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QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION SERIES	
TITLE	**OPTICAL DATA REDUCTION AND VALIDATION (IMPROVE PROTOCOL)**
TYPE	**STANDARD OPERATING PROCEDURE**
NUMBER	**4400**
DATE	**NOVEMBER 2004**

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REVISION HISTORY			
REVISION NO.	CHANGE DESCRIPTION	DATE	AUTHORIZATIONS

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1.0 PURPOSE AND APPLICABILITY

This standard operating procedure (SOP) outlines the steps for data reduction and validation of optical monitoring data using IMPROVE Protocols. Optical monitoring data are collected from transmissometers or ambient nephelometers, which are used to measure atmospheric extinction (b_{ext}) and atmospheric scattering (b_{scat}), respectively. Data reduction and validation steps include:

- Processing data daily to convert raw data to Level-A validation format.
- Reviewing data visually for details on monitoring system performance.
- Processing data through Level-0 to search for questionable data and verify quality assurance codes, calibration parameters, and estimate precision.
- Processing data through Level-1 validation to compute hourly averages, calculate uncertainty values, and identify data affected by weather or optical interferences.

The following technical instructions (TIs) provide detailed information regarding specific optical data reduction and validation procedures:

- TI 4400-5000 *Transmissometer Data Reduction and Validation (IMPROVE Protocol)*
- TI 4400-5010 *Nephelometer Data Reduction and Validation (IMPROVE Protocol)*

2.0 RESPONSIBILITIES

2.1 PROGRAM MANAGER

The program manager shall:

- Review Level-1 validated data with the project manager to ensure quality and accurate data validation.
- Coordinate with the Contracting Officer's Technical Representative (COTR) for desired method of data reduction required of the IMPROVE Program.

2.2 PROJECT MANAGER

The project manager shall:

- Review and verify calibration results for each instrument.
- Review Level-1 validated data with the program manager, data analysts, and field specialists.

2.3 DATA ANALYSTS

The data analysts shall:

- Perform data validation procedures described in the appropriate technical instruction.
- Resolve data validation problems with the project manager and field specialists.
- Identify instrument or data collection and validation problems and initiate corrective actions.
- Review data with the project manager and field specialists.

2.4 FIELD SPECIALISTS

The field specialists shall:

- Review data with the project manager and data analysts.
- Provide input as to the cause of instrument problems and specific siting characteristics.

3.0 REQUIRED EQUIPMENT AND MATERIALS

All data reduction and validation occurs on IBM PC-compatible systems. The required computer system components include:

- Pentium class computer system with VGA and 80 megabyte hard disk and 64 megabytes of RAM
- Microsoft Windows98 or Windows2000 operating system and compatible printer
- Software for processing raw data:
  - ASCII text editor such as Ultraedit.32
  - File viewing utility
  - Transmissometer and nephelometer quarterly processing software

4.0 METHODS

Data reduction and validation begins with the raw data files and consists of three levels of validation: Level-A, Level-0, and Level-1. During processing of the data files, a calendar quarter data file is created for each site. Calendar quarters are defined as:

1st Quarter	(January, February, and March)
2nd Quarter	(April, May, and June)
3rd Quarter	(July, August, and September)
4th Quarter	(October, November, and December)

This sections includes two (2) major subsections:

4.1 Transmissometer Data Reduction and Validation
4.2 Nephelometer Data Reduction and Validation

4.1 TRANSMISSOMETER DATA REDUCTION AND VALIDATION

Transmissometer data reduction and validation procedures are presented in Figure 4-1, Transmissometer Data Processing Flowchart, and are described in the following subsections.

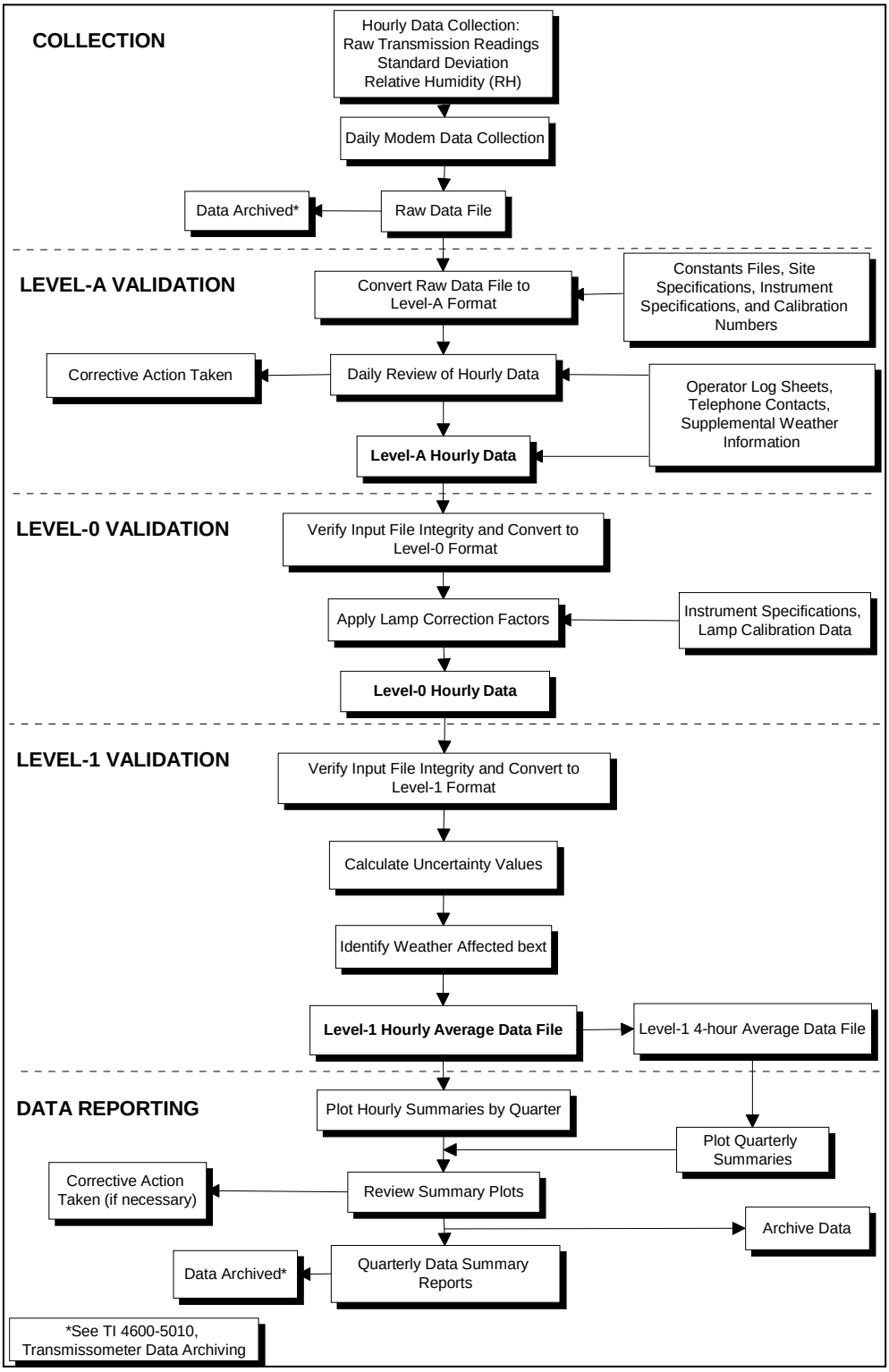

Figure 4-1. Transmissometer Data Processing Flowchart.

4.1.1 Daily Reduction and Validation Procedures

Transmissometer data collected at each monitoring site are recovered daily from satellite data collection platforms (DCPs). Along with extinction, ambient temperature and relative humidity are also monitored. The data are appended into site-specific Level-A files and reviewed to determine if the transmissometer is functioning properly. Corrective action is taken when an instrument malfunction or data problem is detected.

4.1.2 Bi-Monthly Reduction and Validation Procedures

Raw data plots are generated bi-monthly from the Level-A files. Data from operator log sheets are checked against data collected to identify inconsistencies and errors. Information from the log sheets and comments from the bi-monthly plots are entered into the Quality Assurance (QA) Database. As completed log sheets from transmissometer sites are received, the pertinent information (visibility conditions, alignment, system timing, instrument problems, etc.) is manually transferred to the bi-monthly plots. This procedure helps to identify the exact time of lamp changes, alignment corrections, and other actions done by the site operator affecting instrument operation.

4.1.3 Quarterly Reduction and Validation Procedures

4.1.3.1 Level-A Validation

Raw data files are converted to Level-A validation format on a daily basis and Level-A validation is performed on a quarterly basis. Site-specific lamp files, code files, and the processing file are all updated with the most current information available regarding lamps, instrument and support equipment operation, and calibration parameters. These files are inputted into quarterly processing software. Level-A processing performs the following functions for each site:

- Generating Level-A formatted quarterly data files, which include only the data records for the quarter to be processed.
- Recalculating b_{ext} from the raw readings, using calibration information in the lamp files.
- Removing periods in the raw file when the b_{ext} exceeds a number of consecutive times specified. In effect, this removes periods of constant b_{ext}.
- Adding validity codes specified in the code files to the raw files.

4.1.3.2 Level-0 Validation

Data and validity codes at Level-0 validation are checked for inconsistencies. The same validity codes used at Level-A apply at Level-0. Level-0 processing performs the following functions for each site:

- Generating Level-0 formatted quarterly data files, which include only the data records for the quarter to be processed.

- Correcting b_{ext} data for lamp drift. This value is based on the calculated average drift of a number of lamps.

- Generating Level-1 formatted data files (the hourly average file and the hourly average file with weather affected and validity interference codes). These files include only the data records for the quarter to be processed.

4.1.3.3 Level-1 Validation

Level-1 validation includes calculating uncertainty values for all data, and identifying b_{ext} values affected by weather or optical interferences. The data are then reduced to four-hour average values of extinction (b_{ext}), standard visual range (SVR), and haziness (dv). The time periods of the four-hour average values are:

03:00	0000 – 0359 hours
07:00	0400 – 0759 hours
11:00	0800 – 1159 hours
15:00	1200 – 1559 hours
19:00	1600 – 1959 hours
23:00	2000 – 2359 hours

The four-hour average b_{ext} and average dv, along with the average relative humidity, average temperature, and the transmissometer validity code are recorded and kept in the database.

