provided to lock the top section in place.
5. **Attach the solar panel to the tower's mast.** The solar panel is attached to the mast using two hose clamps. Orient the panel so that if faces south and is tilted downward approximately 15 degrees below level. Note that tilt shown in Figure 15 is too steep.
6. **Attach the Pelican case containing the datalogger and ozone analyzer.** The Pelican case has attached to its backside a flat metal plate. This plate fits into a slot on the tripod mast that is formed between the mast and another metal plate running parallel to the mast. Slide the plate on the Pelican case into the slot on the mast. A bolt is supplied with the Pelican case. Run the bolt through the hole in the mast and into the female threaded hole on the backside of the Pelican case and secure using a socket wrench.

Figure 15 – An assembled POMS III at CHCH in 2010.

7. **Connect the meteorological sensor pack to the datalogger via the quick connect on the bottom of the Pelican case.** There are two quick connects of differing sizes on the bottom of the Pelican case. Connect the sensor pack connector to the Pelican case connector that matches its size.
8. **Connect the ozone intake line from the meteorological sensor pack/ozone intake to the port on the bottom of the Pelican case.** At the bottom end of the intake line is a female coupler. Screw the coupler onto the male coupler that is attached to the bottom side of the Pelican case. There is only one such male coupler.
9. **Use electrical tape or cable ties to secure the meteorological sensor pack's signal cable and the ozone intake line to the tower's mast.** Use tape or a cable tie about every ½ meter.
10. **Install and connect the satellite transmitter's whip antenna.** Route the base of the whip antenna and its cable through the hole on the top-left of the Pelican case. Secure the antenna using the supplied nut. If necessary, place a strand of plumber's putty around the base of the antenna and on the outside of the case to prevent water from entering the case. Connect the antenna cable to the port on the satellite transmitter.
11. **Connect the batteries to each other.** There are two short sections of cable with which to connect the battery cases. The quick connects on the cables are color-coded to match their receptor connectors on the battery cases. One of the battery cases contains the power controller and has three connectors on it: one for connecting to the other batteries, one for connecting to the solar panel and one for connecting to the datalogger/ozone analyzer/satellite modem. Again, match the colors on the connectors for connecting to this battery case. Place each of the battery cases on one of the tripod's feet to help hold the tower in place.

12. **Connect the solar panel to the series of batteries.** Connect the cable from the solar panel to the aforementioned connector on the battery case by matching the colors of the connectors.
13. **Connect the series of batteries to the datalogger/ozone analyzer via the quick connect at the bottom of the Pelican case.** A third short section of cable should be connected between the aforementioned battery case connector to the connector on the bottom of the Pelican case. Use the color coding for attaching to the battery case and use the size of the connector to determine which connector to plug into on the bottom of the Pelican case.
14. **Perform a routine biweekly maintenance visit.** This will ensure that the POMS is working properly after it has been assembled on site. Performing this biweekly visit also allows for the training of new site operators while an actual maintenance visit is being performed. Inform the NPS Monitoring Support Contractor of any problems noted.
15. **Train site operators.** It is a good idea to run through an actual site visit (as in step 14), so that new site operators can see how to execute each of the steps detailed in the subsequent section "Biweekly Maintenance Visits: Servicing an Installed Second or Third Generation POMS (POMS II or POMS III)". Having seen the steps carried out also makes the site operators more comfortable with maintaining the POMS.
16. **For newly established sites, use handheld GPS to get site coordinates.** Consult the owner's manual for the GPS device being used to find out how to take a waypoint with that GPS device. Use the UTM NAD83 coordinate system. Forward these coordinates to CUPN's GIS specialist upon return to the office.
17. **Take site photographs from each of the cardinal directions.** Take one good photograph of the POMS from each of the cardinal directions (north, east, south, and west). Additional, artistic photographs that may be useful in reports should also be taken. These should be JPEG formatted and medium resolution (800 X 600 pixels and normal image quality is sufficient). Upon return to the office, these photographs should be transferred to the CUPN's hard drive which undergoes tape-backup on a regular basis.
18. **Call the NPS Monitoring Support Contractor so installation at the site can be documented.** The contractor's phone number is printed on the maintenance field form.

Biweekly Maintenance Visits: Servicing an Installed Second or Third Generation POMS (POMS II or POMS III)

Regular maintenance of POMS units is an important activity that will ensure that the POMS is operating properly and that the air supply to the ozone analyzer is adequate. The primary reasons for biweekly maintenance visits are to:

1. Ensure that the POMS has not been damaged.
2. Ensure that the POMS has sufficient power.
3. Ensure that the Campbell Scientific datalogger is functioning properly.
4. Ensure that the meteorological sensors are functioning properly.
5. Ensure that the ozone analyzer is working properly.
6. Exchange the particle filter that is on the intake side of the ozone analyzer.

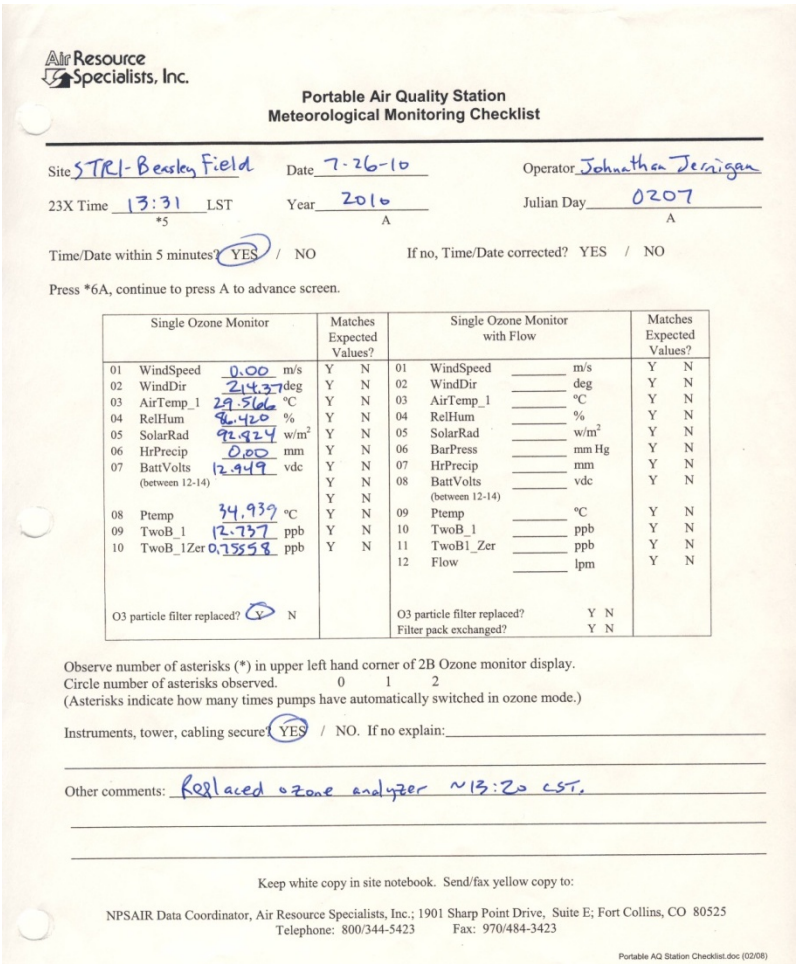
POMS II Checklist

1. **Retrieve a new site checklist form from the notebook.** These forms are stored in a three ring binder that is typically stored on-site in the battery case (although some site operators opt to keep these binders in their office). An example of a completed maintenance form is shown in Figure 16.

2. **Fill in the site name and observer information on the checklist.** These data include the site name, operator name, and information on the condition of the tripod assembly (is it secure?).
3. **Fill in the date and time (local standard time) from the datalogger by keying *5.** Keying *5 will display the time, and to view the date (as year and Julian day), the user must press the "A" key to advance to the next datum. Keying "A" once displays the year, and keying the "A" key once more will display the Julian day.
4. **Fill in the current meteorological, battery level, and ozone data from the datalogger.** This is accomplished by keying "*6" to enter *6 mode and keying "A" to advance forward or keying "B" to back up through various parameters. If any of the data are unreasonable (such as negative values for ozone concentration data), the site operator should contact the NPS monitoring support contractor to let them now about the problem.
5. **Flag the ozone data.** Flagging the ozone data is accomplished by keying "D" from *6 mode and then keying "7" to turn Bit 7 on. By flagging the data, the operator indicates to users of the data that the instrumentation is being serviced and the data are being affected by this servicing. Flagging the data indicates to users that those data are invalid and should be discarded. For more general information on flags, see the text on flags in the subsequent section "Notes on Campbell Scientific Datalogger Modes and Commands."
6. **Change out the particle filter in the orange filter holder that is attached to the 2B analyzer's intake line.** This circular, paper-thin filter is in the path of the air as it makes its way to the ozone analyzer. It is the job of the filter to catch dust and debris so that it does not enter into the ozone analyzer. Clogged filters will prevent sufficient airflow from entering the ozone analyzer, so these filters need to be changed biweekly. Change the filter by unscrewing the top half of the filter holder from the bottom half of the filter holder. It may be necessary to use the filter wrenches provided to loosen the two halves from one another. The old filter should be removed and discarded. Installation of the new filter should be done carefully, as improper handling of the filter can result in oils from the operator's fingers getting onto the filter (this will attract and hold excessive amounts of dirt and prevent airflow). To avoid this problem, hold the new filter at the very edge of the filter, drop it into place on the filter holder, and reattach the two filter halves to one another. Use the filter wrenches to snug the filter halves together. If a fresh supply of filters is necessary, contact either the NPS Monitoring Support Contractor (or the project lead who will then contact the NPS Monitoring Support Contractor).
7. **Verify that no supply lines came loose while the particle filter was being replaced.** Pay particular attention to the air supply line as it enters the ozone analyzer, as this connection has a tendency to come loose.
8. **Unflag the ozone data.** This is accomplished by keying "D" from *6 mode and then keying "7" to turn Bit 7 off. This activity has exactly the same sequence of steps as step 5, but here the ozone data are being unflagged rather than flagged. It should be noted that it takes several minutes for the ozone analyzer to recover after being serviced. So, ozone data will continue to be affected even after the flag has been turned off. The NPS Monitoring Support Contractor will invalidate these data as appropriate during the data validation process.
9. **Complete the checklist.** Complete the "other comments" section of the checklist, wherein the user should document any problems, unusual conditions, or supplies needed. It is also a good idea to review the checklist to make certain that each item on the checklist has been

addressed. Call the project lead or NPS Monitoring Support Contractor to report any problems that were discovered.

10. **Close and lock the datalogger and ozone analyzer enclosures.** Both of these enclosures (as well as the battery case) are equipped with padlocks. These should be in place upon departure to prevent theft or damage to the equipment between site visits.
11. **Upon return to the office, mail only the yellow carbon copy of the checklist to the address indicated on the bottom of the checklist.** The yellow carbon copy should be mailed to the NPS Monitoring Support Contractor. Alternatively, the form may be faxed to the NPS Monitoring Support Contractor using the number provided on the form. The white original should remain in the notebook provided.



Air Resource Specialists, Inc.

Portable Air Quality Station
Meteorological Monitoring Checklist

Site STRI-Beasley Field Date 7-26-10 Operator Johnathan Derrigan

23X Time 13:31 LST (*5) Year 2010 (A) Julian Day 0207 (A)

Time/Date within 5 minutes? YES / NO If no, Time/Date corrected? YES / NO

Press *6A, continue to press A to advance screen.

Single Ozone Monitor				Matches Expected Values?	Single Ozone Monitor with Flow				Matches Expected Values?
01	WindSpeed	0.00	m/s	Y N	01	WindSpeed		m/s	Y N
02	WindDir	214.37	deg	Y N	02	WindDir		deg	Y N
03	AirTemp_1	29.566	°C	Y N	03	AirTemp_1		°C	Y N
04	RelHum	82.420	%	Y N	04	RelHum		%	Y N
05	SolarRad	92.824	w/m²	Y N	05	SolarRad		w/m²	Y N
06	HrPrecip	0.00	mm	Y N	06	BarPress		mm Hg	Y N
07	BattVolts (between 12-14)	12.949	vdc	Y N	07	HrPrecip		mm	Y N
				Y N	08	BattVolts (between 12-14)		vdc	Y N
08	Ptemp	34.939	°C	Y N	09	Ptemp		°C	Y N
09	TwoB_1	12.737	ppb	Y N	10	TwoB_1		ppb	Y N
10	TwoB_1Zer	0.75558	ppb	Y N	11	TwoB1_Zer		ppb	Y N
					12	Flow		lpm	Y N
O3 particle filter replaced? Y N					O3 particle filter replaced? Y N Filter pack exchanged? Y N				

Observe number of asterisks (*) in upper left hand corner of 2B Ozone monitor display.
Circle number of asterisks observed. 0 1 2
(Asterisks indicate how many times pumps have automatically switched in ozone mode.)

