APPENDIX A

HISTORIC AIR QUALITY MONITORING EFFORTS

The monitoring efforts identified below describe past data collection efforts that are not currently part of the WRNF's annual monitoring efforts.

1. Visibility

Scene Monitoring

Since the 1970's photographic images were used to establish visibility conditions at Class I Wilderness areas on the WRNF. In the late 1990's the use of cameras for visibility monitoring was discontinued nationally by the Forest and the resulting photographs archived for baseline reference.

Maroon Bells/Snowmass Wilderness: Between 1991 and 1999, visibility for the area was monitored using camera images. Daily photographs images were taken from an automatic camera installed on the top of Aspen Mountain (AJAX). The camera alignment was towards Mt. Sopris with the majority of samples taken between June and November of each year. Images from that effort are available at the following website: http://www.fsvisimages.com/gallery/MABE/start.htm.

Eagle's Nest Wilderness: Between 1993 and 2000, visibility was monitored using camera images. Daily photographic images were collected using an automatic camera installed at Vail Ski Mountain. The site was located at 10,007 feet and aligned toward West Peak in the Wilderness. Visibility data at this site often reflected some of the best visibility in the nation. Historic images from this site are available on the web at: http://www.fsvisimages.com/gallery/EANE/start.htm.

Other Photo Monitoring Efforts: Other attempts to monitor visibility occurred in the 1970's and 1980's, none of which provided reliable "baseline" data. They are mentioned here to complete a history of visibility monitoring within the WRNF.

In 1979, photo points were established at several locations in the Flat Tops and Eagles Nest Wildernesses. Camera images were taken on established azimuths to record visual conditions of representative view areas within the wildernesses. Data on the type of cameras used, camera settings, camera lens, filters, film, time, date, temperature, relative humidity, wind conditions, viewing conditions, etc. were recorded. This program for monitoring visibility was discontinued after the first year. Photos and data for two of the locations in the Flat Tops Wilderness (Shingle Peak, and Sheep Mountain) remain on file in the Eagle Ranger District office (File designation: 2320). These photos provide a general idea of selected visibility conditions in 1979-1980.

Air Monitoring for Oil Shale (AMOS) was originated as a two year multi-agency project to collect background visibility/particulate data and air trajectory information. The USGS, USFS, and EPA were involved in this effort. Monitoring was conducted from Fall 1981 to Spring 1983. Two visibility monitoring sites were established west of the Flat Tops Wilderness: 1) Blair Mountain on the west border of Flat Tops and 2) Monument Peak overlooking the Piceance Basin and Parachute Creek area. Six stacked filter particulate monitoring sites were established: New Castle, West Rifle, Buford, Browns Park, and two other sites. No formal results or data analyses were released from the project due to low data recovery caused by severe snow and temperature conditions during the study.

2. Water

Water Chemistry

EPA Western Lakes Survey (WLS)

In 1985, the EPA conducted a nationwide study of acid deposition. The effort included sampling and analyses of lakes in six of the seven WRNF Wilderness areas (Table A.1). The WLS was a one-time stratified random sampling effort designed to provide large scale regional information about lake chemistry throughout the United States.

The data did not give detailed information about the processes occurring over time in any one lake but did provide some indication of the buffering abilities of the sampled lakes. Of the 18 lakes sampled in the six wildernesses, 10 were considered "sensitive" with alkalinities less than 200 ueq/l. Such lakes have limited ability to buffer any incoming acidity. None of these lakes are currently acidic. For more information on the results of this survey for lakes within the WRNF, see http://www.fs.fed.us/ARMdata/.