Level-1 validated transmissometer and relative humidity data are summarized in quarterly summary plots:

- **4-Hour Average Variation in Visual Air Quality (Excluding Weather-Affected Data)**
  Timeline of 4-hour average extinction data excluding data affected by weather. The data are plotted as b_{ext} (Mm^{-1}), standard visual range (SVR), and deciview (dv).

- **Relative Humidity**
  Timeline of hourly relative humidity. Note that periods of high extinction are often associated with periods of high relative humidity.

- **Frequency of Occurrence and Cumulative Frequency Summary**
  Frequency of occurrence distribution of hourly extinction data, both including and excluding weather-affected data. The 10% to 90% values are plotted in 10% increments and are summarized in the table next to the plot. The 50% values represent the median of the valid hourly averages.

- **Visibility Metric**
  Visibility statistics for data (excluding weather-affected data), including:
  - Mean of the cleanest 20% of valid data
  - Mean of all valid data
  - Mean of the dirtiest 20% of valid data

- **Transmissometer Data Recovery**
  Data collection statistics, including:
  - Total number of hourly averages possible in the period
  - Number of valid hourly averages including weather-affected data
  - Number of valid hourly averages excluding weather-affected data
  - Percent of all valid hourly averages not affected by weather

Problems identified in the Level-1 quarterly summary plot review are resolved by editing the code, lamp, and/or constants files to identify additional data as valid or invalid and performing the Level-0 and Level-1 validation procedures again. When the Level-1 quarterly summary plots have passed the review process, the raw through Level-1 validated data and associated files are archived as described in TI 4600-5010, *Transmissometer Data Archives (IMPROVE Protocol)*.

4.2 NEPHELOMETER DATA REDUCTION AND VALIDATION

Nephelometer validation begins with the raw nephelometer files and consists of three levels: Level-A, Level-0, and Level-1. Level-A validation is performed daily. Level-0 and Level-1 are performed quarterly. Data reduction and validation procedures are presented in Figure 4-2, Nephelometer Data Processing Flowchart, and is described in the following subsections.

4.2.1 Daily Reduction and Validation Procedures

Level-A validation of raw nephelometer and meteorological data occurs daily, immediately after collection. Validation tasks performed are:

- Parameters are extracted from the raw file and are appended to site-specific quarterly data files (raw scattered light, direct light, chamber temperature, status code, normalized scattered light, ambient temperature, relative humidity, and power failure information).

- Clean air zero and span calibrations recorded by the datalogger are extracted from the raw data file and appended to instrument-specific QA calibration files.

- Validity codes are assigned to the nephelometer data. Meteorological data are not assigned validity codes.

After Level-A validation, the data and operator log sheets are visually reviewed to identify operational problems and initiate corrective procedures. Level-A validated data are plotted weekly. Comments regarding the operation of the nephelometer are noted on the plots. If a new problem is identified beyond those discovered in the daily data review, corrective actions are initiated.

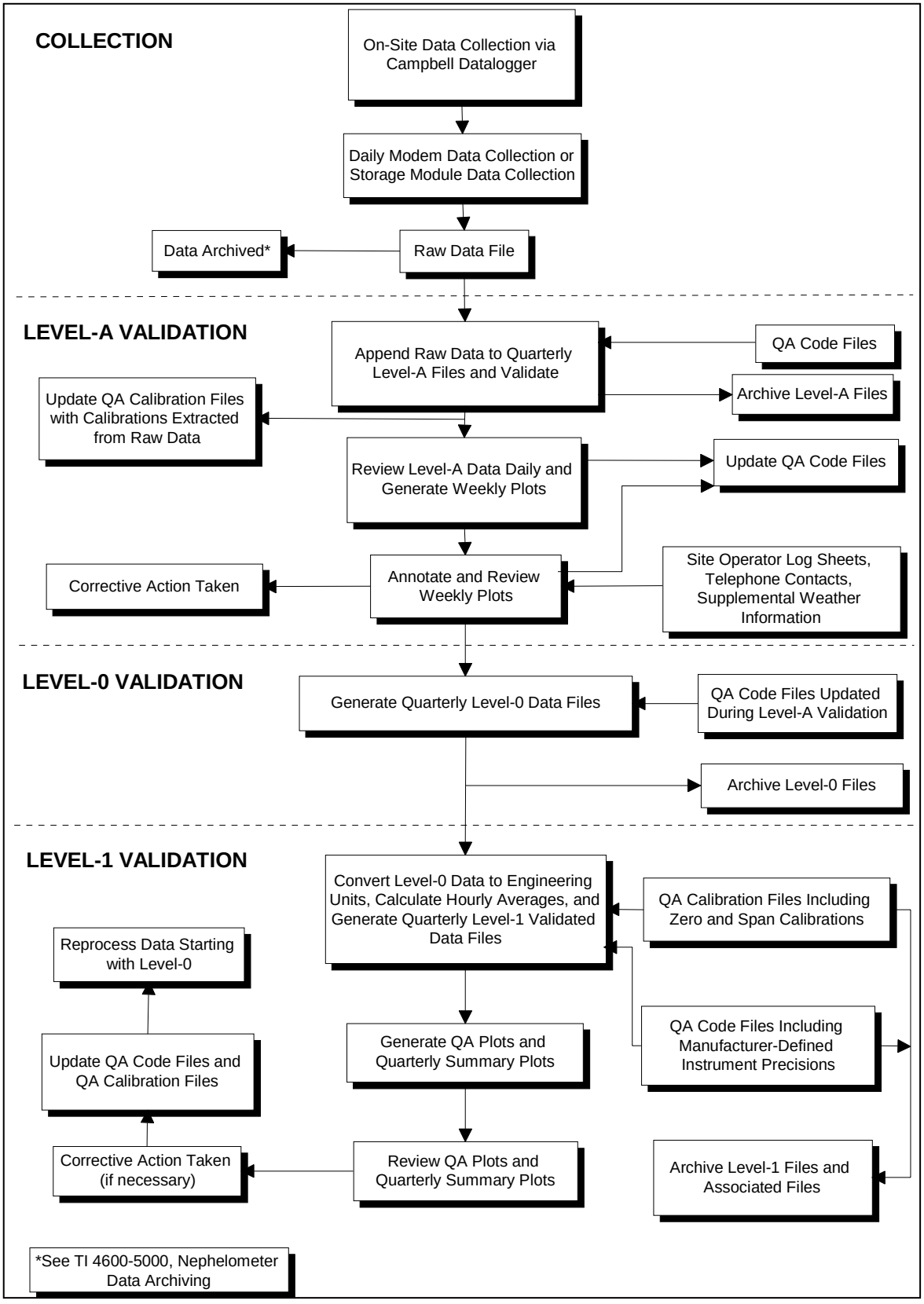

Figure 4-2. Nephelometer Data Processing Flowchart.

4.2.2 Quarterly Reduction and Validation Procedures

Quarterly reduction and validation includes updating code files, calibration files, and processing through Level-0 and Level-1 validation.

4.2.2.1 Updating Files

QA code files and QA calibration files are updated quarterly and are inputted into quarterly processing software.

The QA code files are site-specific files containing the time-tagged operational history of each site. Each file includes QA codes that identify periods as invalid, precision estimates, QA calibration file names, and a Rayleigh coefficient.

The QA calibration files are nephelometer-specific files containing all zero and span calibrations performed on a nephelometer during a specific time period, including the initial zero and span performed during installation. The calibration information in the QA calibration files is used during data reduction to calculate the scattering coefficient based on the raw data and to estimate the precision of that data. The files also include parameters to help identify invalid calibrations.

QA calibration plots are generated showing nephelometer zero and span calibrations recorded in the instrument-specific QA calibration files, and an estimate of the precision of the nephelometer data based on those calibrations. Final QA calibration plots are generated after validating the zero and span calibrations based on the preliminary plots. Any invalid calibrations shown on the final plots as valid must be edited manually. Uncertainty estimates generated during QA calibration plot review are entered manually in the QA code files. The uncertainty estimates appear in the Level-1 data file for reference.

4.2.2.2 Level-0 Validation

Level-0 validation of nephelometer and meteorological data is performed quarterly. The Level-A data and plots are reviewed to identify periods of invalid nephelometer data caused by a burned out lamp, power failures, water contamination, or other problems. Level-A meteorological data are also reviewed to identify invalid periods caused by sensor failures. Corrective actions are initiated if required.

The nephelometer data validation constants file (Nprocess.con) is updated and verified for correct information and contains the following:

Level-0 Validation Constants	Level-1 Validation Constants
Raw nephelometer underrange and overrange	Nephelometer raw standard deviation / mean filter
Raw nephelometer rate-of-change	Nephelometer b_{scat} rate-of-change filter
Ambient temperature underrange and overrange	Nephelometer b_{scat} RH filter
Relative humidity underrange and overrange	Nephelometer b_{scat} maximum filter

The constants file is then used to generate Level-0 validated nephelometer data.

4.2.2.3 Level-1 Validation

Level-1 validation of nephelometer and meteorological data is performed quarterly following Level-0 validation. Level-1 validation performs the following tasks:

- Computing hourly averages from Level-0 data
- Validating QA calibration file entries
- Converting hourly average data to engineering units
- Performing overrange/underrange checks
- Identifying nephelometer b_{scat} data affected by meteorological interference
- Estimating precision

Level-1 validated nephelometer and relative humidity data are summarized in quarterly summary plots:

- **4-Hour Average Variation in Visual Air Quality (Filtered Data)**
  Timeline of 4-hour average scattering data filtered to remove data affected by meteorological interference. The data are plotted as b_{scat} (km^{-1}).

- **Relative Humidity**
  Timeline of hourly relative humidity. Note that periods of high scattering are often associated with periods of high relative humidity.

- **Frequency of Occurrence and Cumulative Frequency Summary**
  Frequency of occurrence distribution of hourly scattering data, both unfiltered and filtered for meteorological interference. The 10% to 90% values are plotted in 10% increments and are summarized in the table next to the plot. The 50% values represents the median of the valid hourly averages.