Instruments, tower, cabling secure? YES / NO. If no explain:

Other comments: Replaced ozone analyzer ~13:20 CST.

Keep white copy in site notebook. Send/fax yellow copy to:

NPSAIR Data Coordinator, Air Resource Specialists, Inc.; 1901 Sharp Point Drive, Suite E; Fort Collins, CO 80525
Telephone: 800/344-5423 Fax: 970/484-3423

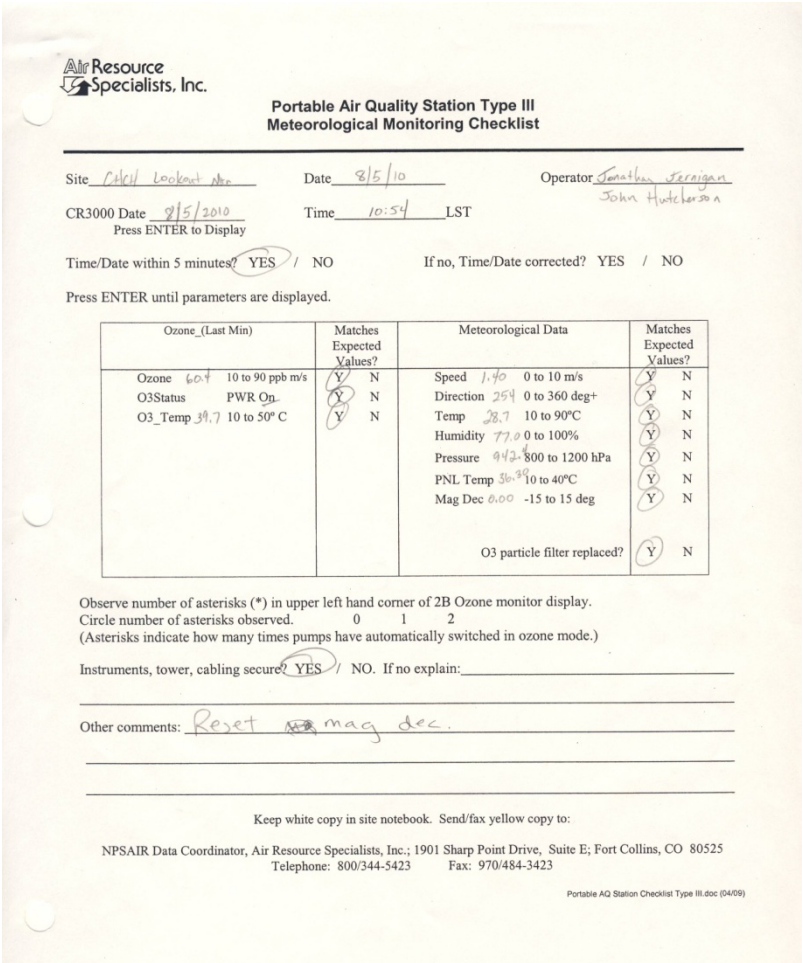
Portable AQ Station Checklist.doc (02/08)

Figure 16 – An example POMS II maintenance visit form.

POMS III Checklist

1. **Retrieve a new site checklist form from the notebook.** These forms are stored in a three ring binder that is typically stored on-site in the battery case (although some site operators opt to keep these binders in their office). An example of a completed maintenance form is shown in Figure 17.

2. **Fill in the site name and observer information on the checklist.** These data include the site name, operator name, and information on the condition of the tripod assembly (is it secure?).
3. **Fill in the date and time (local standard time) from the datalogger by pressing the "Enter" key.** Upon arrival, the datalogger display should be blank. Keying "Enter" will activate the display and show the date and time.
4. **Fill in the current meteorological and battery level data from the datalogger.** This is accomplished by keying "Enter" from the screen in step 3, arrowing down to "Met Data" and keying "Enter". If any of the data are unreasonable (such as negative values for wind speed data or battery voltage below 12), the site operator should contact the project lead or the NPS monitoring support contractor to let them know about the problem.
5. **Fill in the ozone data from the datalogger.** Press the escape ("Esc") key from the screen in step 4. Arrow down to select "Ozone_(Last Min)" and press "Enter". Make certain that the data are reasonable (for example, no concentrations that are negative or higher than 100 ppb or so). If values seem unreasonable, contact the project lead or the NPS Monitoring Support Contractor.
6. **Change out the particle filter in the orange filter holder that is attached to the 2B analyzer's intake line.** This circular, paper-thin filter is in the path of the air as it makes its way to the ozone analyzer. It is the job of the filter to catch dust and debris so that it does not enter into the ozone analyzer. Clogged filters will prevent sufficient airflow from entering the ozone analyzer, so these filters need to be changed biweekly. Change the filter by unscrewing the top half of the filter holder from the bottom half of the filter holder. It may be necessary to use the filter wrenches provided to loosen the two halves from one another. The old filter should be removed and discarded. Installation of the new filter should be done carefully, as improper handling of the filter can result in oils from the operator's fingers getting onto the filter (this will attract and hold excessive amounts of dirt and prevent airflow). To avoid this problem, hold the new filter at the very edge of the filter, drop it into place on the filter holder, and reattach the two filter halves to one another. Use the filter wrenches to snug the filter halves together. If a fresh supply of filters is necessary, contact either the NPS Monitoring Support Contractor (or the project lead who will then contact the NPS Monitoring Support Contractor).
7. **Verify that no supply lines came loose while the particle filter was being replaced.** Pay particular attention to the air supply line as it enters the ozone analyzer, as this connection has a tendency to come loose.
8. **Complete the checklist.** Complete the "other comments" section of the checklist, wherein the user should document any problems, unusual conditions, or supplies needed. It is also a good idea to review the checklist to make certain that each item on the checklist has been addressed. Call the project lead or NPS Monitoring Support Contractor to report any problems that were discovered.
9. **Close the datalogger and ozone analyzer enclosures.**
10. **Upon return to the office, mail only the yellow carbon copy of the checklist to the address indicated on the bottom of the checklist.** The yellow carbon copy should be mailed to the NPS Monitoring Support Contractor. Alternatively, the form may be faxed to the NPS Monitoring Support Contractor using the number provided on the form. The white original should remain in the notebook provided.



Air Resource Specialists, Inc.

Portable Air Quality Station Type III
Meteorological Monitoring Checklist

Site Circh Lookout Mtn Date 8/5/10 Operator Jonathan Jernigan, John Hutchinson

CR3000 Date 8/5/2010 Time 10:54 LST
Press ENTER to Display

Time/Date within 5 minutes? YES / NO If no, Time/Date corrected? YES / NO

Press ENTER until parameters are displayed.

Ozone_(Last Min)	Matches Expected Values?	Meteorological Data	Matches Expected Values?
Ozone 60.4 10 to 90 ppb m/s	Y N	Speed 1.40 0 to 10 m/s	Y N
O3Status PWR On	Y N	Direction 254 0 to 360 deg+	Y N
O3_Temp 39.7 10 to 50° C	Y N	Temp 28.7 10 to 90°C	Y N
		Humidity 77.0 0 to 100%	Y N
		Pressure 942.4 800 to 1200 hPa	Y N
		PNL Temp 36.39 10 to 40°C	Y N
		Mag Dec 0.00 -15 to 15 deg	Y N
		O3 particle filter replaced?	Y N

Observe number of asterisks (*) in upper left hand corner of 2B Ozone monitor display.
Circle number of asterisks observed. 0 1 2
(Asterisks indicate how many times pumps have automatically switched in ozone mode.)

Instruments, tower, cabling secure? YES / NO. If no explain:

Other comments: Reset mag dec.

Keep white copy in site notebook. Send/fax yellow copy to:

NPSAIR Data Coordinator, Air Resource Specialists, Inc.; 1901 Sharp Point Drive, Suite E; Fort Collins, CO 80525
Telephone: 800/344-5423 Fax: 970/484-3423

Portable AQ Station Checklist Type III.doc (04/09)

Figure 17 – An example POMS III maintenance visit form.

Notes on Modes and Commands Used by the Campbell Scientific Datalogger in a POMS II

The POMS II system uses a CR23X datalogger while the POMS III uses a CR3000 datalogger. The notes in this section apply to a POMS II's CR23X. No notes are provided for the CR3000 since it is a later generation datalogger with a simpler interface.

In the POMS II, a Campbell Scientific, Inc. CR23X datalogger is used to control the instrumentation, store data, and transmit data via satellite uplink. The basic operation of these Campbell Scientific dataloggers is the subject of this section. These dataloggers have an attached wiring panel to which sensors are attached. The user interfaces with the datalogger via an LCD display and a keypad, both of which are built into the datalogger. For this protocol, the primary interactions with the datalogger will be to:

- View and change, as necessary, date/time information.
- View meteorological, battery voltage, and ozone data as they are being collected.
- Activate data collection events.
- Transfer data from the datalogger to the storage module.
- Return the datalogger to its normal state.

Modes

Each of these tasks is accomplished within a particular "mode." Modes are referred to as "* modes" (pronounced "star modes") since, in order to enter the modes, the *-key must be depressed prior to the mode number. Modes used in this protocol are:

*0 Mode – Log data and display active program tables.
*5 Mode – Display date/time information.
*6 Mode – Display data in intermediate storage. Toggle flags within this mode.

To enter each mode, key in "*" followed by the mode number. For most modes, this sequence will take the user directly into the requested mode. *6 mode, however, functions slightly differently. This mode is used to view intermediate storage, in which data are temporarily stored as they are collected from data sources (sources such as sensors or user-defined variables). Each measurement is stored in a "memory location" and memory locations use numeric labels. That is, there are memory locations 1, 2, 3, and so forth. Keying "*6" does not take the user directly into *6 mode. The datalogger will wait to let the user key in the memory location to be viewed. For example, keying "*612A" places the user in *6 mode (from the "*6" portion of the sequence) and allows the user to view the datum in memory location 12 (the 12 part of the sequence). The "A" portion of the sequence functions like an "enter" keystroke on a PC keyboard, communicating to the datalogger that the user has completed and accepted the keystroke sequence. Leaving a memory location out of the sequence (i.e., keying "*6A") takes the user, by default, to memory location 1.

> Side note: Campbell Scientific dataloggers have two types of data storage: intermediate storage and final storage. Intermediate storage contains raw data as collected directly from sensors or as defined by the user. Data in final storage are derivatives of the data in intermediate storage. *6 mode displays *intermediate* data.

Within each mode, it may be possible to execute mode-specific commands. In *5 and *6 modes, for example, keying "A" advances the user through pieces of information. Keying "B" in these modes backs the user up through these same pieces of information. Descriptions of each mode and the functionalities of each follow.

- *0 Mode – Campbell Scientific refers to this mode as the "LOG data and indicate active Tables" mode. Keying "*0" from any mode returns the user to a screen that may be called the home screen or log screen. In this mode, the user may see which program table(s) is (are) being executed. Program tables are distinct blocks of computer code that may be executed simultaneously and independently of one another. Campbell Scientific datalogger programs consist of two program tables (labeled tables 1 and 2). Entering *0 mode will display one of the following screens where each screen has the indicated meaning:

  - "LOG" – Indicates that no program table is being executed.
  - "LOG 1" – Indicates that program table 1 is being executed.
  - "LOG 2" – Indicates that program table 2 is being executed.
  - "LOG 12" – Indicates that program tables 1 and 2 are being executed.

- *5 Mode – Displays the current time and date information. Key “A” to advance (or ascend) through the list below and key “B” to back up through the list below.

  - Time
  - Year
  - Julian day
  - Time set screen

- *6 Mode – Displays intermediate memory used for temporary data storage. The display has the format LL : DDDDD, where LL is two digit memory location label and DDDDD is the most recent value stored to that location. The colon in the middle is used to indicate the program’s execution; the colon flashes whenever the program is executed. Data shown are from the most recent program execution. A typical display may read “06 : 12.369” indicating that the most recent datum stored to memory location 6 is 12.369. The user may view these data by either keying *6xxA (where xx is the desired memory location) or by keying “*6A” to enter *6 mode. Once in *6 mode, the user may press the A key to advance up through memory locations or press the B key to back up through memory locations. Some loggers may also display text descriptions of the fields being shown, and may show more than one field at a time.

Flags

This SOP uses flags to mark data as valid or invalid. In this SOP, flags may be regarded as variables that the user may adjust. The CR10X supports eight such flags and each flag is referenced by a numeric identifier (i.e., Flag 1, Flag 2, …, Flag 8). Each flag will have one of two possible values: either zero or one. To view (and alter) the value of these flags, the user should be in *6 mode (if the user is not in *6 mode, then “*6A” should be keyed). Once in *6 mode (while viewing any memory location), keying “D” will take the user to the flag screen where each of the flags is shown. One possible display is “00100000”. The first digit is the value of Flag 1, the second digit is the value of Flag 2, and so on. In this example, all flags have values of zero, with the exception of Flag 3, which has a value of one.