Tabor Lake, Collegiate Peaks Wilderness

Table A.1. EPA WLS Sample Locations in White River NF Wildernesses

WILDERNESS AND LAKE NAME	ALKALINITY (UEQ/L)
FLAT TOPS WILDERNESS	
No-name #4E3-012	1089
Little Trappers	958
No-name #4E3-061	118
No-name #4E2-063	448
Deer	335
Surprise	131
Twin Lakes (south)	193
Oyster	210
Ned Wilson	50
HOLY CROSS WILDERNESS	
Paradise	137
Fancy	117
HUNTER-FRYINGPAN WILDERNESS	
Independence	219
Granite	73
MAROON BELLS-SNOWMASS WILDERNESS	
No-name #4E3-032	181
Pierre	64
EAGLES NEST WILDERNESS	
Upper Piney	159
No-name #4E3-021	305
COLLEGIATE PEAKS WILDERNESS	
Grizzly	663

Ned Wilson Lake Monitoring - USGS

Up until 2006, the Regional Forester granted the USGS permission to install and maintain monitoring instruments in the Wilderness at Ned Wilson Lake and to access this area by helicopter in the spring when travel to the lake was hindered by avalanche threats. The data collected included precipitation, wind speed, wind direction, relative humidity, solar radiation, and air temperature. The instruments used were the following:

1. Belfort weighing bucket gage to record the amount of precipitation continuously. These data were used to calculate the amount of water entering the watershed.

2. Meteorological stations and data logger to continuously measure wind speed, wind direction, relative humidity, solar radiation, and air temperature. These data were used to calculate evaporation of water from the lake in the preparation of mass-balances of water for the watershed.

3. Wetfall collector was used to collect samples of rain or snow during June-September. These data were used to calculate the amount of solutes deposited by wetfall and to detect trends in rain and snow chemistry.

4. Bulk collector was used throughout the year to measure precipitation chemistry especially in the fall, winter, and spring when the wetfall collector is not in use. Samples were collected every 2 weeks during the summer and every 8 weeks during the rest of the year.

5. A flume and automatic recorder to continuously monitor the amount of water leaving the lake. These data were used in determining how rapidly the lake volume turns over, and to calculate the mass balance of solutes for the watershed. The measurements were made in June-September when surface water flow is possible.

6. A temperature recorder with a submersible data logger to continuously monitors lake temperature throughout the year. These data were used in computing lake evaporation.

Additionally, samples were collected from Ned Wilson Lake once every two weeks during the July-September period and approximately once every 8 weeks during the period of ice cover (October-June). Samples were collected at mid-depth in this non-stratified lake using a vanDorn sampler from a raft, or during ice-cover through holes drilled in the ice. During summer, samples were also collected from an unnamed spring and a small lake that is tributary to Ned Wilson lake.

Data from the Ned Wilson Lake study was used in the early 1990's to compare to similar data from the Mt. Zirkel Wilderness which was determined to be significantly impacted by air pollution from the Hayden Power Plant. While both wilderness areas share the

same regional air, local sources of air pollution differed between the two. Comparisons between data from both wildernesses helped determine the significance of local pollution sources.

In 2006, the Regional Office did not extend permission to the USGS to allow monitoring instrumentation in and helicopter access to Ned Wilson Lake. As such the instruments were removed from the Wilderness to an alternate site near Ripple Creek Pass.

In addition to the Ned Wilson Lake site, the USGS operated and maintained a bulk snow collector near Blair Mountain between 1983 and 1987.

Ned Wilson Lake Monitoring - EPA (through contract to USGS)

Lake chemistry studies were conducted by the EPA on three Flat Tops Wilderness lakes during the latter half of August in 1982 and 1983. The lakes sampled were Ned Wilson, Oyster, and Upper Island Lakes. In addition to water chemistry analysis, phytoplankton, periphyton, zooplankton, macroinvertebrates, and sediments were sampled. This work was not published, but summary data is available in draft format (Baldigo and Baker Undated).