- **Visibility Metric**
  Visibility statistics for data filtered for meteorological interference, including:
  - Mean of the cleanest 20% of valid data
  - Mean of all valid data
  - Mean of the dirtiest 20% of valid data

- **Nephelometer Data Recovery**
  Data collection statistics, including
  - Total number of hourly averages possible in the period
  - Number of valid hourly averages including filtered and unfiltered data
  - Number of valid hourly averages including filtered data only
  - Filtered data as percent of unfiltered and filtered data

Problems identified in the Level-1 quarterly summary plot review are resolved by editing the QA code and/or calibration files to identify additional data as valid or invalid and performing the Level-0 and Level-1 validation procedures again. When the Level-1 quarterly summary plots have passed the review process, the raw through Level-1 validated data and associated QA files are archived as described in TI 4600-5000, *Nephelometer Data Archives (IMPROVE Protocol).*

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QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION SERIES	
TITLE	**NEPHELOMETER DATA REDUCTION AND VALIDATION (IMPROVE PROTOCOL)**
TYPE	**TECHNICAL INSTRUCTION**
NUMBER	**4400-5010**
DATE	**AUGUST 1994**

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OTHER		

REVISION HISTORY			
REVISION NO.	CHANGE DESCRIPTION	DATE	AUTHORIZATIONS
1.0	Change file formats and software procedures used.	November 2004	

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1.0 PURPOSE AND APPLICABILITY

This technical instruction (TI) describes the steps of nephelometer data reduction and validation, to assure quality data and ensure that data are placed in a format consistent with IMPROVE Protocol. This TI is referenced in SOP 4400, *Optical Monitoring Data Reduction and Validation (IMPROVE Protocol)*.

The Optec NGN-2 nephelometer measures the atmospheric scattering coefficient (b_{scat}) of total atmospheric extinction (b_{ext}). The raw nephelometer output is converted to b_{scat} using instrument- and time-specific calibration information.

This TI is a guide to the reduction and validation of Optec NGN-2 nephelometer and collocated meteorological data (ambient temperature and relative humidity). Data reduction and validation begin with the daily interrogation of the on-site datalogger and end with Level-1 validated nephelometer and meteorological data. Nephelometer and meteorological data undergo the following reduction and validation steps:

- Processing data daily to convert the raw data to Level-A validation format.
- Reviewing data visually for details on monitoring system performance.
- Processing data through Level-0 validation to verify quality assurance validation codes, calibration parameters, and estimate precision.
- Determining zero calibration validation parameters.
- Processing data through Level-1 validation to compute hourly averages, perform overrange/underrange checks, and identify data affected by meteorological interference.

Because most stations are remote, daily data review is critical to the identification and resolution of problems.

2.0 RESPONSIBILITIES

2.1 PROGRAM MANAGER

The program manager shall:

- Review Level-1 validated data with the project manager to ensure quality and accurate data validation.
- Coordinate with the Contracting Officer's Technical Representative (COTR) for desired method of data reduction required of the IMPROVE Program.

2.2 PROJECT MANAGER

The project manager shall:

- Review and verify calibration results for each instrument.
- Review Level-1 validated data with the program manager, data analysts, and field specialists.

2.3 DATA ANALYSTS

The data analysts shall:

- Perform data validation procedures described in this technical instruction.
- Resolve data validation problems with the project manager and field specialists.
- Identify instrument or data collection and validation problems and initiate corrective actions.
- Review data with the project manager and field specialists.

2.4 FIELD SPECIALISTS

The field specialists shall:

- Review data with the project manager and data analysts.
- Provide input as to the cause of instrument problems and specific siting characteristics.

3.0 REQUIRED EQUIPMENT AND MATERIALS

All data reduction and validation occurs on IBM PC-compatible computer systems. The required computer system components include:

- Pentium class computer system with VGA and 80 megabyte hard disk and 64 megabytes of RAM
- Microsoft Windows98 or Windows2000 operating system and compatible printer
- Software for processing raw nephelometer data:
  - NGN_pull.exe and NGN_plot.exe
  - NGN_seas.exe and NGN_QA.exe
  - NGN_nsum.exe
- ASCII text editor such as UltraEdit.32
- File viewing utility
- Completed operator log sheets

4.0 METHODS

Data reduction and validation begin with the daily interrogation of the on-site datalogger and end with Level-1 validated nephelometer and associated meteorological data.

This section includes three (3) subsections:

4.1 Daily Collection Procedures
4.2 Daily Reduction and Validation Procedures
4.3 Quarterly Reduction and Validation Procedures

Figure 4-1 is a flowchart of the data reduction and validation procedures for nephelometer and collocated meteorological data. These procedures are described in the following subsections.

4.1 DAILY COLLECTION PROCEDURES

On-site dataloggers are interrogated daily via telephone modem for all raw nephelometer and meteorological data available since the last download. At sites where telephone access is unavailable, the data are collected via storage module at regular intervals. Raw data collected are saved in daily site-specific ASCII files. Refer to the following documentation for detailed data collection procedures:

- SOP 4300 *Collection of Optical Monitoring Data*
- TI 4300-4002 *Nephelometer Data Collection via Telephone Modem*
- TI 4300-4006 *Nephelometer Data Collection via Campbell Scientific Data Storage Module*

Figure 4-2 presents the file format of raw data collected via telephone modem or Campbell Scientific storage module. The data analyst verifies that all data were collected. Any data collection problems are immediately reported to the project manager. Ongoing data collection problems are resolved according to TI 4100-3300, *Troubleshooting and Emergency Maintenance Procedures for Optec NGN-2 Nephelometer Systems (IMPROVE Protocol) (Type 1)* and TI 4100-3305, *Troubleshooting and Emergency Maintenance Procedures for Optec NGN-2 Nephelometer Systems (IMPROVE Protocol) (Type 2).*

4.2 DAILY REDUCTION AND VALIDATION PROCEDURES

Validation begins with the raw nephelometer files (*xxxxxyyc.jjj*) where *xxxxx* is the five-character site code, *yy* is the year, c is the form of data collection (D or a number 1 to 9), and *jjj* is the Julian date. Validation consists of three levels: Level-A, Level-0, and Level-1. Level-A validation is performed daily. Level-0 and Level-1 are performed quarterly. Processing at each level is presented in Figure 4-1, Nephelometer Data Processing Flowchart, and described in the following subsections.

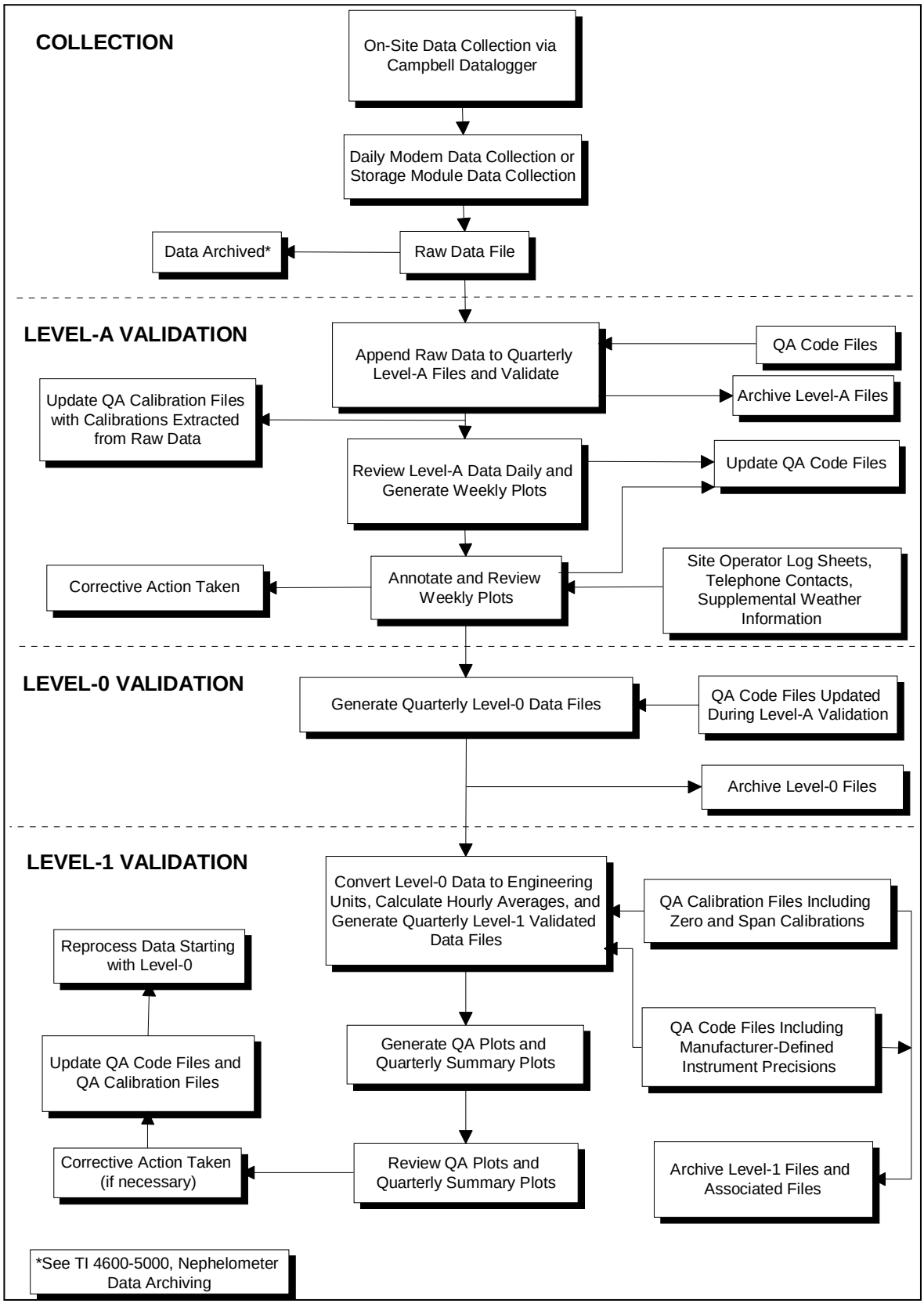


Figure 4-1. Nephelometer Data Processing Flowchart.