The value of flags may be user-adjusted or program-adjusted. To user-adjust a flag value, press the numeric key that corresponds to the flag number. This will toggle that flag between the values zero and one. From the previous example, Flag 3 may be returned to a value of zero by keying “3” on the keypad (and back to one again by keying “3” a second time). For this SOP, flag 1 is used to control power to the ozone analyzer. When this value is user-adjusted to a value of one, the ozone analyzer is powered up. To toggle between powering the analyzer up and powering the analyzer down, repeatedly key “1”.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #OC5: Ozone Concentration - Post-Sampling

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP explains procedures that all field observers using the ozone and foliar injury protocol for the Cumberland Piedmont Network (CUPN) should be familiar with and follow after the field sampling is completed.

Closing out a trip to move a Portable Ozone Monitoring Station (POMS)

Upon return to the office, any tools that were taken on the trip should be cleaned and put away. If the POMS were removed on the trip, then the POMS should be placed in storage. Storage modules and ozone analyzers should be forwarded to the NPS Monitoring Support Contractor. Any field forms that were filled out while on the trip should be sent to the NPS Monitoring Support Contractor and archived. Travel vouchers should also be completed.

Storage of a POMS

The network POMS should be stored in a CUPN weatherproof facility at MACA. Storing the unit at MACA allows the project lead to have convenient access to the POMS for preseason preparations. Storing the POMS in a weatherproof facility keeps the unit from being exposed to the weather. Assembly and disassembly instructions may be found in SOP #OC4.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #OC6: Ozone Concentration - Data Management

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Introduction

This SOP describes management of the ozone concentration data collected from monitors nearby and within parks of the Cumberland Piedmont Network (CUPN). Data collected through this protocol will be uploaded to central databases from multiple monitors each year, and many, if not most of these monitors are managed by other agencies and programs, such as EPA, states, and Air Resources Division of NPS (NPS-ARD). The design and management of these data are handled with rigorous QA/QC controls, due to the regulatory environment for which they are being used.

Ozone concentration data collected using a POMS require no staff-level data entry, since data collection is datalogger driven with satellite uplinks. Validation and archival of ozone concentration data will be performed by the NPS Monitoring Support Contractor. In addition to the ozone concentration data collected by the POMS, data from nearby state-operated sites will be collected for each of the CUPN parks (except for those parks that have on-park equivalent methods). Data from these nearby monitors will be used to calculate the exposure level for each of the CUPN parks. The CUPN will not validate or archive the state-operated ozone concentration data since those tasks are handled by the state that operates the site.

For the ozone concentration portion of this protocol, acquisition, validation, and storage of POMS data are the responsibility of the NPS Monitoring Support Contractor. These data are available from the contractor upon request through NPS-ARD and after the end of the ozone season. The data are generally made available as comma delimited text or Excel files. See “data analysis” SOP #OC7 for details on usage.

Data Validation

Data validation consistent with the NPS-ARD network (the US-wide network of stations maintained by NPS-ARD) standards ensures timely validation of data using procedures that meet EPA standards. Three levels of data validation performed for the NPS-ARD network are illustrated in Figure 18. Only final validation level data, meeting all NPS and EPA validation

requirements, are acceptable for submission to the NPS-validated data archives and the EPA AQS national database. More detailed information regarding NPS-ARD data validation procedures can be found in Standard Operating Procedure 3450, *Ambient Air Quality and Meteorological Monitoring Data Validation* (this document is posted on NPS-ARD's website) and its associated technical instructions.

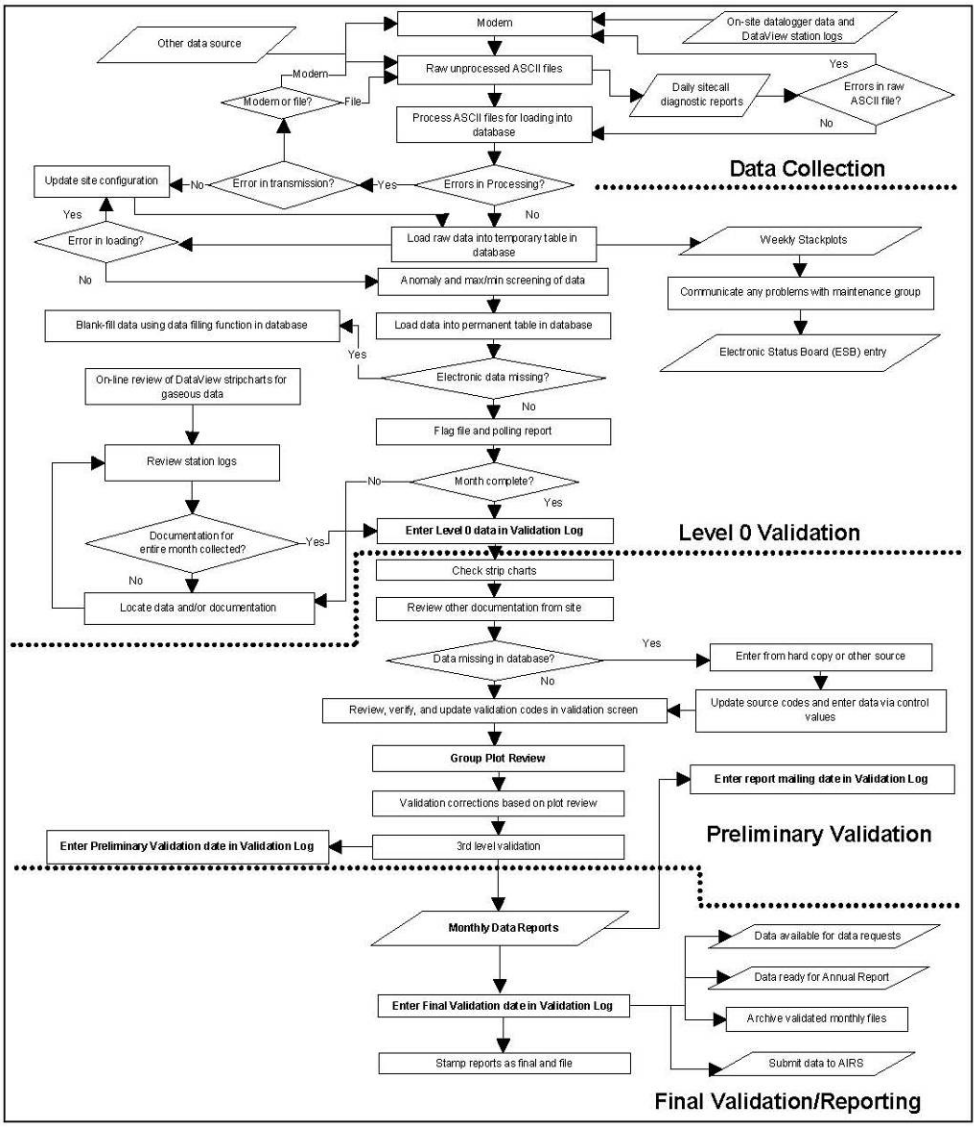


Figure 18 – NPS Gaseous Pollutant Monitoring Program Network Data Collection, Validation, and Reporting Flow Diagram (Ray 2004).

Reliance upon offsite data management procedures emphasizes the need to document external quality assurance/quality control (QA/QC) methods, statistical summaries, and interpretations which is handled through reporting and/or websites of other agencies. The ARD performs monthly/quarterly submittal of final validated regulatory data to the EPA's AQS database. These data include hourly average ambient air quality and meteorological data, precision data from ozone analyzer precision checks, and accuracy data from audit reports on ozone analyzers.

Database Administration

This section relates to spreadsheets and other data derived from primary sources (ARD/EPA).

Data Maintenance

Datasets are rarely static. They often change through additions, corrections, and improvements made following the archiving of a dataset. There are three main caveats to this process:

1. Only make changes that improve or update the data while maintaining data integrity.
2. Once archived, document any changes made to the dataset.
3. Be prepared to recover from mistakes made during editing.

Any editing of archived data is accomplished jointly by the project leader and data manager. Every change must be documented in the edit log and accompanied by an explanation that includes pre- and post-edit data descriptions.

Data Organization

The CUPN has established a template directory structure, composed of seven folders and four subfolders for each vital sign monitoring project (Figure 19). Project files which are being modified, considered draft, and/or certain files currently in use (e.g., a copy of the field data form) should reside within this directory. A similar directory structure will contain archived files (\CUPN_Archive\). Both the working and archive directories will be accessible via the MACA Local Area Network, with access permissions maintained by the data manager(s) and/or MACA Information Technology Staff.

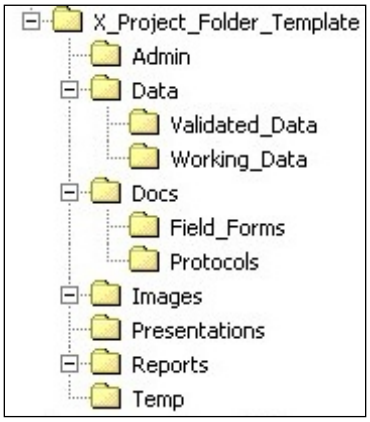


Figure 19 – CUPN project directory structure.

The data tables utilized for data entry and validation reside within the “Working_Data” folder. Once data in these tables are validated by the project leader, a data manager will append the records to the data tables in the “Validated_Data” folder and the “working” data tables will be emptied. As indicated, the data tables containing the master protocol-specific data for the project are contained in the “Validated_Data” folder. These data have been validated and are available as read-only except to CUPN data managers.

Data Security and Integrity

As many different users will be accessing the database, it is imperative that the data remain secure. Although MS Access provides a means for allowing User-Level Securities to different groups of uses, the data managers have determined that it will be more effective to create user groups within the local area network operating system that will have different security levels. Generally, three levels of users will be given different sets of permissions. CUPN data managers will have all permissions, including insert, delete, and modify for all folders in the folder structure. Project leaders/program coordinators, will have the same permissions as program data managers except for read-only permission to the shared data tables and archived data. Those entering the data will have insert and modify permission to the observation data and read-only permission to the lookup and shared data tables.

Version Control

Prior to any major changes of a dataset, a copy is stored with the appropriate version number. This allows for the tracking of changes over time. With proper controls and communication, versioning ensures that only the most current version is used in any analysis. Versioning of archived datasets is handled in the same manner as protocol narrative and SOP versioning (see SOP #OC9). Frequent users of the data are notified of the updates, and provided with a copy of the most recent archived version.

Data Logs and Backups

Once the data are archived, any changes made to the data must be documented in an edit log. From this point forward, original field data forms should not be altered. Field forms can be reconciled to the database through the use of the edit log. Secure data archiving is essential for protecting data files from corruption. Once a dataset has passed the specified QA/QC procedures, a data manager will make a formal entry on the Integrated Resource Management Applications site (IRMA). Subsequently, an electronic version of the dataset is maintained in a read-only format on the program server. Incremental or differential tape backups of all project databases are regularly conducted. Backup copies of the data are maintained in a secure alternate location.

Data Availability

In addition to the "standardized" data dissemination strategies noted in Chapter IX of the DMP (Moore et al. 2005), data will be made available for research and management applications on request (per the framework established in the DMP). Data requests should be directed to the CUPN coordinators.

Literature Cited

Moore, W. J., R. Byrd, and T. Leibfreid. 2005. Data management plan for the Cumberland Piedmont Network and Mammoth Cave National Park Prototype monitoring program. USDI National Park Service. Mammoth Cave, KY. 81pp.

Ray, John D. 2004. *Ozone Monitoring Protocol: Guidance on Selecting and Conducting Ozone Monitoring.* Air Resources Division, Research and Monitoring Branch, National Park Service, Lakewood, Colorado, USA.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #OC7: Ozone Concentration - Data Analysis

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP outlines the data flow and expected analyses of the ozone concentration data collected within the CUPN. The monitoring questions and subsequent analysis of the supporting data address issues related to status and trends in ozone concentration/exposure throughout the CUPN. The status and trends of this parameter are understood to impact many of the plant species that populate CUPN parks. Specific monitoring questions will be addressed using a combination of summary and descriptive statistics, graphic analysis, and multivariate comparative and correlative analysis.

The protocol was designed to answer the following monitoring questions related to ozone concentration/exposure:

- What is the cumulative ozone exposure in CUPN parks within a typical April-October growing period?
- What is the trend in cumulative ozone exposure in CUPN parks across time (years)?

Data Flow

Ozone concentration data collected using a POMS will require no data entry since data collection is datalogger driven with satellite uplinks. Validation and archival of ozone concentration data from a POMS will be performed by the NPS Monitoring Support Contractor. In addition to the ozone concentration data collected by the POMS, data from nearby state-operated sites will be collected for each of the CUPN parks, as applicable. The CUPN will not validate or archive the state-operated ozone data since those tasks are handled by the state that operates the site. Ozone exposure indices will be calculated and then incorporated into regular reports that go out to each of the CUPN parks. These reports will be archived as outlined in the “Reporting” SOP (#OC8).