AWW Wilderness Water Quality Monitoring Project

Jointly sponsored by the Aspen Wilderness Workshop (now the Wilderness Workshop) and the Aspen Ranger District, was initiated in 1985. Initially, 42 lakes were in the sampling program that spanned the Maroon Bells/Snowmass Wilderness, Hunter-Frying Pan Wilderness and the west portion of the Collegiate Peaks Wilderness. Sampling during these earlier years was sporadic (i.e. not all lakes were sampled every year and lakes were not always sampled at the same time each year). Lake samples were tested for pH, conductivity, and alkalinity. More than half of the lakes sampled since the program began showed alkalinities less than 200 ueq/l, indicating greater sensitivity to acidic deposition.

The data collected assisted in determining sensitive lakes suitable for long term monitoring. The five lakes chosen are part of the WRNF's current air monitoring program and have been sampled annually and under uniform protocol established in 1991 for Region 2 Forests.

3. Soils

The Flat Tops Soil Survey project included mapping of the Flat Tops Wilderness between 1980 and 1981. The level of mapping within the wilderness area was at an Order 3 (1:24,000). The survey was correlated by USDA Natural Resource Conservation Service (NRCS) in 1986 and needs updating to meet current standards for Forest Service ecological unit inventories.

The Maroon Bells/Snowmass and Eagle's Nest Wilderness areas were surveyed between 1991 and 1993 as part of the Holy Cross Soil Survey Area project. The level of mapping is at an Order 3 intensity. The Holy Cross Survey meets the standards for Forest Service ecological unit inventories. However, it has not been through a final correlation by the NRCS and remains as a draft document and map.

4. Flora

Flora have been inventoried and analyzed in each of the WRNF's three Class I Wilderness areas. Floristic monitoring of these three areas is assumed to provide representative data for the WRNF's five Class II Wilderness areas.

Lichens

Lichens are sensitive to high concentrations of gaseous pollutants such as sulfur dioxide and are often used as indicators of air pollution. Because they accumulate elements they can be analyzed to determine the presence and effects of air pollutants (USDA Forest Service 1993a).

Dr. Hale Study – 1982

A baseline study of the lichens in the Flat Tops Wilderness was completed in July-August 1982 (Hale 1982). Twenty-one collecting sites were surveyed and inventoried and about 1000 lichen collections made. A total of 137 species was collected, representing 16 fruticose species, 47 foliose, and 74 crustose. Seven species are designated as indicator species, either because of their known sensitivity to air pollution or because of their value as bioaccumulators.

Twelve permanent lichen study plots were established at five major sites in the northeastern and southwestern sections of the Flat Tops. These 20 X 25 cm plots were documented with color photographs from which species composition and coverage can be determined and used in future comparisons. These photographs are kept in the WRNF Supervisor's Office.

Twenty-six mass samples of the important lichen indicator species were collected for elemental analysis. An elemental analysis was used to determine the concentrations of airborne pollutants that have been absorbed by the lichens. Lead and zinc as well as sulfur all occur in uniformly low concentration (lead 19-76 ppm, zinc 29-85 ppm, and sulfur 0.11-0.16%) over the whole region.

Dr. Nash Study – 1992

A floristic study of lichens in the Flat Tops Wilderness was also conducted in 1992, visiting 17 of the 21 sites visited by Hale in 1982. The 1992 study identified 52 additional species, increasing the total number of lichen species identified in the Flat Tops to 189 (Nash, et.al. 1992).

The twelve permanent lichen study plots established in 1982 were re-investigated and re-photographed in 1992. In addition, thirty-two samples were collected for elemental analysis. The 1992 samples were of the same species and collected at the same sites as those collected in 1982.

Vigor and lichen species diversity in 1992 appeared to be equal to, or greater, than the 1982 survey. There was no indication that air quality has had a deleterious effect on lichens in the Flat Tops Wilderness. The 1992 elemental analysis indicates that several of the heavy elements such as copper, lead, iron, and boron have decreased while zinc and manganese have increased. The increases in zinc and manganese may be due to different procedure used in the analysis (pers. Com. Janet Marsh – John McCarthy, 5/10/1993). Aluminum, calcium, magnesium, and sodium showed little significant change over the ten year period (Nash et.al. 1992).