5-Minute Analog Data

```
01+0163.  02+1993.  03+0059.  04+0755.  05+582.6  06+0999.  07+2.234  08+097.1
```

Element #	Description
01	Datalogger program array identifier
02	Year
03	Julian date
04	Time (HHMM) at the end of the data period
05	Nephelometer A1 channel (mV x 2.0)
06	Nephelometer A2 channel (mV x 2.0)
07	Ambient air temperature (°C)
08	Ambient relative humidity (%)

5-Minute Serial Data

```
01+0119.  02+1993.  03+0059.  04+0757.  05+1.000  06+0891.  07+3493.  08+510.0
09+2.000  10+3.510  11+2.000  12+0755.  13+509.3  14+0999.  15+2.456  16+097.1
```

Element #	Description
01	Datalogger program array identifier
02	Year
03	Julian date
04	Time (HHMM) the serial stream was received by the datalogger
05	Nephelometer status code
06	Nephelometer raw scattered light reading (counts)
07	Nephelometer direct light reading (counts)
08	Nephelometer normalized scattered light reading (counts)
09	Nephelometer integration time (minutes)
10	Nephelometer chamber temperature (°C)
11	Not used
12	Nephelometer time (HHMM)
13	Nephelometer A1 channel (mV x 2.0)
14	Nephelometer A2 channel (mV x 2.0)
15	Ambient air temperature(°C)
16	Ambient relative humidity (%)

Hourly Code Summary

```
01+0104.  02+1993.  03+0059.  04+0800.  05+50.00  06+0.000
```

Element #	Description
01	Datalogger program array identifier
02	Year
03	Julian date
04	Time (HHMM) at the end of the data period
05	Nephelometer code summary for the past hour
06	Support system code summary for the past hour

The nephelometer code summary is the sum of any or all of the following:

Code	Description
50	Ambient reading
100	Clean air calibration
300	Span calibration
500	Lamp burned out
1000	Precipitation event detected
2000	Chopper motor start-up failure

The support system code summary is the sum of any or all of the following:

Code	Description
300	Datalogger power low (CR10, 21X, or 23X)
500	DC power supply voltage low
1000	AC power outage
2000	Blue Earth serial data buffer restarted

Figure 4-2. Raw Modem or Storage Module Data File Format.

4.2.1 Level-A Validation

Level-A validation of raw nephelometer and meteorological data occurs immediately after collection and is performed daily using NGN_pull.exe software. Validation tasks the software performs are:

- The parameters listed below are extracted from the raw data file and are appended to site-specific quarterly data files:

  - Serial nephelometer raw scattered light (counts)
  - Serial nephelometer direct light (counts)
  - Serial nephelometer chamber temperature (°C)
  - Serial nephelometer status code (1-9)
  - Analog nephelometer normalized scattered light (1 mVDC = 1 count)
  - Analog status code (1 VDC = code 1)
  - Ambient temperature (°C)
  - Relative humidity (%)
  - AC and DC power failure information

- Automatic clean air zero calibrations and operator-initiated clean air zero and span calibrations recorded by the datalogger are extracted from the raw data file and appended to instrument-specific QA calibration files. Figure 4-3 shows an example QA calibration file.

- Three Level-A validity codes are assigned to the nephelometer data:

  - The *Power Code*, generated by the datalogger, is an hourly summary of any AC or DC power problems that occurred during the previous hour.

  - The *Nephelometer Status Code,* generated by the nephelometer, indicates the type of measurement (ambient, clean air zero, or span calibration), or problem (rain, lamp out, or chopper motor failure).

  - The *Data Type Code* indicates the source of the nephelometer data (serial or analog).

- Meteorological data are not assigned Level-A validity codes. Meteorological parameter values that exceed the field sizes of the Level-A file are set to -99.

- Data at this point are at Level-A validation. Level-A files are located in the O:/neph/daily directory of the ARS computer network. Figure 4-4 shows an example Level-A validated data file and the associated validity codes.

```
BOWA                    Site Code
NGN-2-21                Nephelometer Identification
Number 2                Nephelometer Operational Cycle Number
37                      Initial Clean Air Calibration
106                     Initial Span Calibration
30,50,50,0,500          Zero Calibration Validation Parameters:
                        - Window size (30 days)
                        - Maximum distance from mean (50 counts)
                        - Maximum distance from linear regression line (50 counts)
                        - Absolute minimum (20 counts)
                        - Absolute maximum (500 counts)
----------              Comment (not used)
----------              Comment (not used)
----------              Comment (not used)

01-18-2004 07:15:11     Date and Time of Last Update
04,124,1420,-099.00,0037.05,022.46,023.92,019.78,1,Comment
04,124,1445,-099.00,0106.06,022.37,024.07,021.06,A,Comment
04,124,1500,0037.26,-099.00,022.03,024.16,019.07,I,Comment
```

Field (separated by commas)
Year
Julian Date
Time (HHMM)
Clean Air Calibration or -99 (counts)
Span Calibration or -99 (counts)
Ambient Temperature (°C)
Nephelometer Chamber Temperature (°C)
Relative Humidity (%)
Validity Code (1=Valid serial, A=Analog, Other=Invalid)
Comment (no commas allowed in comment)

Figure 4-3. Example Nephelometer QA Calibration File.

```
ARSDATA v8.20040628 10-29-2004 11:45:30-----------------------------------------------------
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------

ACAD2 20041001 275 0000 10 123.42 123.10 -99.00 -99.00 -99.000  13.10 13.16 69.82 2690
ACAD2 20041001 275 0005 11 122.40 122.40 -99.00 -99.00 -99.000 -99.00 13.13 69.70 -99
ACAD2 20041001 275 0010 11 122.40 122.40 -99.00 -99.00 -99.000 -99.00 13.14 69.09 -99
ACAD2 20041001 275 0015 20 117.56 117.60 -99.00 -99.00 -99.000  13.57 13.30 68.25 2722
ACAD2 20041001 275 0020 21 117.60 117.60 -99.00 -99.00 -99.000 -99.00 13.31 67.81 -99

                                        Column Number
         1         2         3         4         5         6         7         8         9
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789
```

Columns	Description
1-5	Site abbreviation (five characters)
7-10	Year
11-12	Month
13-14	Day
16-18	Julian Date
20-21	Hour
22-23	Minute
24	Power Code (Space = No power failure)
25	Nephelometer status code (1-9)
26	Nephelometer Data Type Code (0=Serial 1=Analog)
28-33	Nephelometer Serial Calculated Normalized Reading (Counts)
35-40	Nephelometer Analog Reading (1 mVDC = 1 Count)
42-47	Not used
49-54	Not used
56-62	Not used
64-69	Nephelometer Chamber Temperature (°C)
71-75	Ambient Temperature (°C)
77-81	Relative Humidity (%)
83-86	Nephelometer Direct Light Intensity (Counts); -99 when analog reading

Figure 4-4. Level-A Validated Nephelometer Data File Format.

4.2.2 Review of Data

After Level-A validation, the data analyst visually reviews the raw and Level-A data file listings and operator log sheets received from the monitoring locations to identify operational problems and initiate corrective procedures. Level-A validated data are plotted weekly using the NGN_plot.exe software. The plots are posted and visually reviewed by the data analyst, field specialist, and project manager. Comments regarding the operation of the nephelometer are noted on the plots. An example weekly plot is shown in Figure 4-5. If a new problem is identified beyond those discovered in the daily data review, corrective actions are initiated.

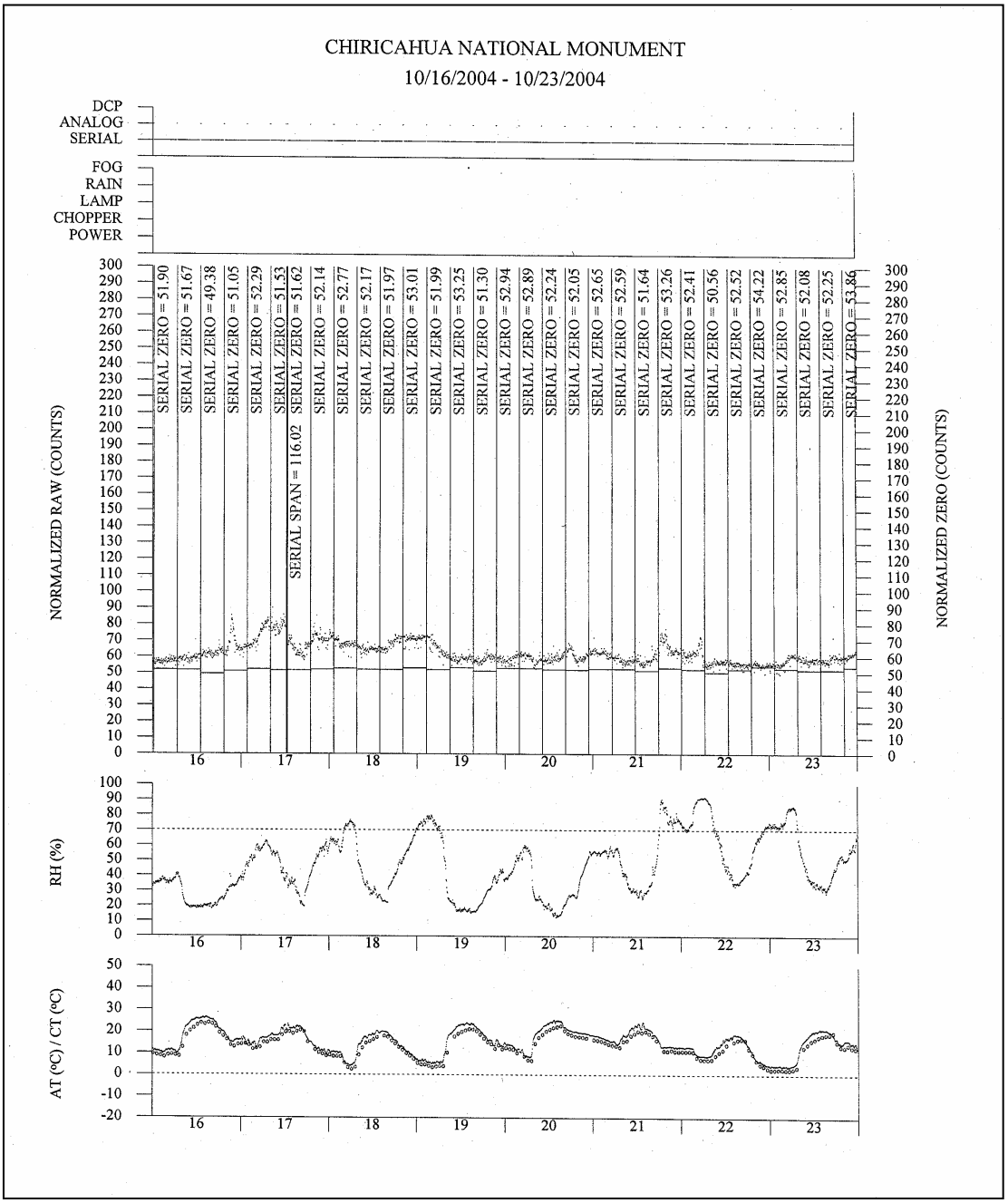


Figure 4-5. Example Weekly Plot of Level-A Validated Nephelometer and Meteorological Data.