Data Analysis

These POMS data are available from the contractor through its website. The data are available as comma delimited text files. For advanced analyses, these data will be imported into a

commercial off-the-shelf statistical analysis software package such as SigmaPlot. To import data into SigmaPlot:

1. Launch SigmaPlot.
2. Click on File to view the File menu.
3. Select Import from the File menu.
4. A window will open in which the user can select the appropriate file type and the file to be imported. There will be a drop-down list from which the appropriate file type may be selected. Select "Plain Text" or "Excel," as appropriate. Then, navigate to the appropriate folder and select the desired file.
5. Follow the on-screen directions to finish importing the selected file.

Table 9 – Example of cumulative ozone exposure indices presented for sampled parks in annual reports. This table is from CUPN's 2009 report.

Park Name	Data Source	8 to 8 SUM06 in 2009 Growing Season (ppm-hrs)	8 to 8 W126 in 2009 Growing Season (ppm-hrs)	Highest Consecutive 3-Month W126 in 2009 Growing Season
COWP	COWP State Operated Site	2.11	5.81	2.92
FODO	POMS (27 May 2009 to 15 July 2009)	1.37	1.83	N/A
MACA	Houchins' Meadow Site	9.66	11.17	6.45
SHIL	POMS (16 July 2009 to 30 Oct 2009)	0.00	0.74	N/A

Table 10 – Example of cumulative ozone exposure indices provided for non-sampled parks. This table is from CUPN's 2009 report.

Park Name	FIPS of Nearby Site	County, State of Nearby Site	8 to 8 SUM06 in 2009 Growing Season (ppm-hrs) [Is level sufficient to cause foliar injury in sensitive plants? (Y/N)]	8 to 8 W126 in 2009 Growing Season (ppm-hrs) [Is level sufficient to cause foliar injury in sensitive plants? (Y/N)]	Highest Consecutive 3-Month W126 in 2009 Growing Season [Is level sufficient to cause foliar injury in sensitive plants? (Y/N)]
ABLI	210930006	Hardin County, KY	10.74 [Y]	12.09 [Y]	7.15 [Y]
CARL	370210030	Buncombe County, NC	4.49 [N]	6.40 [N]	4.55 [N]
CHCH	130550001	Chattooga County, GA	8.93 [Y]	9.27 [Y]	5.04 [N]
CUGA	N/A	N/A	1.21 (24 hour SUM06 is 4.34) [N]	4.87 [N]	3.53 [N]
GUCO	371570099	Rockingham County, NC	13.27 [Y]	13.21 [Y]	7.34 [Y]
KIMO	450910006	York County, SC	4.29 [N]	5.89 [N]	3.34 [N]
LIRI	130550001	Chattooga County, GA	8.93 [Y]	9.27 [Y]	5.04 [N]
NISI	450010001	Abbeville County, SC	2.97 [N]	6.97 [N]	3.18 [N]
RUCA	470654003	Hamilton County, TN	16.47 [Y]	15.98 [Y]	8.58 [Y]
STRI	471490101	Rutherford County, TN	10.11 [Y]	11.34 [Y]	6.17 [Y]

NAAQS and Cumulative Exposure Indices

When possible, ozone data at active parks will be evaluated for attainment of the current NAAQS. Compliance with the NAAQS will be evaluated by computing the relevant index using the Monitoring Support Contractor's website. The contractor's website computes the 4th highest 8-hour average of ozone. As detailed at http://www.epa.gov/air/criteria.html, the standard is based upon a 3-year average of each year's 4th highest 8-hour averages. Sites with at least 3 consecutive years of data (such as COWP, CUGA and MACA) may be evaluated for attainment of the NAAQS. Since each POMS will be at a park only one year at a time, the CUPN will not be able to obtain the 3-year average for POMS sites. So, only the 4th highest 8-hour average for each year will be considered.

Whenever possible, cumulative ozone exposure indices will be computed each year for all parks in the network. This includes parks that have been sampled in that year (either for both ozone concentration and foliar injury or for just foliar injury). Indices that will be computed include:

- 8 to 8 SUM06
- 8 to 8 W126 (for growing season)
- Highest consecutive 3-month W126 (for growing season)

Tables 9 and 10 show these data as presented in CUPN's 2009 report. Only 8 to 8 values are shown, but 24-hour indices may also be computed.

For future reports, the indices will be computed using either the Monitoring Support Contractor's website or SigmaPlot. For POMS, COWP and MACA data, the Monitoring Support Contractor's website contains built-in functions that compute exposure indices.

Data that are obtained through EPA's Data Mart must be analyzed using SigmaPlot. SigmaPlot was used to compute the indices shown in tables 9 and 10. User-defined programs (called transforms) allow the user to perform such computations within SigmaPlot. In CUPN reports, whenever a transform is used for computation, that transform will be provided as an appendix to the report.

As an alternative to computing exposure indices for itself, the CUPN may request that NPS-ARD perform the computations. The indices provided by NPS-ARD would be presented in reports and stored in data files on the CUPN server.

Please note that in Table 10, the column "FIPS of Nearby Site" is used to identify the site from which the data were collected. In the future (and as suggested by an external reviewer of this protocol), the "AQS ID" code will be used instead.

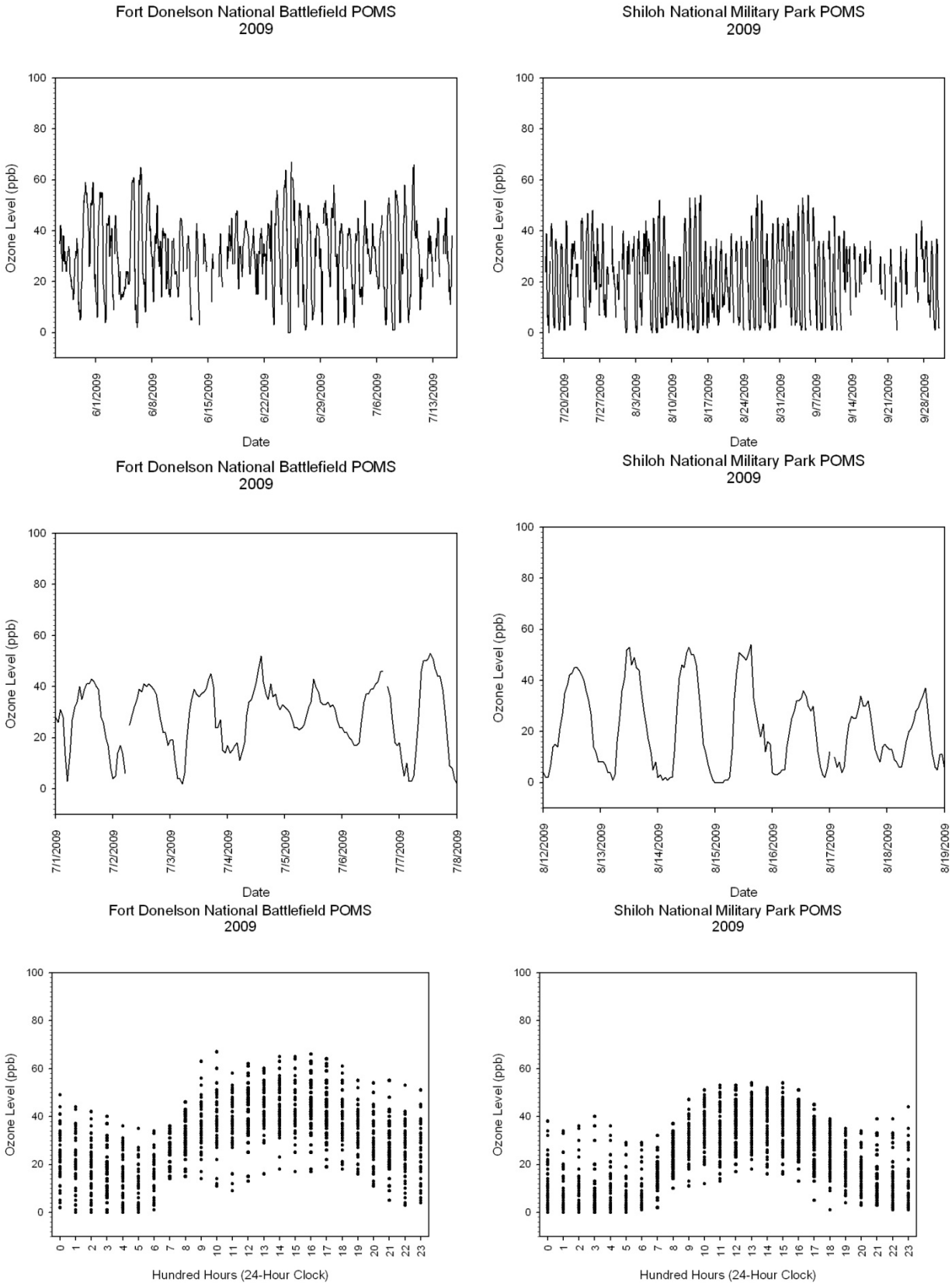


Figure 20 – Time series plots of ozone data collected in 2009. Diurnal pattern plots are also shown.

Time Series and Diurnal Plots

Time series plots will be generated for the entire growing season as well as up to the time of foliar injury assessments. Plots will also be generated that show the diurnal patterns in the ozone data. Figure 20 shows examples of these plots. The diurnal plots are constructed with the hour of the day on the x-axis and the ozone value on the y-axis. Such plots can show if a site tends to have low ozone values at night and high ozone values during the day (typical of urban sites) or if the site has little diurnal variability (typical of rural and high-elevation sites). These diurnal patterns are important to plant response since plant stomata are mostly closed at night resulting in less ozone uptake into the leaf. Please note that data shown in Figure 20 were collected in 2009 under a draft version of this protocol when only one POMS was used to collect data at two parks.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #OC8: Ozone Concentration - Reporting

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP gives step-by-step instructions for reporting on ozone and ozone effects parameters (ozone concentration and foliar injury assessment data) at parks throughout the Cumberland Piedmont Network (CUPN). This SOP describes the procedure for formatting a report, the report review process, and distribution of completed reports. Efficient reporting on monitoring results is critical in assisting park resource managers with management decisions. Therefore, a reporting schedule is given with key reporting dates identified. Timely production of appropriate reports is the responsibility of the project leader and the CUPN coordinators. All reports will follow the Natural Resources Technical Report series format and numbering system.

Report Format

General

Reports should be produced on high quality white paper, 215 x 280 mm in size. Font size of all text should be 12 point unless smaller font aids in fitting information on tables. Times New Roman font should be the standard font utilized. However, other text fonts are acceptable if used consistently throughout the document. Text is left justified with 3-cm margins on all sides. Words should not be hyphenated on the right side of text.

Page numbers and headers should be placed in the upper-right corner of each page starting with page two of the report. One exception to page numbering and headers is with figures (including pictures and illustrations), if a separate figure title page is used, place number and heading on these pages and leave them off pages containing the figures. Headers should contain an abbreviated version of the report title.

Bolding and underlining should be used minimally in the body of the text unless used on section headings and subheadings. Use italic font for scientific names of species. While common names are generally used, scientific names should be included parenthetically with first mention of the common name. Thereafter, common name only will generally be used.

Three levels of section headings may be used. First-level headings are all upper-case letters, bolded and left-justified with a sequenced whole number to its left. Second-level headings are bolded and left justified similar to first-level headings with sequenced numbers to the first decimal place. However, only the first letter in each word is capitalized. Third-level headings are indented five spaces and the first letter in each word is capitalized. Third-level headings are not bolded, underlined or numbered. Third-level headings may be italicized followed by a period and two hyphens or bulleted.

Reports should be direct and concise, avoiding superfluous wording. Refer to CBE Style Manual (CBE Style Manual Committee 1994) or Writing with Precision, Clarity and Economy (Mack 1986) for aids in writing. Also see Strunk and White (1979), Day (1983), and "Notes on Writing Papers and Theses" (Lertzman 1995) for help in structuring sentences and paragraphs for clarity.

Tables

Tables should be placed within the text of a report or immediately following the literature cited section. Tables should be numbered in sequence regardless of where they are located. Table headers are placed at the top of a table. Horizontal lines are used to separate the table heading from column headings, column headings from the table and to signify the end of the table. Vertical gridlines lines should not appear on a table.

Figures

Figures should be placed within the text of a report or immediately following tables behind the literature cited sections. Figures should be numbered in sequence regardless of where they are located. Figure captions are placed below the figure if it is included in the text or on a separate sheet of paper preceding the figure if included after the literature cited section. Both tables and figures should contain information not presented in the body of the text. Also, tables and figures should not duplicate information already presented in the body of the text.

Pictures

Treat as figures.