Geiser Study – 1996

Limited inventory was performed in 1994 by Linda Geiser in order to compare Mt. Zirkel lichens with other areas in Colorado and Wyoming (Jackson 1996).

Vascular Plants

No complete lists of vascular plants have been compiled for the WRNF. The Rocky Mountain Herbarium at the University of Wyoming conducted a floristic study in the Flat Tops Wilderness in 1991 (Vanderhorst 1992 and 1993). The survey includes herbaceous plants, shrubs, and trees with an emphasis on rare and endangered species.

The University of Colorado, Boulder herbarium conducted a floristic study in the Eagles Nest Wilderness in 1990 and 1991 (Hogan 1992) that also emphasized rare and endangered species.

An overview of the sensitivities to air pollutants of vascular plants found in Colorado was prepared for Region 2 in 1990 (Bunin 1990). Ozone sensitive plants found on National Parks and Fish and Wildlife lands were identified in 2003 (Porter 2003). Table 2 identifies sensitive plant species that have been recorded in Vanderhorst's and Hogan's floristic studies within WRNF Class I Wilderness areas.

Amelanchier alnifolia *(Saskatoon serviceberry) is sensitive to ozone pollution.*

Table A2 - Sensitive plant species within WRNF that are sensitive to air pollutants[1]

Scientific Name	Common Name	Documented Class I location[2]	Pollutant[3]	Ozone injury Bioindicator?[4]
Acer glabrum	Rocky mountain maple	EA, FT	SO_2	
Acer negundo interius	Manitoba maple	FT	SO_2	
Amelanchier alnifolia	Saskatoon serviceberry	EA, FT	O_3, SO_2	
Amelanchier utahensis	Utah serviceberry	FT	SO_2	
Apocynum androsaemifolium	Spreading dogbane	FT	O_3	yes
Artemisia ludoviciana	Silver wormwood	EA, FT	O_3	yes
Pinus ponderosa	Ponderosa Pine	FT	O_3	yes
Populus tremuloides	Quaking aspen	EA, FT	O_3, SO_2	yes
Rhus trilobata	Skunkbrush	FT	O_3	yes
Rubus parviflorus	Thimbleberry	FT	O_3	
Rudbeckia laciniata	Cutleaf coneflower	FT	O_3	yes
Salix scouleriana	Scouler's willow	FT	O_3	yes
Sambucus racemosa	Red elderberry	EA, FT	O_3	yes

[1] Sensitivity information from Bunin, 1990 and Porter, 2003.
[2] Information from Vanderhorst, 1993 and Hogan, 1992; "EN" = Eagle's Nest Wilderness; "FT" = Flat Tops Wilderness; no floristic survey available for Maroon Bells/Snowmass Wilderness
[3] Sulfur dioxide (Bunin 1990) or ozone (Porter 2003); nitrogen oxide sensitivity not assessed
[4] Exhibits foliar symptoms in the field that can be easily recognized by subject experts as ozone injury

Plankton

Research has indicated that phytoplankton (free-floating algae) and zooplankton can serve as indicators of acidification (Sprules 1975; Yan 1980; Confer 1983; Keller 1984; Havens 1985; Schindler 1985; Yan 1985; Price 1985; Malley 1986; Mills 1986; Schindler 1987). Recent research in lakes within the Rocky Mountain National Park found that plankton taxa changed around the 1950's indicating a shift towards eutrophication. This change was more pronounced on the east side of the continental divide (Wolfe et al. 2003) .

Plankton are widely dispersed, free-floating microscopic organisms that reproduce rapidly. These characteristics often allow changes in response to ecosystem stress to be seen and quantified at an earlier stage of perturbation than with larger organisms. Certain crustaceous zooplankters are very sensitive to environmental stress; a single female of Daphnia species has the potential to leave 1310 descendants in 60 days, yet a minor imbalance of the system can lead to sudden local disappearance of the species (Davies, 1955). Phytoplankton can display significant change in species composition in as little as two weeks (Biological Methods Panel Committee on Oceanography, 1969).