4.3 QUARTERLY REDUCTION AND VALIDATION PROCEDURES

During daily Level-A validation, data are appended to calendar quarter data files for each site. Calendar quarters are defined as:

1st Quarter	(January, February, and March)
2nd Quarter	(April, May, and June)
3rd Quarter	(July, August, and September)
4th Quarter	(October, November, and December)

The file structure at this point in validation is *xxxxx*_N.*yyq*, where *xxxxx* is the five-character site code, N indicates nephelometer data, *yy* is the year, and *q* is the quarter (1, 2, 3, or 4). Quarterly reduction and validation includes updating code files, calibration files, and processing through Level-0 and Level-1 validation. Processing at each level is presented in Figure 4-1, Nephelometer Data Processing Flowchart, and described in the following subsections.

4.3.1 Update Code Files

The QA code files are site-specific files (*xxxxx*_C, where *xxxxx* is the 5-character site abbreviation) containing the time-tagged operational history of each site. Specifically, each file includes:

- QA codes entered manually during Level-A validation, that identify periods as invalid
- Precision estimates for nephelometer and meteorological instrumentation
- QA calibration file names
- Rayleigh coefficient

Editing the QA code files is the only method of manually invalidating data. Quarterly updating of the QA code files includes:

- Filing log sheets
- Entering Level-A plot review information in the QA code files
- Editing the Rayleigh coefficient

Hardcopy log sheets are chronologically filed by site. Periods identified in the review of Level-A data as invalid are recorded in the site-specific QA code files. The following codes are used in the QA code files:

1:	Valid
x:	Invalid (*x* = any other character)

Figure 4-6 shows an example QA code file.

```
Big Bend National Park
Nephelometer Calibration File
10/07/04



0.01045                                                                    (Rayleigh coefficient)
-------------------------------------------------------------------------------------------------
YR    JUL TIME  LAMP NCODE N-PR CCODE CT-PR ACODE AT-PR RCODE RH-PR QA File, Comment
-------------------------------------------------------------------------------------------------
1998,  56, 1300, 1,  1,    0.15,  1,  1.0,   1,   1.0,  1,    2.0,  007_8.QA, newnetwork neph installed
2/25/98!
1998,  62, 2220, 1,  L,    0.15,  1,  1.0,   1,   1.0,  1,    2.0,  007_8.QA, lamp out!
1998,  67, 1225, 2,  1,    0.15,  1,  1.0,   1,   1.0,  1,    2.0,  007_8.QA, lamp replaced!
1998, 160, 2155, 2,  P,    0.15,  1,  1.0,   1,   1.0,  1,    2.0,  007_8.QA, power outage!
1998, 160, 2340, 2   1,    0.15,  1,  1.0    1,   1.0,  1,    2.0,  007_9.QA, power restored!
1998, 172, 1825, 2,  P,    0.15,  1,  1.0,   1,   1.0,  1,    2.0,  007_8.QA, power outage!
```

Field	Description
YR	Year
JUL	Julian Date
TIME	Time (HHMM)
LAMP	Lamp number
NCODE	Nephelometer validity code (1 = valid, Other = invalid)
N-PR	Nephelometer factory-defined precision (%, 0.20 – 20%)
CCODE	Chamber temperature validity code (1 = valid, Other = invalid)
CT-PR	Chamber temperature factory-defined precision (°C)
ACODE	Ambient temperature validity code (1 = valid, Other = invalid)
AT-PR	Ambient temperature factory-defined precision (°C)
RCODE	Relative humidity validity code (1 = valid, Other = invalid)
RH-PR	Relative humidity factory-defined precision (%)
QA FILE	Name of the QA calibration file in use
COMMENT	Comment – No commas allowed

Figure 4-6. Example Nephelometer QA Code File.

4.3.2 Update Calibration Files

The QA calibration files are nephelometer-specific files containing all zero and span calibrations performed on a nephelometer during a specific time period, including the initial zero and span performed during installation. The calibration information in the QA calibration files are used during data reduction to calculate the scattering coefficient based on the nephelometer raw data and to estimate the precision of that data. The files also include parameters used by software to help identify invalid calibrations.

The QA calibration file names are defined in the QA code files. The file structure is *xxx*_N.qa, where *xxx* is the instrument number, N is the number of QA file for the instrument (1, 2, 3, etc.), and qa indicates this is a QA file. A new QA calibration file must be defined for the following reasons:

- A new nephelometer was installed at the site
- A significant change in the operation of the nephelometer was indicated by the raw data

There may be several QA calibration files defined in each QA code file. This usually indicates that the nephelometer (or another nephelometer) has been installed more than once.

The quarterly update of QA calibration files includes the following:

- Update of the QA file header information
- Generation of preliminary QA calibration plots and uncertainty estimates
- Review and manual validation of QA file entries
- Generation of final QA calibration plots and uncertainty estimates

Each QA calibration file header must be updated manually to include correct information for the parameters detailed in Figure 4-4, including:

- Site and instrument number
- Initial zero and span calibration
- Zero calibration validation parameters

The QA calibration file header can be edited using the NGN_seas.exe software (described below) or using any ASCII text editor.

The data analyst uses NGN_QA.exe software to generate QA calibration plots showing nephelometer zero and span calibrations recorded in the instrument-specific QA calibration files, and an estimate of the precision of the nephelometer data based on those calibrations.

GENERATE PRELIMINARY PLOTS AND UNCERTAINTY ANALYSIS

Execute the NGN_QA.exe software from the Windows Program Manager. The display will appear as shown in Figure 4-7.

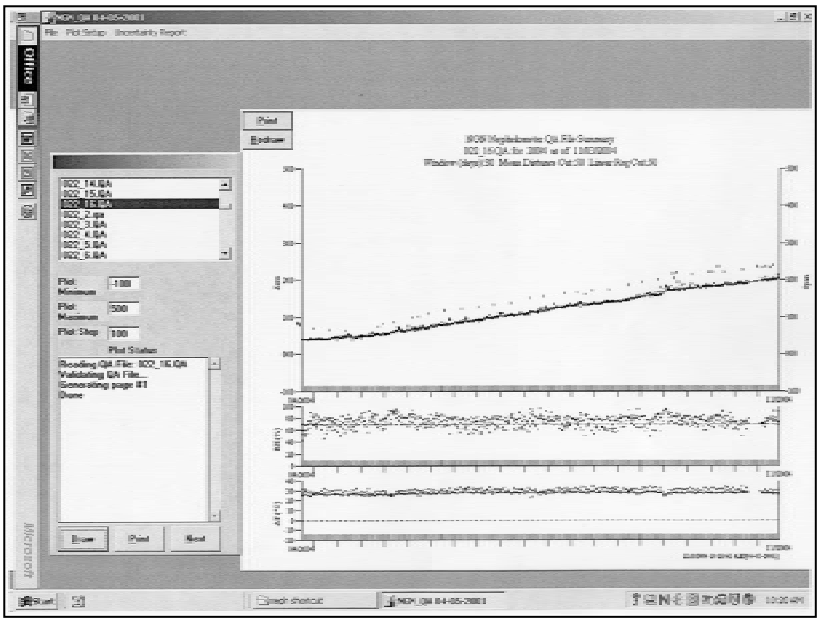


Figure 4-7. NGN_QA Software Display.

Highlight the QA calibration files to plot. The files will be plotted with at most, one year of information per plot.

The highlighted plots can be plotted to the screen or printer. An example plot is shown in Figure 4-8 and an example uncertainty analyses is shown in Figure 4-9. The following procedures are used to generate the plots and uncertainty analysis:

- Highlight the file(s) to plot. Click **Draw** (refer to Figure 4-7) and the plot will appear on screen, or **Print**, and the plot will go to printer. Click **Next** to view the next plot.

- Highlight the file desired for an uncertainty analysis report. Click **Uncertainty Report** from the top toolbar (refer to Figure 4-7). Choose **Display Uncertainty Report,** for the plot to appear on the screen, or **Print Uncertainty Report** for the plot to go to the printer.

The NGN_QA.exe software does not change the QA file – it simply identifies which calibrations will be identified as invalid during Level-0 and Level-1 data validation.