Report Outline

TITLE PAGE

- Title
- Author(s)
- Institutions
- Prepared for
- Date

TABLE OF CONTENT PAGE (optional)

EXECUTIVE SUMMARY PAGE (abstract)

1.0 INTRODUCTION

1.1 Background

1.2 Justification for Study

1.3 Objectives

2.0 METHODS

2.1 Study area(s)

2.2 Field method(s)

2.3 Analytical method(s)

3.0 RESULTS

4.0 DISCUSSION

5.0 MANAGEMENT IMPLICATIONS

6.0 ACKNOWLEDGEMENTS

7.0 LITERATURE CITED

(See Section IV, Literature Cited for format examples)

APPENDICES (optional)

Review Procedure

Internal Review

Annual reports on ozone and ozone effects monitoring will be written by the project leader, and/or crew leader(s) under the direction of the project leader. One or more internal reviews for grammatical soundness will be sought prior to submitting the report to CUPN management staff. Internal review by CUPN personnel skilled in technical writing for clarity and directness should fulfill this review requirement. Internal reviews will be conducted by CUPN staff and/or other persons sought out for their language skills.

If reports are written to update findings only and they do not deviate significantly from previously reviewed and distributed reports then the review process may stop here. However, review by park staff and subsequent external reviews must be sought for new reports or those that deviate significantly from previously reviewed and distributed reports. Also, if management activities within a park are not clearly understood, then park review should be sought for a report to clarify results and management implications.

Park Review

Park staff (generally Resource Managers) are in a unique position in that they can supply details about management actives that may influence findings presented in a report. Also, they will be the ones applying management recommendations to their park. Therefore, review by park staff is vital to the interpretation of findings and the assessment of proposed management implications. Review by park staff should be conducted before a report is submitted for external review.

External Review

External review by two or more experts in air quality monitoring should be sought for the first report in a series of annual reports and trend reports. In addition, analytical methods employed on data presented in the report need to be reviewed by one or more statisticians. If a report updates a previously reviewed and distributed report then external review is not required. However, external reviews must be sought for new reports or those that deviate significantly from previously reviewed and distributed reports. In order to conserve reviewer time, external reviews must follow the internal and park review process.

All review comments must be addressed, be it there inclusion in the report or reason for excluding them from the report. The responsibility to edit a report falls to the senior author of the report or their designee.

Distribution Procedure

Identifying Stakeholders

The primary stakeholders in our ozone and ozone effects monitoring efforts are the National Park Service management staff at CUPN parks. Potential stakeholders include state and federal wildlife agencies, universities, and the general public. Natural resource specialists conducting (or considering conducting) ozone or ozone effects monitoring should be interested in project results.

Distributing Reports

Annual reports will be provided to resource managers at CUPN parks as appropriate. Additionally, a copy will be archived according to current NPS guidelines and a copy will be kept on file in the CUPN office of the National Park Service, Mammoth Cave, Kentucky. Reports will be available to all interested parties upon request.

All data collected by the CUPN is, of course, public property and is subject to requests under the Freedom of Information Act (FOIA). The data management plan for the CUPN Monitoring program (Moore et al. 2004) describes appropriate procedures to respond to FOIA requests, including the protection of sensitive data such as endangered species locations. Reports containing non-sensitive data will be disseminated through the CUPN websites. Through the websites, those requesting information will be asked to provide information to document by whom and for what purpose the report is being used. By documenting requests, users can be informed when updated reports are available. Users requesting paper copies will be documented also.

In an effort to disseminate findings in a timely manner, annual reports should be completed by March 31 of the year following data collection. A brief (2-3 paragraphs) summary of sampling activities, preliminary results, and any public interest highlights that occurred during each federal fiscal year will be written by October 15 for inclusion in the CUPN Annual Administrative Report. More extensive summary reports (long-term trend reports) should be completed every five years. These reports will be centered upon ozone and ozone effects data, but will also synthesize findings among several vital signs being monitored across the CUPN that display cross correlation. Summary reports may be used in place of annual reports for the year in which the last data is collected.

Literature Cited

Moore, W. J., R. Byrd, and T. R. Leibfreid. 2005. Data management plan for the Cumberland Piedmont Network and Mammoth Cave National Park Prototype Monitoring Program. USDI National Park Service. Mammoth Cave, KY. 81pp.

CBE Style Manual Committee. 1994. Scientific style and format: the CBE manual for authors, editors, and publishers. Sixth edition. Council of Biology Editors, Cambridge University Press, New York, New York, USA.

Day, R. A. 1983. How to write and publish a scientific paper. Second edition. ISI Press, Philadelphia, Pennsylvania, USA.

Lertzman, K. 1995. Notes on writing papers and theses. Bulletin of the Ecological Society of America **76**:86-90.

Mack, R. N. 1986. Writing with precision, clarity, and economy. Bulletin of the Ecological Society of America **67**:31-35.

Strunk, W. Jr., and E. B. White. 1979. The elements of style. Third edition. Macmillan, New York, New York, USA.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #OC9: Ozone Concentration - Revising the Protocol

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This Standard Operating Procedure explains how to make changes to the ozone and ozone effects monitoring Protocol Narrative for the Cumberland Piedmont Network (CUPN) and accompanying SOPs, and how to track these changes. Any changes in the ozone and foliar injury monitoring protocol will adhere to the guidelines contained in this SOP. Observers asked to edit the Protocol Narrative or any one of the SOPs need to follow this outlined procedure in order to eliminate confusion in how data are collected and analyzed. All observers should be familiar with this SOP in order to identify and use the most current methodologies, and should see the revision history log attached to each SOP.

Procedures

1. The ozone and foliar injury monitoring protocol for the CUPN and (Narrative and accompanying SOPs) has attempted to incorporate the most sound methodologies for collecting and analyzing data. However, all protocols regardless of how sound require editing as new and different information becomes available. Required edits should be made in a timely manner and appropriate reviews undertaken.
2. All edits require review for clarity and technical soundness. Oversight of the revision process for all protocols is the responsibility of the CUPN coordinator(s). When a potential modification to a protocol is identified, the project leader consults with the coordinator(s), who then decides whether the change should be considered “small” or “significant”. Small changes or additions to existing methods will be reviewed in-house by CUPN staff designated by the coordinator(s). However, if a substantial change, such as a change in methods is sought, then an outside review may be required. The need will be determined by the protocol coordinators and project leader. Reviewers will be selected based on the type of change (i.e., changes in sampling sites versus changes in sampling design or sampling analysis). Regional and National staff of the National Park Service, as well as the U.S.

Geological Survey-Biological Resource Discipline, with familiarity in ecological research and data analysis will be utilized as reviewers. Also, experts in air quality monitoring, research, and statistical methodologies outside of the National Park Service will be utilized in the review process, as needed.

3. Document all edits and protocol versioning in the Revision History Log that accompanies the Protocol Narrative and each SOP. Log changes in the Protocol Narrative or SOP being edited only. Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02…1.3…1.41…etc) for minor changes , such as changes to grammar, spelling, formatting, or minor modifications in the process that do not affect interpretation of the data. Major revisions, such as significant changes in the process or changes that affect interpretation of the data, should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 …etc). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number.
4. Depending upon the magnitude and nature of a proposed change, it could have significant implications for data management. The database may have to be edited by the data manager to accompany changes in the Protocol Narrative and SOPs. Thus the data manager must be consulted prior to implementing changes to protocols. Immediately after the changes to the Protocol Narrative or SOP(s) have been made, inform the data manager, so the new version number can be incorporated in the metadata of the project database.
5. Post new versions on the Internet and in the “Narratives” or “SOP” subfolder for the project on the network server. Forward copies to all individuals with a previous version of the affected Protocol Narrative or SOP. Archive a copy of each previous version in the CUPN archives.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #FoIn1: Foliar Injury - Training of Field Personnel

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Foliar injury sampling requires an overall project leader and additional staff as outlined in the Table 11. The project leader (who also serves as a crew leader) oversees and directs project operations, including training of crew members who will only assist the crew leader (but will not make foliar injury determinations). Each crew consists of one crew leader and at least one crew member. The project crew leader has expertise in ozone injury sampling methods. The project crew member has varied and less expertise, and is responsible for assisting the crew leader with data collection.

Table 11 – Tasks and personnel needed for foliar injury assessments.

Task	Personnel required
Foliar Injury Survey Initiation	CUPN coordinators or project lead
Foliar Injury Survey	Crew leader and one (minimum) or two member field crew

To ensure high data quality, crew leaders should be thoroughly familiar with SOP #FoIn2, which deals with pre-sampling and training exercises, and SOP #FoIn4 which deals with field sampling. The overall project leader should be a permanent staff member.

Transient personnel (e.g., student interns, short-term or seasonal employees, volunteers, etc.) should serve as project crew members (i.e., field assistants). While review of SOP #FoIn4 for crew members is encouraged, it is not essential because the tasks assigned to crew members can be easily taught and rehearsed during a pre-sampling “training” meeting prior to start of field work. In this meeting, the project leader or crew leader also reviews member roles, steps in the sampling process, the particular safety Job Hazard Analyses, and two-way radio use.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #FoIn2: Foliar Injury - Pre-Sampling

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP describes tasks to be performed prior to site visits. This SOP gives procedures for:

- USFS Workshop/Certification and Online Assessment Exercises
- General Site Visit Preparation

It must be noted that the NPS requires research/collecting permits be obtained before any field work can commence. So, each year and for each park, the project lead must submit an application through the NPS Research Permit and Reporting System https://science.nature.nps.gov/research/ac/ResearchIndex. A travel authorization should also be completed prior to departure when overnight stays are needed.

USFS Workshop/Certification and NPS-ARD Online Training

A crew should have one person who is especially knowledgeable in the assessment of foliar injury. For this reason, one member of CUPN staff (usually the project/crew leader) must, as prescribed by the USFS, participate annually in USFS workshops on foliar injury assessments or take the annual exams necessary to be re-certified by the USFS to conduct surveys.

Additionally, an online foliar injury assessment exercise has been developed and is maintained by the NPS Air Resources Division (NPS-ARD). Any staff member who may be participating in a foliar injury assessment session should complete the online training. This training should be completed prior to field assessments. The exercise should be completed multiple times to assure that the crew member can correctly assess foliar injury in the field. This is true for crew members who will be making injury assessments in the field, but not for those whose anticipated role is to provide support services. Crew members that will not be assessing injury are not required to be considered "proficient" at assessing injury, but are still encouraged to complete the online exercises so that they gain familiarity with the appearance of foliar injury. The URL for the training exercise is http://www2.nature.nps.gov/air/edu/O3Training/index.cfm.

General Site Visit Preparation

1. **Acquire an NPS research/collecting permit.** The crew should carry a photocopy of the permit while in the field.
2. **Obtain travel authorization.** This applies to all crew members.
3. **Copies of field data forms from recent sampling events should be reviewed to identify any unique events or hazards that may be encountered.**
4. **Review the list of sensitive plants and be able to identify each species.** Also, review list of species known to occur in the park unit. Proper assessment requires that samplers be able to identify the species of interest. Review of the field guide book or other plant guide with plates is helpful.
5. **Complete foliar injury refresher training as detailed in the previous section of this SOP.**
6. **Schedule the site visit.** Site visits should be scheduled with host parks regardless of whether the crew needs an escort to the site. At the very least and as a courtesy, a host park should always be notified of an upcoming site visit. Usually, however, it is necessary to have personnel from the host park escort the site crew to the site.
7. **Print copies of the foliar injury, site mapping and voucher specimen field forms.** The USFS provides updated copies of these forms each year.
8. **Know how to navigate to the destination park and know the location of sampling sites.** To locate a particular site, it may be sufficient to arrange for personnel at the host park to escort the crew to the site.
9. **Obtain or request that personnel at the host park obtain any keys necessary to access sites.**
10. **Gather equipment and supplies.** All equipment should be examined to be sure that it is functioning properly. Supplies should be inventoried and, as necessary, purchased. A list of equipment and supplies is given below.

    List of equipment and supplies:
    - ☐ Plant press
    - ☐ Petiole labels for voucher leaf samples
    - ☐ Field forms
    - ☐ Handheld GPS
    - ☐ 10X hand lens
    - ☐ Digital camera
    - ☐ Field guides or reference samples
    - ☐ Plant guides including trees, shrubs, herbs of interest
    - ☐ Compass
    - ☐ Rangefinder or tape measure
    - ☐ Park radio or cell phone
    - ☐ Park Plant List and Ozone Sensitive Species List
    - ☐ Replacement batteries
    - ☐ Snake stick (for pulling high branches into view)

11. **Depart for the field site and/or host park.**

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #FoIn3: Foliar Injury - Establishment and Location of Sampling Sites

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP explains the procedures used for establishing and locating foliar injury assessment locations to be followed by the Cumberland Piedmont Network (CUPN).