In addition to species changes, acidification may affect the food chain of a lake. Phytoplankton are primary producers in the food chain and zooplankton are intermediary. Disruptions in these portions of the food chain may lead to widespread injury at upper trophic levels.

Regional and local studies

Studies to quantify and identify taxa have occurred in lakes in Rocky Mountain National Park, Colorado and in the Snowy and Wind River Ranges of Wyoming (McKnight et al. 1990; Spaulding et al. 1992). It is difficult to make comparisons between studies because interspecies variability is so great (Davies 1955; Price 1985).

Phytoplankton and zooplankton samples were collected from Ned Wilson, Oyster, and Upper Island Lakes in the Flat Tops Wilderness by the USGS under contract to the EPA in 1983 (Baldigo and Baker Undated). The biotic data gathered may be useful in comparing to any future samples gathered but does not really provide a "baseline" because several years of sample collection are necessary to learn the range of natural population variability by season and by year. Setting firm objectives and consultation with experts in this field will be required before monitoring of phytoplankton and/or zooplankton is performed.

5. Fauna

Aquatic biota can be profoundly impacted by changes in acidification; however, these effects are difficult to quantify and document. Baseline monitoring must often be conducted for several years to determine the range of species variability under natural conditions. Only when this is understood can change due to acidic deposition or other

pollution impacts be assessed or predicted. Although few models are available for predicting impacts, trends can be defined using standard statistical techniques. Geographic information systems may be useful for mapping and assessing distribution information.

Amphibians

The distribution and breeding success of amphibian populations can be affected by low pH (Karns 1984; Clark 1986a 1986b; Freda and Dunson 1986; Gascon and Planass 1986; Leuven et al. 1986). Five species of amphibians including tiger salamander, western boreal toad, chorus frogs, leopard frogs, and wood frogs are potentially present in some or all of the three Class I wilderness areas on the WRNF. Leopard frogs and boreal toad populations are declining in Western Colorado, but it is uncertain if the decline is associated with human-caused environmental acidification or natural fluctuations in population (Hammerson 1999).

The Colorado Natural Heritage Program, Colorado Division of Wildlife and the WRNF have been monitoring amphibian populations over much of the Forest with an emphasis on boreal toads. The Colorado Natural Heritage Program holds a list of Threatened, Endangered and Sensitive species in Colorado. The Colorado Division of Wildlife has compiled information on amphibians into a GIS data base. The information is operated, maintained and available via the Division's Grand Junction office (970-248-7175).

Tiger salamanders have been observed in most of the lakes in the Flat Tops Wilderness (Larry Green, Colorado Division of Wildlife). Chorus frogs are just as numerous (Rachael Reinhart, personal communication, 4/1/97). Boreal toads have been sighted in the Flat Tops, Eagle's Nest and Maroon Bells/Snowmass wilderness areas. More information is needed to document the extent and distribution of amphibians in lakes in the WRNF wilderness areas.

Research at the Rocky Mountain Biological Laboratory indicates that the tiger salamander is sensitive to pH values less than 6.0 (Harte 1989). In Mt. Zirkel Wilderness, 60 to 100 percent of tiger salamander eggs were dead or unviable in ponds with ph 5.0 or less. Between ph 5.0 and 6.0, 40 percent of the eggs were dead or unviable. Research indicates that these eggs will hatch slower at pH less than 6.0 and subsequent growth will be inhibited as well (Turk 1997).

Aquatic Invertebrates

Benthic lake fauna are not a Forest AQRV. They are mentioned here because a population of invertebrates were sampled in 1995 by Barry Baldigo of the USGS (pers. comm, 4/2/97) using an Ekman sampler.