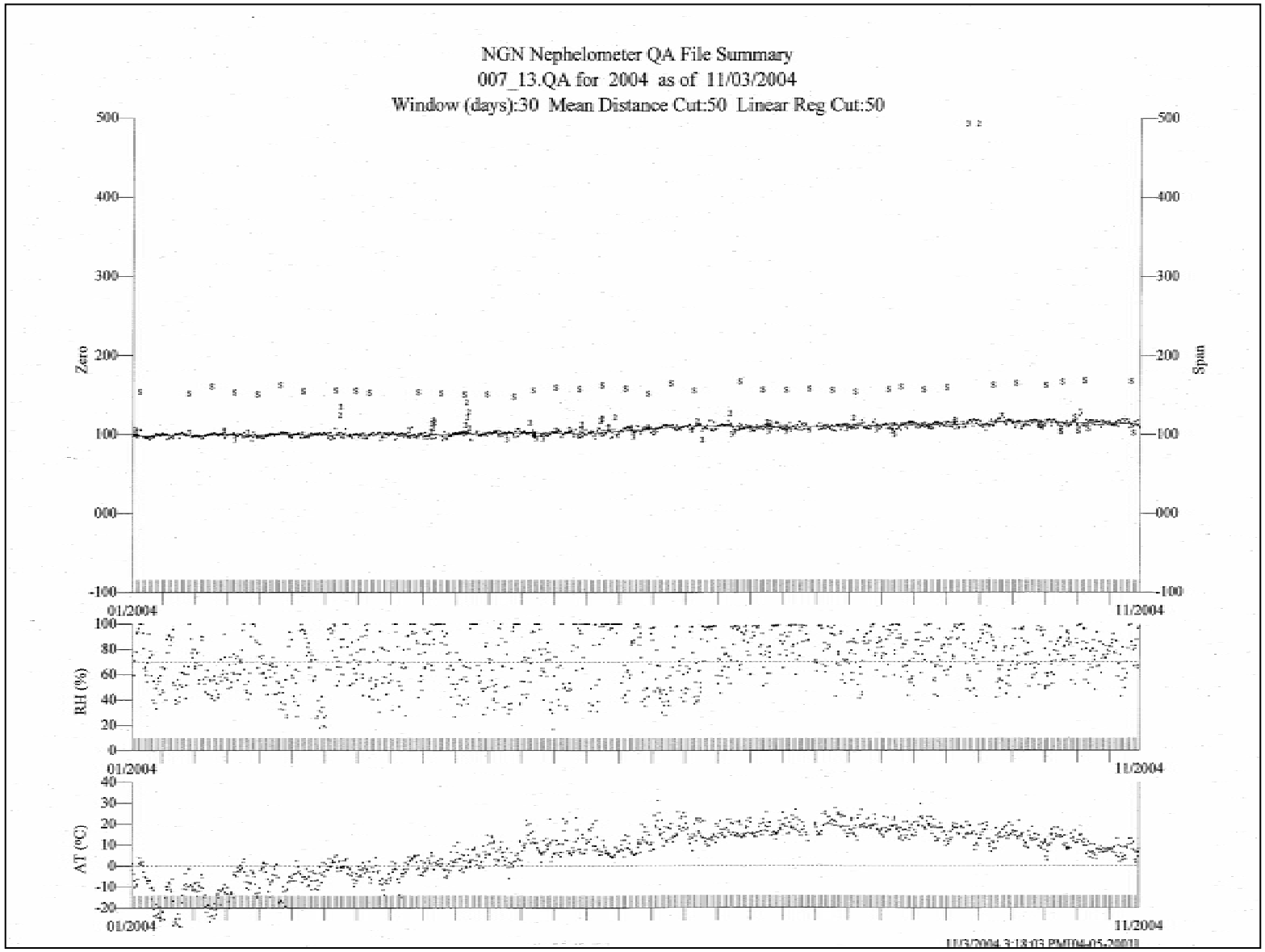


Figure 4-8. Example QA Calibration File Plot.

Nephelometer QA File Uncertainty Analysis - 11/03/2004

File:007_14.qa

Rayleigh (1/Mm) (b,spo): 11.269
Span (1/Mm) (b,spf): 80.009900

The following calibration checks were made:

YEAR/MM/DD	JD	TIME	ZERO	YEAR/MM/DD	JD	TIME	SPAN	DIFF	SLOPE m(t)
2003/09/23	266	0855	0101.440	2003/09/23	266	0840	0155.630	0054.190	0001.268516
2003/09/30	273	0950	0097.170	2003/09/30	273	0935	0147.760	0050.590	0001.358784
2003/10/07	280	1115	0097.940	2003/10/07	280	1055	0151.390	0053.450	0001.286079
2003/10/14	287	1000	0093.730	2003/10/14	287	0945	0143.030	0049.300	0001.394339
2003/10/20	293	1240	0095.240	2003/10/20	293	1225	0148.770	0053.530	0001.284156
2003/10/20	293	1720	0092.670	2003/10/20	293	1700	0152.480	0059.810	0001.149321
2003/10/21	294	1055	0096.460	2003/10/21	294	1040	0159.250	0062.790	0001.094775
2003/10/28	301	1000	0094.170	2003/10/28	301	0945	0153.350	0059.180	0001.161556
2003/11/04	308	1205	0095.350	2003/11/04	308	1150	0156.150	0060.800	0001.130607
2003/11/12	316	1025	0093.680	2003/11/12	316	1005	0158.610	0064.930	0001.058692
2003/11/18	322	1030	0095.240	2003/11/18	322	1010	0155.470	0060.230	0001.141307
2003/11/25	329	1115	0093.500	2003/11/25	329	1055	0158.420	0064.920	0001.058856
2003/12/02	336	1105	0094.710	2003/12/02	336	1050	0159.760	0065.050	0001.056739
2003/12/09	343	1035	0096.970	2003/12/09	343	1015	0160.000	0063.030	0001.090606
2003/12/18	352	1150	0094.750	2003/12/18	352	1130	0154.840	0060.090	0001.143966
2003/12/23	357	1100	0097.600	2003/12/23	357	1045	0156.790	0059.190	0001.161360
2003/12/30	364	0955	0098.170	2003/12/30	364	0940	0155.300	0057.130	0001.203236
2004/01/05	005	1025	0096.700	2004/01/05	005	1005	0159.820	0063.120	0001.089051
2004/01/20	020	1120	0098.630	2004/01/20	020	1105	0157.740	0059.110	0001.162932
2004/01/27	027	1115	0098.680	2004/01/27	027	1100	0166.580	0067.900	0001.012384
2004/02/03	034	1015	0100.150	2004/02/03	034	1000	0159.100	0058.950	0001.166088
2004/02/10	041	1030	0097.960	2004/02/10	041	1015	0156.760	0058.800	0001.169063
2004/02/17	048	1120	0101.970	2004/02/17	048	1100	0168.330	0066.360	0001.035879
2004/02/24	055	1025	0100.630	2004/02/24	055	1010	0160.540	0059.910	0001.147403
2004/03/05	065	0935	0100.480	2004/03/05	065	0920	0161.680	0061.200	0001.123217
2004/03/11	071	1030	0101.550	2004/03/11	071	1015	0161.100	0059.550	0001.154339
2004/03/15	075	1355	0100.300	2004/03/15	075	1340	0158.760	0058.460	0001.175862
2004/03/30	090	1025	0102.470	2004/03/30	090	1005	0159.610	0057.140	0001.203026
2004/04/06	097	1010	0101.180	2004/04/06	097	0950	0158.340	0057.160	0001.202605
2004/04/13	104	1105	0092.570	2004/04/13	104	1045	0156.820	0064.250	0001.069897
2004/04/20	111	1005	0102.770	2004/04/20	111	0950	0157.120	0054.350	0001.264782
2004/04/28	119	1310	0100.970	2004/04/28	119	1255	0153.850	0052.880	0001.299941
2004/05/04	125	1125	0098.390	2004/05/04	125	1110	0162.240	0063.850	0001.076600
2004/05/11	132	0850	0100.110	2004/05/11	132	0835	0165.770	0065.660	0001.046922
2004/05/18	139	1100	0099.580	2004/05/18	139	1040	0164.020	0064.440	0001.066743
2004/05/25	146	0915	0104.630	2004/05/25	146	0855	0168.410	0063.780	0001.077781
2004/06/01	153	1220	0106.520	2004/06/01	153	1205	0164.310	0057.790	0001.189495
2004/06/08	160	1105	0107.050	2004/06/08	160	1050	0157.780	0050.730	0001.355035
2004/06/15	167	0840	0106.770	2004/06/15	167	0825	0171.110	0064.340	0001.068401

Mean Span-Zero Difference: 59.691
Std. Dev. Span-Zero Difference: 4.720

Mean of the slopes: 1.158983
Std. Dev. of the slopes: 0.095993
Number of samples: 39
Degrees of freedom: 38
T value: 2.03
Uncertainty: 0.1536 (15.3618%)

Figure 4-9. Example Uncertainty Analysis.

REVIEW PLOTS

The data analyst reviews the preliminary QA calibration plots to identify invalid zero and span calibrations caused by incorrect nephelometer operation. The plots show the following:

- Zero calibrations that pass all software validation tests [**.**]
- Span calibrations coded as valid [**s**]
- Zero calibrations that fail at least one software validation test [**m, r, >, <**]
- Manually invalidated zero or span calibrations [**I, 2**, or **3**]
- Ambient temperature and relative humidity [**.**]

Zero calibrations are identified as invalid (code r, m, >,<) for the following reasons:

- Mean Test (**m**) - In a given window of time (usually 30 days), the zero calibration exceeds the mean of all valid zeros in the window by a defined number of counts (usually 50).
- Linear Regression (**r**) - In a given window of time (usually 30 days) the zero calibration exceeds the linear best fit value through the valid zeros in the Test window by a defined number of counts (usually 50).
- Absolute Minimum (<) or Maximum (>) - The zero calibration raw counts are less than the defined absolute minimum (usually 0) or greater than the defined absolute maximum (usually 500).

The window size, mean threshold, linear regression threshold, minimum, and maximum are defined in each QA calibration file as is detailed in Figure 4-4.

Invalid calibrations *not identified by the software* must be invalidated manually by the data analyst. The NGN_seas.exe software or any ASCII text editor can be used to edit the QA calibration files. The following codes are used in the QA calibration file:

1:	Valid serial zero or span
A:	Valid analog zero or span
I, 2, or 3:	Invalid zero or span (invalid zero = I or 2, invalid span = I or 3)

REVIEW PLOTS (continued)	Any code other than 1 is considered invalid by the NGN_seas.exe software during Level-0 and Level-1 data reduction. Analog calibrations are recorded in the QA calibration files for backup purposes only – they are not used for data reduction. If serial datalogging fails, analog calibrations can be coded with a 1 and used in place of serial data.
GENERATE FINAL PLOTS AND UNCERTAINTY ESTIMATES	Final QA calibration plots are generated after validating the zero and span calibrations based on the preliminary plots. Any invalid calibrations shown on the final plots as valid must be edited manually as described above. Uncertainty estimates generated during QA calibration plot review are entered manually in the QA code files. The uncertainty estimates appear in the Level-1 data file for reference.