Establishment of Sampling Sites

Selection of foliar injury assessment sites is based upon criteria established by the USFS protocol. The USFS uses non-randomly selected sites. The USFS criteria include:

- Ease of access – the most easily accessible site(s) are preferred, but other factors from this list should also be considered.
- Size of opening – at least three acres is preferred, but smaller openings may be considered.
- Number of species – more than three species is preferred by the USFS and by the CUPN, but the CUPN will allow plots with only one species.
- Number of plants – the USFS requires 30 plants from 2 species but three or more species is preferred. For the CUPN, every effort will be made to meet the requirement, but sites with fewer plants will be accepted.
- Condition of the soil – low drought potential with good fertility is preferred, but moderately dry and moderately fertile soils are acceptable.
- Site disturbance – no recent disturbance or obvious soil compaction is preferred, but a site with little disturbance and no obvious widespread soil compaction is acceptable.

The USFS protocol also allows split plots – two separate sites that are pooled and treated as one site. Detailed discussions of split plots may be found in the USFS protocol. The CUPN recommends that the opening size, soil conditions and site disturbance criteria be used as established in the USFS protocol. The species count and plant count criteria, however, may be relaxed a bit. Every attempt will be made to meet these criteria, but in some instances meeting the criteria will not be possible. Samplers should get as many plants as possible from at least two species with at least 30 plants from two species being the target.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #FoIn4: Foliar Injury - Sampling

Version 1.0 (November 2011)

Revision History Log:

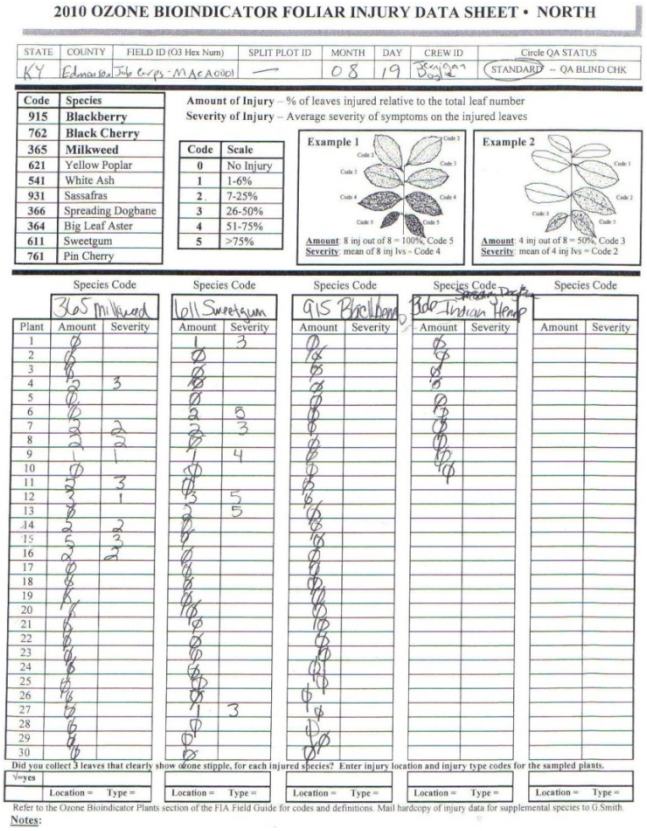
Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP explains the procedures used for foliar injury assessments that should be followed by all project crews. Included are detailed, step-by-step instructions that cover details such as sketching a site map, collecting foliar injury data, and collecting voucher leaf samples. Foliar injury sampling should be completed during the time prescribed by the USFS.

Foliar Injury Sampling Procedure

1. **Complete pre-sampling activities (SOP #FoIn2).**
2. **Depart for the sampling site.**
3. **Collect foliar injury data.** Data should be recorded onto the current year's field form provided by the USFS. The 2010 field form is shown in Figure 21. The sampler should walk systematically throughout the plot, looking at each individual from the selected plant species. Each individual should be visually inspected to determine whether any foliar injury is evident. As prescribed by the USFS, only leaves on the plant that are exposed to direct sunlight should be considered. Further, as is stipulated in the USFS protocol, clonal individuals should be avoided. To avoid such sampling, the USFS protocol advises the sampler to "take several steps between each plant selected for evaluation." Continue to move from one individual to the next until all individuals in the site have been examined. Ideally, thirty individuals from each of at least two species will be examined.
4. **Plant species should be selected from Table 3 with preference given to the list below (especially the bolded species).**

- **Blackberry**
- **Common milkweed**
- Black cherry
- Yellow poplar
- White ash
- Sassafras
- Spreading dogbane
- Big leaf aster
- Sweetgum
- Pin cherry



2010 OZONE BIOINDICATOR FOLIAR INJURY DATA SHEET • NORTH

STATE	COUNTY	FIELD ID (O3 Hex Num)	SPLIT PLOT ID	MONTH	DAY	CREW ID	Circle QA STATUS
KY	Edmonson	Job Corps-MAEA001	—	08	19	Boyd	STANDARD – QA BLIND CHK

Code	Species
915	Blackberry
762	Black Cherry
365	Milkweed
621	Yellow Poplar
541	White Ash
931	Sassafras
366	Spreading Dogbane
364	Big Leaf Aster
611	Sweetgum
761	Pin Cherry

Amount of Injury – % of leaves injured relative to the total leaf number
Severity of Injury – Average severity of symptoms on the injured leaves

Code	Scale
0	No Injury
1	1-6%
2	7-25%
3	26-50%
4	51-75%
5	>75%

Example 1 — **Amount**: 8 inj out of 8 = 100%, Code 5; **Severity**: mean of 8 inj lvs = Code 4

Example 2 — **Amount**: 4 inj out of 8 = 50%, Code 3; **Severity**: mean of 4 inj lvs = Code 2

Plant	Species Code: 365 Milkweed Amount	Severity	Species Code: 611 Sweetgum Amount	Severity	Species Code: 915 Blackberry Amount	Severity	Species Code: 366 Indian Hemp Amount	Severity	Species Code Amount	Severity
1	0		1	3	0		0			
2	0		0		0		0			
3	0		0		0		0			
4	3	3	0		0		0			
5	0		0		0		0			
6	0		2	3	0		0			
7	2	2	2	3	0		0			
8	2	2	0		0		0			
9	0	1	1	4	0		0			
10	0		0		0					
11	2	3	0		0					
12	3	1	3	5	0					
13	0		2	5	0					
14	2	2	0		0					
15	5	3			0					
16	2	2	0		0					
17	0		0		0					
18	0		0		0					
19	0		0		0					
20	0		0		0					
21	0		0		0					
22	0		0		0					
23	0		0		0					
24	0		0		0					
25	0		0		0					
26	0		0		0					
27	0		1	3	0					
28	0		0		0					
29	0		0		0					
30	0		0		0					

Did you collect 3 leaves that clearly show ozone stipple, for each injured species? Enter injury location and injury type codes for the sampled plants.

Y=yes	Location = Type =	Location = Type =	Location = Type =	Location = Type =	Location = Type =

Refer to the Ozone Bioindicator Plants section of the FIA Field Guide for codes and definitions. Mail hardcopy of injury data for supplemental species to G.Smith.
Notes:

Figure 21 – 2010 foliar injury field form.

5. **Evaluate the *amount* of foliar injury.** In the USFS protocol, injury amount is defined as "the percentage of leaves on the plant with ozone injury symptoms relative to the total number of leaves on the plant." The CUPN will use the scale for injury amount that was developed by the USFS shown in Table 12.

Table 12 – Codes used for the "amount" index.

Code	Definition
0	No injury; the plant does not have any leaves with ozone symptoms.
1	1 to 6 percent of the leaves have ozone symptoms
2	7 to 25 percent of the leaves are injured
3	26 to 50 percent of the leaves are injured
4	51 to 75 percent of the leaves are injured
5	>75 percent of the leaves have ozone symptoms

6. **Evaluate the *severity* of foliar injury.** In the USFS protocol, injury severity is defined as "on average, … [the] percent of the leaf area of injured leaves [that] have ozone symptoms." As with the amount index, the severity index is estimated for each plant. The USFS scale for severity is a 0 – 5 scale, similar to that used for the amount index. The severity scale is shown in Table 13.

Table 13 – Codes used for the "severity" index.

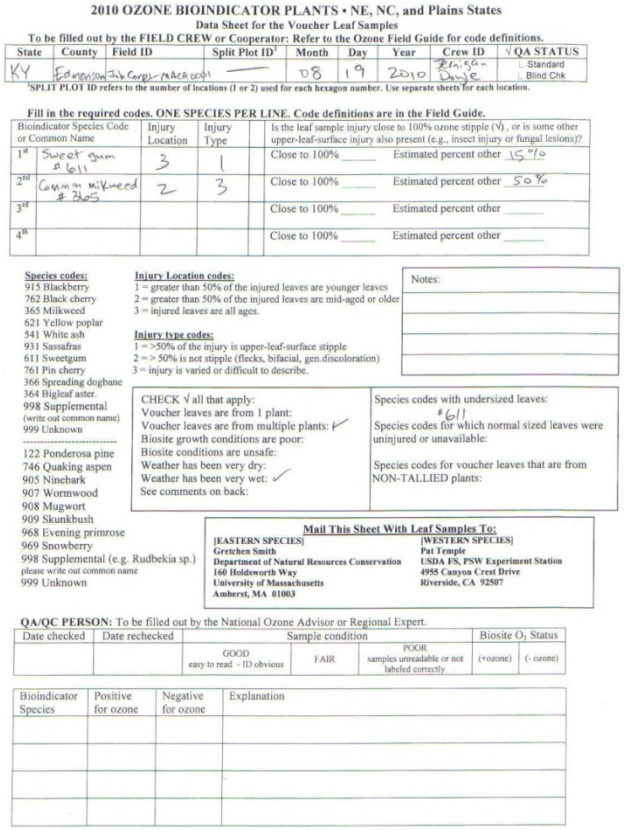
Code	Definition
0	No injury; the plant does not have any leaves with ozone symptoms.
1	On average, 1 to 6 percent of the leaf area of injured leaves have ozone symptoms
2	On average, 7 to 25 percent of the leaf area of injured leaves have ozone symptoms
3	On average, 26 to 50 percent of the leaf area of injured leaves have ozone symptoms
4	On average, 51 to 75 percent of the leaf area of injured leaves have ozone symptoms
5	On average, >75 percent of the leaves have ozone symptoms

Notes on filling out the foliar injury field form

The foliar injury field form (shown in Figure 21) may be divided into two sections. The first section contains information on where, when and who collected the data. The field titled "Field ID (O3 Hex Num)" does not apply to the CUPN. The CUPN uses that field for site name and site code. The site code consists of the four-character park abbreviation from Table 1 and a four digit site identifier such as 0001. The site identifier for each site will remain unchanged from year-to-year. "Split Plot ID" is null, a "1" or a "2" and identifies whether a split plot is being used. The USFS uses split plots when enough species/plants cannot be found at one site, but, when combined, result in enough species/plants. More information on split plots may be found in the USFS protocol. The "Circle QA Status" field is used by the USFS to identify the type of crew that is filling out the field form. The CUPN does not currently use the "Circle QA Status" field.

The second section details the species, amount of ozone injury, and severity of ozone injury for each of the plants observed at the site. This part of the sheet is arranged in columns with each column devoted to one species. As a plant from a given species is encountered in the field, the amount and severity indices are recorded for that plant using the next available plant number within the column for that species. More details on the fields on the form may be found in the USFS protocol.

7. **As appropriate, collect leaf vouchers.** For each species showing foliar injury, at least one voucher specimen should be collected at each site. The general procedures for collecting voucher leaf samples are as follows.
   a. **Collect a voucher specimen that is representative in appearance and severity of what has been observed at the site.** Three leaves are considered one voucher and one voucher should be collected for each species showing foliar injury. Ideally, leaves should come from multiple plants and not be abnormally large or small.
   b. **Immediately label the specimen using a USFS-supplied petiole label.** Site, date, and species should be noted on the label as shown in figures 10 and 11.
   c. **Immediately place the specimen in a plant press.** Specimens should remain in the press for at least 36 hours.



2010 OZONE BIOINDICATOR PLANTS • NE, NC, and Plains States

Data Sheet for the Voucher Leaf Samples

To be filled out by the FIELD CREW or Cooperator: Refer to the Ozone Field Guide for code definitions.

State	County	Field ID	Split Plot ID[1]	Month	Day	Year	Crew ID	√ QA STATUS
KY	Edmonson	Job Corps-PACA 0001	—	08	19	2010	Smith Doyle	☐ Standard ☐ Blind Chk

[1]SPLIT PLOT ID refers to the number of locations (1 or 2) used for each hexagon number. Use separate sheets for each location.

Fill in the required codes. ONE SPECIES PER LINE. Code definitions are in the Field Guide.