4.3.3 Level-0 Validation

Level-0 validation of nephelometer and meteorological data is performed quarterly and serves as an intermediate data reduction step. Level-0 data validation includes:

- Reviewing Level-A data
- Updating the Nprocess.con constants file
- Level-0 validation processing procedures

The data analyst and project manager further review the Level-A nephelometer data and plots to identify periods of invalid nephelometer data caused by a burned out lamp, power failures, water contamination, or other problems. Level-A meteorological data are also reviewed to identify invalid periods caused by sensor failures. Corrective actions are initiated if required.

The nephelometer data validation constants file (Nprocess.con) is verified for correct information and contains the following:

Level-0 Validation Constants	Level-1 Validation Constants
Raw nephelometer underrange and overrange	Nephelometer raw standard deviation / mean filter
Raw nephelometer rate-of-change	Nephelometer b_{scat} rate-of-change filter
Ambient temperature underrange and overrange	Nephelometer b_{scat} RH filter
Relative humidity underrange and overrange	Nephelometer b_{scat} maximum filter

The Nprocess.con file must be updated as described in the following text with the correct data validation constants before Level-0 and Level-1 data validation can proceed. Figure 4-10 is an example nephelometer constants file.

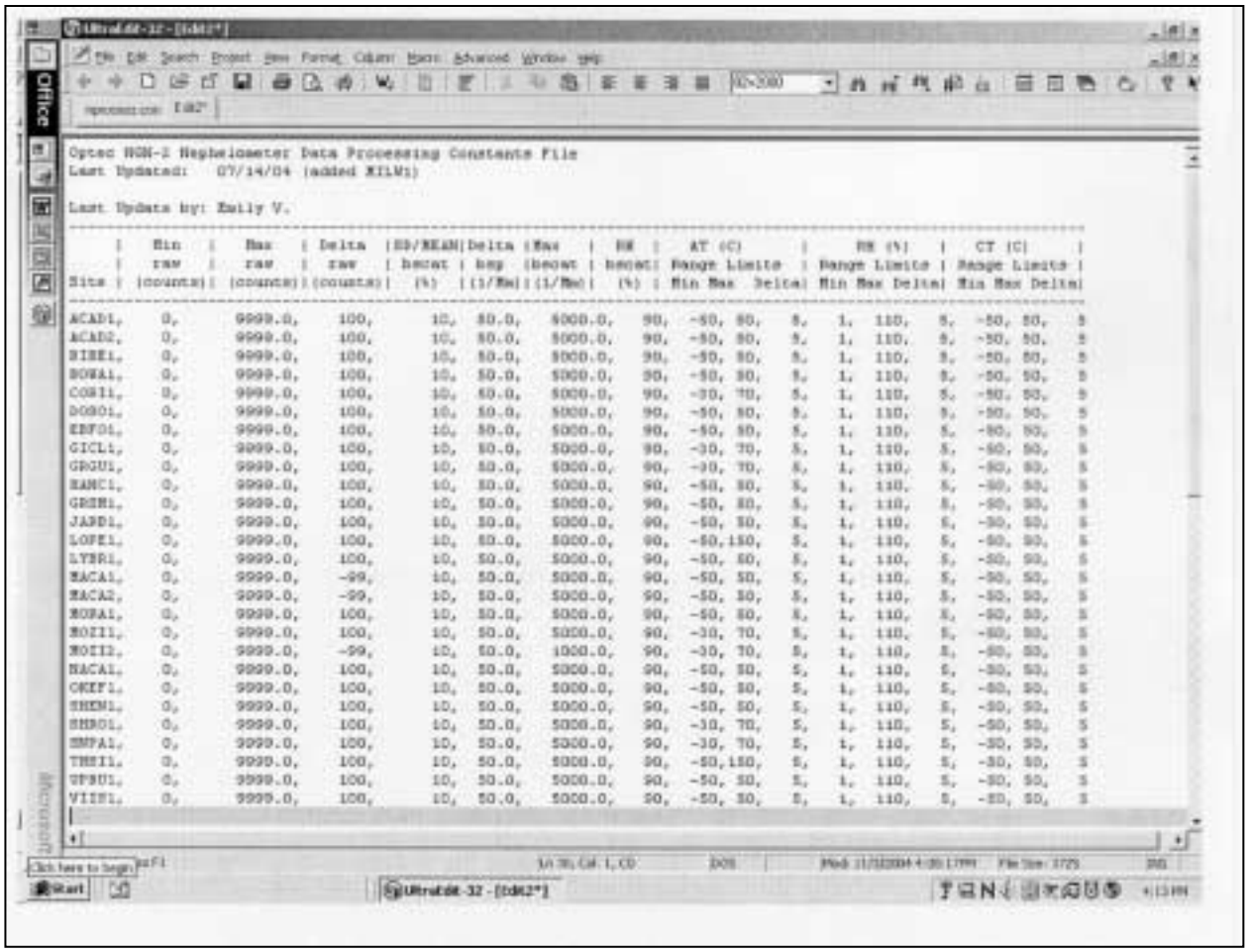


Figure 4-10. Nephelometer Constants (Nprocess.con) File.

Level-0 validated nephelometer data are generated from Level-A data by the NGN_seas.exe software using the following validation criteria:

- Nephelometer data with a Level-A nephelometer status code not equal to 1 are invalid at Level-0.
- Meteorological data with parameter values of -99 are invalid at Level-0.
- Nephelometer and meteorological data identified as invalid in the site-specific QA code files are considered invalid at Level-0.
- Out-of-range data and data whose rate-of-change between 5-minute values exceeds the specified criteria specified in the nephelometer constants file is invalid at Level-0. Table 4-1 lists the range and rate-of-change criteria for IMPROVE nephelometer and meteorological data.

Table 4-1

Nephelometer and Meteorological Level-0 Validation Range Criteria

Parameter	Underrange	Overrange	Rate-of-Change
Nephelometer raw reading (counts)	0	9999	200
Ambient temperature (°C)	-50	70	10
Relative humidity (%)	0	100	25
Nephelometer chamber temperature (°C)	-50	50	10

Nephelometer data can be of any type (serial or analog) to be valid at Level-0 validation. The file naming structure for Level-0 data is *xxxxx*_N0.*yyq*, where *xxxxx* is the five-character site code, N indicates nephelometer data, 0 indicates Level-0, *yy* indicates year and *q* indicates quarter (1, 2, 3, or 4). The Level-0 data file format and validity code summary is shown in Figure 4-11.

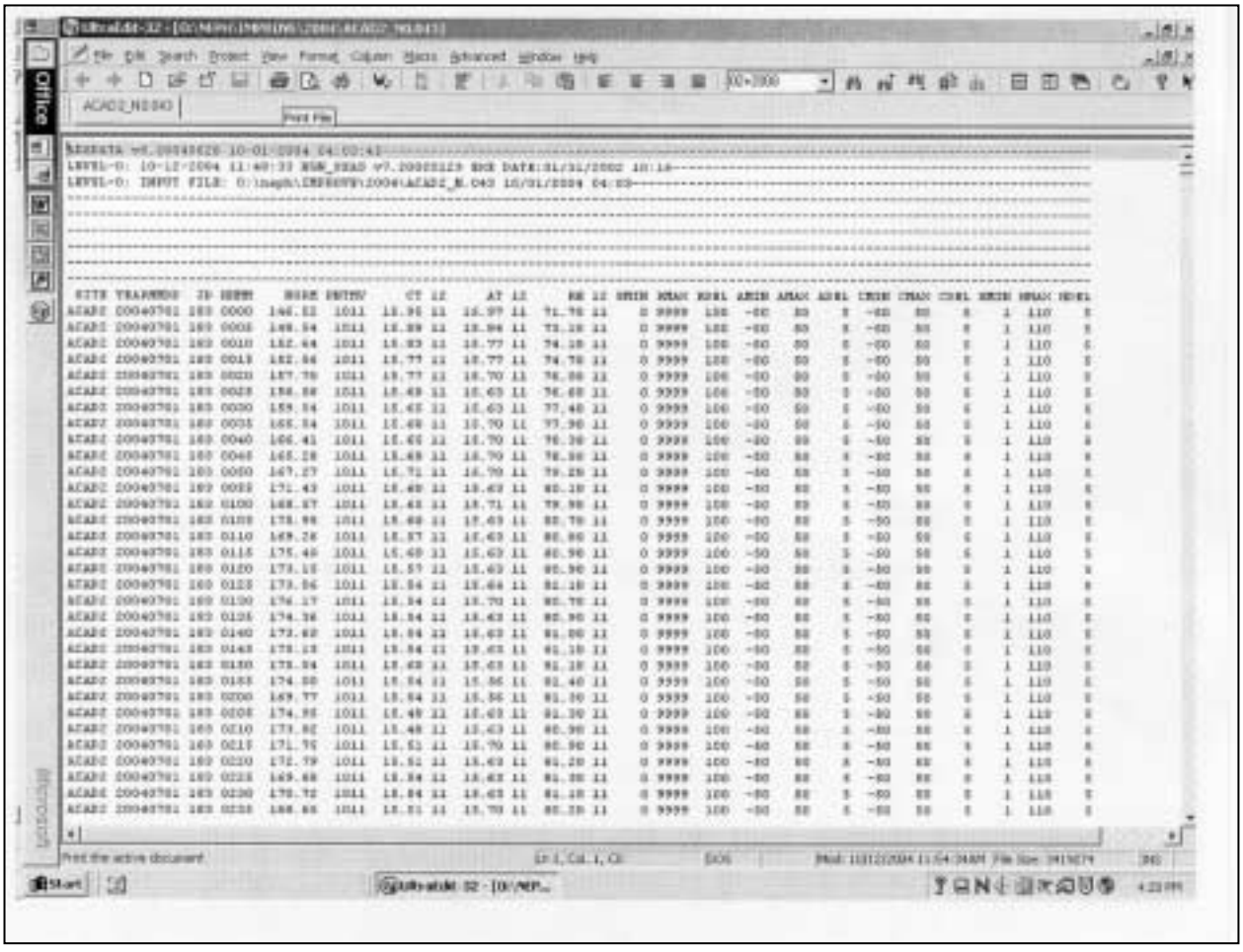


Figure 4-11. Level-0 Validated Nephelometer Data File Format.