Bioindicator Species Code or Common Name	Injury Location	Injury Type	Is the leaf sample injury close to 100% ozone stipple (√), or is some other upper-leaf-surface injury also present (e.g., insect injury or fungal lesions)?
1st Sweet gum #611	3	1	Close to 100% ____ Estimated percent other 15%
2nd Common milkweed #205	2	3	Close to 100% ____ Estimated percent other 50%
3rd			Close to 100% ____ Estimated percent other ____
4th			Close to 100% ____ Estimated percent other ____

Species codes:
915 Blackberry
762 Black cherry
365 Milkweed
621 Yellow poplar
541 White ash
931 Sassafras
611 Sweetgum
761 Pin cherry
366 Spreading dogbane
364 Bigleaf aster.
998 Supplemental (write out common name)
999 Unknown
---
122 Ponderosa pine
746 Quaking aspen
905 Ninebark
907 Wormwood
908 Mugwort
909 Skunkbush
968 Evening primrose
969 Snowberry
998 Supplemental (e.g. Rudbekia sp.) please write out common name
999 Unknown

Injury Location codes:
1 = greater than 50% of the injured leaves are younger leaves
2 = greater than 50% of the injured leaves are mid-aged or older
3 = injured leaves are all ages.

Injury type codes:
1 = >50% of the injury is upper-leaf-surface stipple
2 = > 50% is not stipple (flecks, bifacial, gen.discoloration)
3 = injury is varied or difficult to describe.

Notes:

CHECK √ all that apply:
Voucher leaves are from 1 plant:
Voucher leaves are from multiple plants: ✓
Biosite growth conditions are poor:
Biosite conditions are unsafe:
Weather has been very dry:
Weather has been very wet: ✓
See comments on back:

Species codes with undersized leaves: #611
Species codes for which normal sized leaves were uninjured or unavailable:
Species codes for voucher leaves that are from NON-TALLIED plants:

Mail This Sheet With Leaf Samples To:

[EASTERN SPECIES]
Gretchen Smith
Department of Natural Resources Conservation
160 Holdsworth Way
University of Massachusetts
Amherst, MA 01003

[WESTERN SPECIES]
Pat Temple
USDA FS, PSW Experiment Station
4955 Canyon Crest Drive
Riverside, CA 92507

QA/QC PERSON: To be filled out by the National Ozone Advisor or Regional Expert.

Date checked	Date rechecked	Sample condition			Biosite O_3 Status	
		GOOD easy to read - ID obvious	FAIR	POOR samples unreadable or not labeled correctly	(+ozone)	(- ozone)

Bioindicator Species	Positive for ozone	Negative for ozone	Explanation

Figure 22 – 2010 voucher specimen field form.

d. **Fill out the voucher leaf sample field form.** An example field form is shown in Figure 22. One field form should be completed for each site at which injury is found. The field form is divided into three sections: a general information section, a voucher specimen and site condition section, and a QA/QC section. The general information section contains fields as described above in "Notes on filling out the foliar injury field form".

The voucher and site section contains information on injury parameters as observed across the site and the specimen(s) collected as well as the condition of the site during the visit. The table in this section contains information on voucher specimens and the plant population from which they were taken. The "injury location" datum describes where, on each plant, ozone injury tended to be located. The "injury type" datum describes the mix of ozone injury (such as stipple) and non-ozone injury typical of leaves at the site. The codes in Table 14 are used for each datum (these codes and text are taken from the USFS protocol). The last field in the table addresses percent of injury on the leaves that is ozone stipple. This field is concerned with the voucher specimen and not the population of plants from which the voucher was collected. The remaining questions in the voucher information and site condition section are self-explanatory.

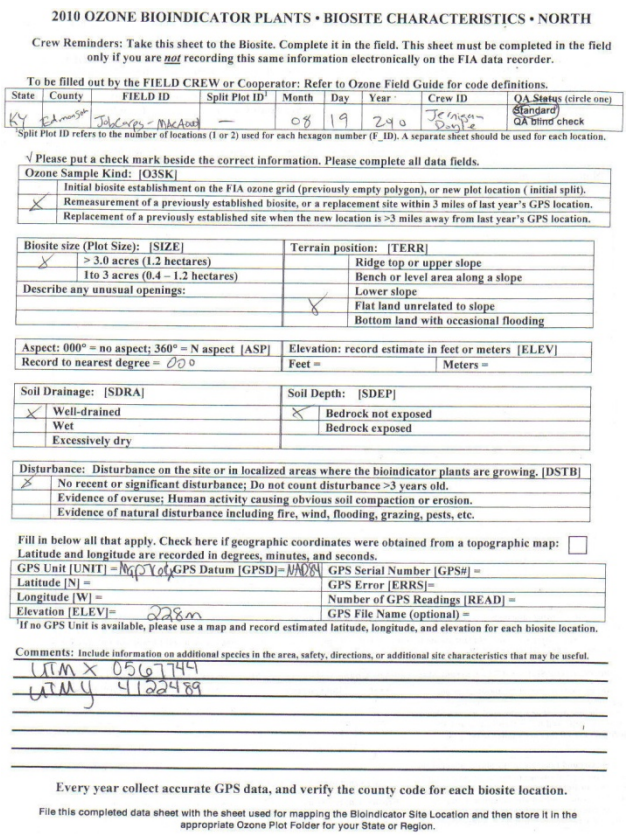
The QA/QC section is not completed in the field; it is completed in the laboratory by laboratory personnel. More information on fields contained in this field form may be found in the USFS protocol.

Table 14 – The codes for “injury location” and “injury type” data.

Injury Location	Injury Type
1 – Greater than 50% of the injured leaves are younger leaves	1 – Greater than 50% of the injury is upper-leaf-surface stipple
2 – Greater than 50% of the injured leaves are mid-aged or older	2 – Greater than 50% is not stipple (tan flecks, bifacial or general discoloration)
3 – Injured leaves are all ages	3 – Injury is varied or difficult to describe

e. **Once all specimens have been collected for the site, secure the plant press.**

8. **Fill out site characteristics field form.** The site characteristics field form includes information about the estimated acreage of the opening and GPS coordinates/elevation at the approximate center of the opening. The field form is also divided into three sections. The first is the general information section, as in the foliar injury data sheet. The second section contains self-explanatory fields that provide general data about site conditions. The final section contains geographic information as collected by a GPS unit. Details for all field entries may be found in the USFS protocol.



2010 OZONE BIOINDICATOR PLANTS • BIOSITE CHARACTERISTICS • NORTH

Crew Reminders: Take this sheet to the Biosite. Complete it in the field. This sheet must be completed in the field only if you are *not* recording this same information electronically on the FIA data recorder.

To be filled out by the FIELD CREW or Cooperator: Refer to Ozone Field Guide for code definitions.

State	County	FIELD ID	Split Plot ID[1]	Month	Day	Year	Crew ID	QA Status (circle one)
KY	Edmonson	Jackcreek - MACA003	—	08	19	2010	Jensen Davis	Standard / QA blind check

[1]Split Plot ID refers to the number of locations (1 or 2) used for each hexagon number (F_ID). A separate sheet should be used for each location.

√ Please put a check mark beside the correct information. Please complete all data fields.

Ozone Sample Kind: [O3SK]	
	Initial biosite establishment on the FIA ozone grid (previously empty polygon), or new plot location (initial split).
X	Remeasurement of a previously established biosite, or a replacement site within 3 miles of last year's GPS location.
	Replacement of a previously established site when the new location is >3 miles away from last year's GPS location.

Biosite size (Plot Size): [SIZE]	
X	> 3.0 acres (1.2 hectares)
	1 to 3 acres (0.4 – 1.2 hectares)
Describe any unusual openings:	

Terrain position: [TERR]	
	Ridge top or upper slope
	Bench or level area along a slope
	Lower slope
X	Flat land unrelated to slope
	Bottom land with occasional flooding

Aspect: 000° = no aspect; 360° = N aspect [ASP]	Elevation: record estimate in feet or meters [ELEV]	
Record to nearest degree = 000	Feet =	Meters =

Soil Drainage: [SDRA]	
X	Well-drained
	Wet
	Excessively dry

Soil Depth: [SDEP]	
X	Bedrock not exposed
	Bedrock exposed

Disturbance: Disturbance on the site or in localized areas where the bioindicator plants are growing. [DSTB]	
X	No recent or significant disturbance; Do not count disturbance >3 years old.
	Evidence of overuse; Human activity causing obvious soil compaction or erosion.
	Evidence of natural disturbance including fire, wind, flooding, grazing, pests, etc.

Fill in below all that apply. Check here if geographic coordinates were obtained from a topographic map: ☐
Latitude and longitude are recorded in degrees, minutes, and seconds.

GPS Unit [UNIT] = Garmin	GPS Datum [GPSD]= NAD83	GPS Serial Number [GPS#] =
Latitude [N] =		GPS Error [ERRS]=
Longitude [W] =		Number of GPS Readings [READ] =
Elevation [ELEV]= 228m		GPS File Name (optional) =

[1]If no GPS Unit is available, please use a map and record estimated latitude, longitude, and elevation for each biosite location.

Comments: Include information on additional species in the area, safety, directions, or additional site characteristics that may be useful.

UTM X 0567744
UTM Y 4122489

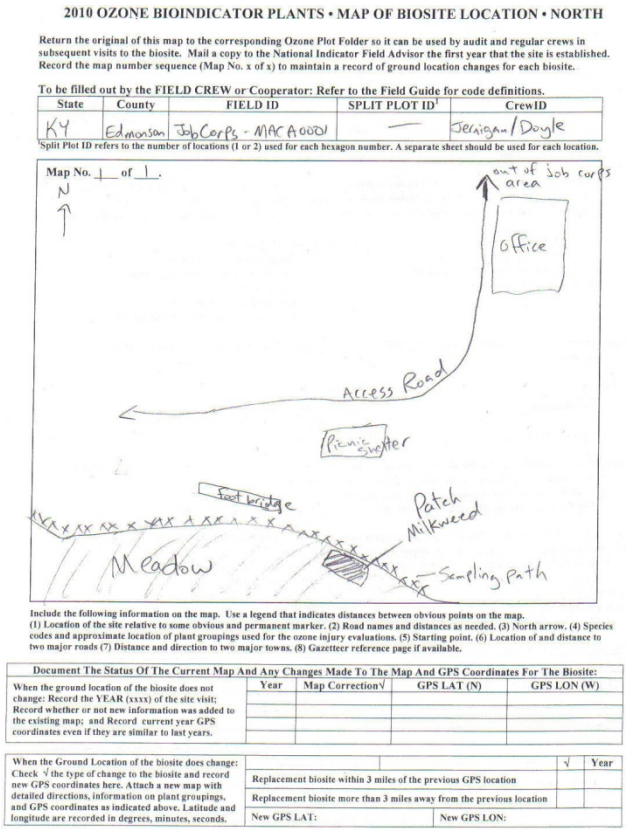
Every year collect accurate GPS data, and verify the county code for each biosite location.

File this completed data sheet with the sheet used for mapping the Bioindicator Site Location and then store it in the appropriate Ozone Plot Folder for your State or Region.

Figure 23 – 2010 site characteristics form. Note that some fields on the form have not been filled in. This scan is a copy of the form immediately upon returning from the sampling. Those empty fields were filled in at a later time.

9. **Sketch a map of the site.** Sketches should be completed each time a site is sampled. The sketch should show the approximate shape of the opening, locations of plant groupings, and the location of the site relative to some landmark such as a town or geographical landmark.

The field form is divided into three sections. The first section contains general information on where, when, and by whom the site map was sketched. This section is similar to the corresponding section of the foliar injury data sheet. The second section is a rectangle in which to draw the site sketch. For an example of a properly sketched site, see sections 9.2.3 and 9.2.4 of the USFS protocol. The final section of the field form contains geographic information as collected with a GPS unit. An example site sketch is also shown in Figure 24.



2010 OZONE BIOINDICATOR PLANTS • MAP OF BIOSITE LOCATION • NORTH

Return the original of this map to the corresponding Ozone Plot Folder so it can be used by audit and regular crews in subsequent visits to the biosite. Mail a copy to the National Indicator Field Advisor the first year that the site is established. Record the map number sequence (Map No. x of x) to maintain a record of ground location changes for each biosite.

To be filled out by the FIELD CREW or Cooperator: Refer to the Field Guide for code definitions.

State	County	FIELD ID	SPLIT PLOT ID[1]	CrewID
KY	Edmonson	JobCorps - MAC A0001	—	Jernigan / Doyle

[1]Split Plot ID refers to the number of locations (1 or 2) used for each hexagon number. A separate sheet should be used for each location.

Map No. 1 of 1.

Include the following information on the map. Use a legend that indicates distances between obvious points on the map. (1) Location of the site relative to some obvious and permanent marker. (2) Road names and distances as needed. (3) North arrow. (4) Species codes and approximate location of plant groupings used for the ozone injury evaluations. (5) Starting point. (6) Location of and distance to two major roads (7) Distance and direction to two major towns. (8) Gazetteer reference page if available.

Document The Status Of The Current Map And Any Changes Made To The Map And GPS Coordinates For The Biosite:				
When the ground location of the biosite does not change: Record the YEAR (xxxx) of the site visit; Record whether or not new information was added to the existing map; and Record current year GPS coordinates even if they are similar to last years.	Year	Map Correction√	GPS LAT (N)	GPS LON (W)

When the Ground Location of the biosite does change: Check √ the type of change to the biosite and record new GPS coordinates here. Attach a new map with detailed directions, information on plant groupings, and GPS coordinates as indicated above. Latitude and longitude are recorded in degrees, minutes, seconds.			√	Year
	Replacement biosite within 3 miles of the previous GPS location			
	Replacement biosite more than 3 miles away from the previous location			
	New GPS LAT:	New GPS LON:		

Figure 24 – 2010 site sketch form. Note that some fields on the form have not been filled in. This scan is a copy of the form immediately upon returning from the sampling. Those empty fields were filled in at a later time.

10. **Prepare equipment, supplies, and voucher specimens for transport to next site or office.**
11. **Take site photographs.**
12. **Go to the next site or return to the office.**

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #FoIn5: Foliar Injury - Post-Sampling

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP describes tasks to be performed after site visits. The crew leader must check, shortly after the event, that all post-sampling activities have been completed (tools have been properly stored, data have been pulled from GPS units, voucher specimens have been processed, etc).

1. **Close out travel authorizations.** Any crew member working under a travel authorization should close out said authorization per the procedures of that member's governing agency.
2. **Review field forms.** Copies of field data forms from the sampling event should be reviewed to assure that any unique events or hazards that were encountered have been noted. Field forms should also be reviewed for completeness and correctness, with corrections made as appropriate. Corrections should be made in such a way that the original data are not lost, so that if the correction is later found to be incorrect, the original data are still preserved.
3. **Offload and archive site photographs on CUPN's network drive.**
4. **Pull any data collected on a handheld GPS unit.** Data should be archived according to procedures outlined in this protocol's data management SOP.
5. **Properly store equipment and supplies.** All equipment should be examined to be sure that it is functioning properly. Any malfunctioning equipment should be repaired or replaced. Supplies should be inventoried and, as necessary, purchased.
6. **Enter field data into the ozone database.** Once data have been entered, field forms should be archived in accordance with established NPS guidelines.
7. **Process voucher leaf samples.** Once voucher specimens have been in the plant press long enough to properly dry (at least 36 hours), the CUPN data manager will inspect the specimens and take digital photographs of them. The vouchers will be mounted and labeled for the photograph. Once photographed, specimens will be preserved in the CUPN office at MACA in accordance with established NPS procedures or returned to the originating park if so requested by that park. Photographic vouchers will be archived on the CUPN server using guidelines as established in the NPS museum handbook.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #FoIn6: Foliar Injury – Data Management

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP describes tasks to be performed for data management. The crew leader must check, shortly after field sampling, that all data management activities have been completed (data have been entered from field forms, GIS data have been processed from GPS units, voucher specimen data have been processed, etc).

Introduction

There are three database components to manage in foliar injury monitoring:

1. **Foliar injury data:** In MSAccess/NRDT format. This template structure was developed by the NPS-IM Program (NPS 2006) and helps to standardize database development across Networks. The custom tables needed for foliar injury will be under development in FY12. Table structure will closely adhere to NRDT standards. Field forms will follow format used by the US Forest Service in *Phase 3 Field Guide – Section 9 (2008)*. The field guide, including a description of database fields is included as Appendix A and can be found online at http://www.fia.fs.fed.us/library/field-guides-methods-proc/ . Hardcopy field forms will be scanned after QA/QC is completed and stored on the CUPN server.
2. **GIS data:** In ArcGIS format. The spatial component of foliar injury monitoring will be managed in ArcGIS with metadata according to procedures outlined in the CUPN data management plan (Moore et al 2005). The GIS layers will be created from hardcopy field forms and data from GPS units. Since monitoring locations/sites are variable, GIS layers will likely change with each repeated event. Centroid points will represent areas where species were monitored on each park (sites) and locations of targeted species populations will be represented by x,y coordinates (locations).
3. **Voucher and Archival Data:** In ICMS format. This is the NPS museum standard and will be followed according to guidelines established by that program. Leaf specimens, photographic vouchers, and archival material will be entered into ICMS, according to procedures established in the NPS museum handbook.

Data Entry, Verification, Validation.

Field monitoring will occur during July and August for foliar injury surveys. Immediately upon returning from the field, the field crew leader will check the field data forms for completeness and accuracy. Following completion of the review, hardcopy sampling forms and voucher specimens/photographs will be submitted to the CUPN office at Mammoth Cave, Ky. A data manager will recheck the data forms for completeness and accuracy, before data are entered into the USFS database. Once all the data are entered, it will then be checked to hardcopy (verification) by data manager(s) and for validity (validation) by project lead. After certifying the validity of the data content for each sampling trip, the data forms will be scanned and copied to the project's Validated_Data folder. The CUPN biological/curatorial specialist will handle the voucher specimen data entry into ICMS, and the CUPN GIS specialist will process the ArcGIS layer with metadata.

Database Administration

Data Maintenance

Datasets are rarely static. They often change through additions, corrections, and improvements made following the archiving of a dataset. There are three main caveats to this process:

4. Only make changes that improve or update the data while maintaining data integrity.
5. Once archived, document any changes made to the dataset.
6. Be prepared to recover from mistakes made during editing.

Any editing of archived data is accomplished jointly by the project leader and a data manager. Every change must be documented in the edit log and accompanied by an explanation that includes pre- and post-edit data descriptions.

Data Organization

CUPN has established a template directory structure, composed of seven folders and four subfolders for each vital sign monitoring project (Figure 25). Project files which are being modified, considered draft, and/or certain files currently in use (e.g., a copy of the field data form) should reside within this directory. A similar directory structure will contain archived files (\CUPN_Archive\). Both the working and archive directories will be accessible via the MACA Local Area Network, with access permissions maintained by the data manager(s) and/or MACA Information Technology Staff.

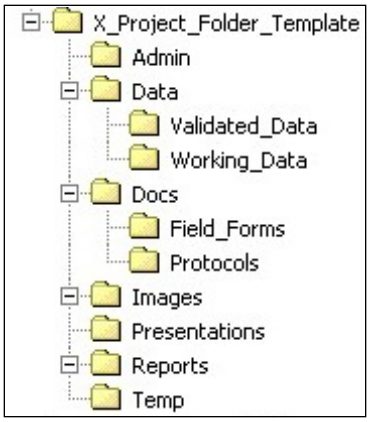


Figure 25 – CUPN project directory structure.

The data tables utilized for data entry and validation reside within the "Working_Data" folder. Once data in these tables are validated by the project leader, a data manager will append the records to the data tables in the "Validated_Data" folder and the "working" data tables will be emptied. As indicated, the data tables containing the master protocol-specific data for the project are contained in the "Validated_Data" folder. These data have been validated and are available as read-only except to CUPN data managers.

Data Security and Integrity

As many different users will be accessing the data, it is imperative that the data remain secure. To address this need, data managers have created user groups within the local area network operating system that will have different security levels. Generally, three levels of users will be given different sets of permissions. CUPN data managers will have all permissions, including insert, delete, and modify for all folders in the folder structure. Project leaders/program coordinators, will have the same permissions as program data managers except for read-only permission to the shared data tables and archived data. Those entering the data will have insert and modify permission to the observation data and read-only permission to the lookup and shared data tables.

Version Control

Prior to any major changes of a dataset, a copy is stored with the appropriate version number. This allows for the tracking of changes over time. With proper controls and communication, versioning ensures that only the most current version is used in any analysis. Versioning of archived datasets is anticipated to be handled in the same manner as protocol narrative and SOP versioning (see SOP #FoIn9). Frequent users of the data are notified of the updates, and provided with a copy of the most recent archived version.

Data Logs and Backups

Once the data are archived, any changes made to the data must be documented in an edit log. From this point forward, original field data forms should not be altered. Field forms can be reconciled to the database through the use of the edit log. Secure data archiving is essential for protecting data files from corruption. Once a dataset has passed the specified QA/QC procedures, an electronic version of the dataset will be maintained in a read-only format on the

program server. Incremental or differential tape backups of all project databases are regularly conducted. Backup copies of the data are maintained in a secure alternate location.

Data Availability

In addition to the "standardized" data dissemination strategies noted in Chapter IX of the DMP, data will be made available for research and management applications on request (per the framework established in the DMP). Data requests should be directed to the CUPN Coordinator.

Literature Cited

Moore, W. J., R. Byrd, and T. Leibfreid. 2005. Data management plan for the Cumberland Piedmont Network and Mammoth Cave National Park Prototype monitoring program. USDI National Park Service. Mammoth Cave, KY. 81pp.

NPS, Washington Support Office, Inventory and Monitoring Program. 2006. Natural Resource Database Template Revised Documentation. National Park Service. Fort Collins, CO.

United States Forest Service. 2008. Phase 3 Field Guide – Section 9. Ozone Bioindicator Plants (east). Southern Research Station. Knoxville, TN. 49pp.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #FoIn7: Foliar Injury - Data Analysis

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP outlines the data flow and expected analyses of the foliar injury data collected within the CUPN. The monitoring questions and subsequent analysis of the supporting data address issues related to status and trends in foliar injury throughout the CUPN. The status and trends of this parameter are understood to be impacted by the cumulative ozone exposure during the April through October growing season in most CUPN parks. Data collected through this protocol may be used to assess those impacts in CUPN parks. These data may be collected over multi-year scales. Monitoring questions will be addressed using a combination of summary and descriptive statistics, graphic analysis, and multivariate comparative and correlative analysis.

The protocol was designed to answer the following monitoring questions related to foliar injury:

- At select CUPN parks, is foliar injury occurring and what is the severity of that injury?
- What are the trends in foliar injury occurrence and severity?

Data Flow and Data Analysis

Foliar injury data will be handwritten onto field forms as they are collected in the field. Validation and archival of these data will be performed by CUPN staff, primarily the project lead in accordance with procedures outlined in the data management SOP (#FoIn6). Data entry will be carried out by CUPN/USFS staff. Analysis of the data will be handled by the project lead. Foliar injury data will be incorporated into annual and multi-year reports that go out to each of the CUPN parks, and these reports will be archived as outlined in the reporting SOP (#FoIn8). Files created during data analysis will be stored on the CUPN server.

For annual reports, analysis will be limited to sorting the data by park, site, species and whether the damage was confirmed or unconfirmed during the USFS voucher inspection. These data will be presented in tabular form within annual reports. A cursory review of these tables will provide the answer to the CUPN's first monitoring question (is foliar injury occurring and what is the severity of that injury?). Multi-year reports will be written every time a sampling cycle is

completed (that is, all of the parks have been sampled as shown in Table 4). The analyses presented in these reports will use data collected during one six year cycle. In addition to exploring the correlation between ozone exposure indices and injury data, basic statistics will be computed for the injury data. These statistics may be based on pooled data over different time periods and may include:

- Site-level maximum damage amount and severity
- Site-level minimum non-zero damage amount and severity
- Site-level mean damage amount and severity
- Site-level standard deviation of the damage amount and severity
- Site-level proportion of plants that showed injury
- Park-level maximum damage amount and severity
- Park-level minimum non-zero damage amount and severity
- Park-level mean damage amount and severity
- Park-level standard deviation of the damage amount and severity
- Park-level proportion of plants that showed injury

These data may be analyzed using trend analysis to determine how the data are trending.

Drought severity will also be considered in annual and multi-year reports. Drought severity will be gauged using the Palmer Drought Severity Index (PDSI). Indices vary primarily between -4 and +4, but values may extend beyond those extremes. Negative values are used to denote drought conditions and positive values are used to denote wet conditions. Details on the PDSI may be found at http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/palmer_drought/wpdanote.shtml.

These are basic questions which the project leader anticipates asking on an annual basis in order to provide "snapshots" of the current dataset. For more advanced analyses, raw foliar injury and ozone concentration data will be imported into a commercial off-the-shelf statistical analysis software package such as SigmaStat or SigmaPlot. The sequence of steps for data import within SigmaStat and SigmaPlot are:

1. Launch SigmaStat or SigmaPlot.
2. Click on File to view the File menu.
3. Select Import from the File menu.
4. A window will open in which the user can select the appropriate file type and the file to be imported. There will be a drop-down list from which the appropriate file type may be selected. Select "Plain Text" or "Excel," as appropriate. Then, navigate to the appropriate folder and select the desired file.
5. Follow the on-screen directions to finish importing the selected file.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #FoIn8: Foliar Injury - Reporting

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Details on the reporting procedure may be found in SOP #OC8.

A Protocol for Monitoring Ozone and Foliar Injury throughout the Cumberland Piedmont Network

Standard Operating Procedure (SOP) #FoIn9: Foliar Injury - Revising the Protocol

Version 1.0 (November 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Details on how to revise this protocol may be found in SOP #OC9.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS XXXXXX, Month Year

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
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