The following are the Level-0 data validation procedures:

EXECUTE PROCESSING SOFTWARE

Execute the NGN_seas.exe software from the Windows Program Manager. The display will appear as shown in Figure 4-12.

Figure 4-12. NGN_seas Software Display.

SET DATA DIRECTORIES

The directories for all files used by NGN_seas.exe area shown on the display. Set the Level-A directory to the location where the Level-A data files exist by clicking the Level-A directory box. A dialog box will appear which allows the user to change the directory. Set the correct directory for the Level-0/1, QA code, and QA calibration files the same way.

CHECK QA CODE FILES

Verify that the QA code (*xxxxx*_C) files have been updated correctly as follows:

- Click the **_C Files** box in the Edit Constants Files frame.
- Highlight the *file* to edit in the File to Edit box.
- Click the **EDIT!** button to load the file into the Windows Notepad editor.
- Verify that the file is correct. Save any changes and exit Notepad.
- Check all the files that will be required for Level-0 validation.

CHECK QA CALIBRATION FILES

Verify that the QA calibration (xxx_N.qa) files have been updated correctly as follows:

- Click the **QA Files** box in the Edit Constants Files frame.
- Highlight the *file* to edit in the File to Edit box.
- Click the **EDIT!** button to load the file into the Windows Notepad editor.

  The following validity codes are used to manually edit the QA calibration files:

1:	Valid serial calibration
I, 2, or 3:	Invalid
A	Valid analog calibration

- Verify that the file is correct. Save any changes and exit Notepad.
- Check all the files that will be required for Level-1 validation.

CHECK CONSTANTS FILE

Verify the Level-0 and Level-1 data validation constants are correct as follows:

- Click the **Nprocess.con** box in the Edit Constants Files frame.
- Highlight the *file* to edit in the File to Edit box.
- Click the **EDIT!** button to load the file into the Windows Notepad editor.
- Edit the constants as required in the file.
- Verify that the file is correct. Save any changes and exit Notepad.
- Check all the files that will be required for Level-1 validation.

START LEVEL-0 VALIDATION

Start Level-0 validation as follows:

- Click the **Update** button to update the list of available Level-A validated files to process.
- Highlight the Level-A validated file(s) to process.
- Click the **green light** icon to start Level-0 validation.
- Click the **red light** icon to stop any processing in progress.

START LEVEL-0 VALIDATION (continued)

- Each highlighted Level-A file will be processed in order. The Level-0 validated data will b output to the file shown in the Output File box.

- The Status box will show the current processing status. When all the highlighted files have been processed the status box will show DONE.

The input, output, QA code, and QA calibration file names being used for processing are updated on the NGN_seas.exe display.

CHECK ERRORS

Any errors encountered by NGN_seas.exe during data validation are recorded in the file NGN_seas.err. The number of errors will be displayed at the bottom of the display.

To check the errors click on **Errors** at the bottom of the display. The Notepad program will be invoked to view the error file. Correct any errors by updating the following files:

- QA code files

- QA calibration files

- Nephelometer constants file

4.3.4 Level-1 Validation

Level-1 validation of nephelometer and meteorological data is performed quarterly following Level-0 validation, and is typically the final validation level for IMPROVE nephelometer data. Level-1 validation of nephelometer and meteorological data is handled by the NGN_seas.exe software, which handles the following tasks:

- Computation of hourly averages from Level-0 data
- Automatic validation of QA calibration file entries
- Conversion of hourly average data to engineering units
- Overrange/underrange checks
- Identification of nephelometer b_{scat} data affected by meteorological interference
- Estimation of precision

COMPUTE HOURLY AVERAGES

Level-1 hourly averages are computed from Level-0 validated data for nephelometer and meteorological parameters. The data in an hourly average period includes the data following the hour. For example, the hourly average for 1100 includes data from 1100 through 1159.

VALIDATE QA CALIBRATION FILE ENTRIES

The zero calibration information in the QA calibration files is used to calculate a calibration line for each nephelometer data point. Validation of QA zeros is detailed in Section 4.3.2.

CONVERT DATA TO ENGINEERING UNITS

Meteorological data (ambient and chamber temperatures and relative humidity) are already in engineering units.

The nephelometer scattering coefficient (b_{scat}) of total extinction (b_{ext}) is calculated by determining a calibration line for each raw nephelometer scattering data point as follows:

- The *zero* is determined by interpolating (in time) between the valid clean air calibrations prior to, and following the data point.

- The *initial span* is determined from the initial calibration of the instrument upon installation.

  Initial Span = Initial upscale span gas calibration – Initial clean air calibration

- The *Rayleigh coefficient* is the site-specific altitude-dependent scattering of particle-free air.

- The *designated span* is determined by the span gas used during the initial calibration, and the Rayleigh coefficient. The span gas SUVA (HFC-134a) (Dupont) has been shown to scatter 7.1 times that of particle-free (Rayleigh) air.

  Designated Span = 7.1 x Rayleigh

- The slope and intercept of the calibration line are:

  Slope = (Designated Span – Rayleigh) / Initial Span
  Intercept = Rayleigh – (Slope x Zero)

- Nephelometer data and calibrations are in unitless counts. If the units for the Rayleigh coefficient are km^{-1}, the units for b_{scat} will also be km^{-1}. Nephelometer scattering (b_{scat}) is calculated from the calibration line as follows:

  b_{scat} *= (Slope x raw nephelometer value) + Intercept*

OVERRANGE/UNDERRANGE CHECKS

The following additional validation checks are performed to complete Level-1 validation:

- Data invalid at Level-0 is invalid at Level-1
- Calculated b_{scat} data less than Rayleigh scattering is invalid
- Meteorological data is not validated beyond Level-1

The file naming structure for Level-1 data is *xxxxx*_N1*p*.*yyq*, where *xxxxx* is the five-character site code, N indicates nephelometer data, 1 indicates Level-1 data, *p* is the averaging period in hours, *yy* is the year, and *q* is the quarter (1, 2, 3, or 4). The file format for Level-1 validated data is provided in Figure 4-13.

IDENTIFY DATA AFFECTED BY METEOROLOGICAL INTERFERENCE

Nephelometer data is filtered to identify periods likely affected by meteorological interference. See Appendix A for detailed filter criteria.

Nephelometer data identified as affected by meteorological interference is still considered valid. An additional validity code is assigned to the hourly average data point in the Level-1 file as shown in Figure 4-13.

ESTIMATE PRECISION

The following methods are used to estimate the precision of Level-1 validated data. Specific calculations for these estimates are presented in Appendix B.

- The precision of meteorological data are defined by the factory specified precision for the sensors. These precision are recorded in the site-specific QA code files.
- The estimated precision of nephelometer data for a given time period is based on calibrations performed during that time period. The precision estimates for are recorded in the site-specific QA code files and are automatically placed in the Level-1 data files.

```
NGN_FULL  V3.2:  02/18/97 03-05-1997 11:23:12----------
LEVEL-0:  NGN_SEAS V3.5 4/8/97 05-14-1997 11:34:01----------
LEVEL-1:  NGN_SEAS V3.5 4/8/97 QA Search Flags:1 DI 05-14-1997 12:15:58----------
LEVEL-1:  Rayleigh= .011188 Span Mult= 0----------
```

SITE	YYYYMMDD	JD	HHMM	INS	BSP	PREC	V	A	RAW-M	RAW-SD	#	N/A	SD/M	DEL	MAX	RH	0123456789mPMOT	YINTER	SLOPE	AT	AT-SD	#	AT-PR	CT	CT-SD	#	CT-PR	RH	RH-SD	#	RH-PR	N/A
MACA	19961201	336	0000	043	48	0.140	1	A	127.61	6.65	12	-99.0	10.0	50	5000	90	0C0000000000000	-75.9	1.03	15.37	0.85	12	1.00	15.74	0.87	12	1.00	93.63	0.29	12	2.000XXX
MACA	19961201	336	0100	043	37	0.140	1	A	120.54	6.14	12	-99.0	10.0	50	5000	90	0C0000000000000	-76.2	1.03	15.47	0.12	12	1.00	15.89	0.09	12	1.00	93.77	0.08	12	2.000XXX
MACA	19961201	336	0200	043	31	0.140	1	A	114.98	2.12	10	-99.0	10.0	50	5000	90	0A2000000000003	-76.4	1.03	15.92	0.16	12	1.00	16.35	0.23	9	1.00	93.48	0.15	12	2.000XXX
MACA	19961201	336	0300	043	29	0.140	1	A	113.51	1.09	12	-99.0	10.0	50	5000	90	0C0000000000000	-76.5	1.03	16.24	0.07	12	1.00	16.66	0.06	12	1.00	91.96	0.51	12	2.000XXX

Field	Description
SITE	Site Abbreviation
YYYYMMDD	Date (4-digit year/month/day)
JD	Julian Date
HHMM	Time using a 24-hour clock in hour/minute format
INS	Nephelometer Serial Number
BSP	b_{sp} (Mm^{-1})
PREC	b_{sp} Estimated Precision (%/100)
V	b_{sp} Validity Code (0 = valid, 1 = interference, 2 = invalid, 9 = suspect)
A	b_{sp} Interference Code[1]
RAW-M	Raw Nephelometer Hourly Average (Counts)
RAW-SD	Standard Deviation of Raw Nephelometer Average (Counts)
#	Number of Data Points in Hourly Nephelometer Average
N/A	(Not Used)
SD/M	Standard Deviation/Mean Interference Threshold
DEL	b_{sp} Rate of Change Interference Threshold
MAX	Maximum b_{sp} Interference Threshold
RH	Relative Humidity Interference Threshold
0123456789mPMOT	Composite Nephelometer Code Summary[2]
YINTER	Y-intercept of Calibration Line Used to Calculate b_{sp}
SLOPE	Slope of Calibration Line Used to Calculate b_{sp}
AT	Average Ambient Temperature (°C)
AT-SD	Standard Deviation of Hourly AT Average
#	Number of Data Points in Hourly AT Average
AT-PR	Estimated Precision of Ambient Temperature
CT	Average Nephelometer Chamber Temperature (°C)
CD-SD	Standard Deviation of Hourly CT Average
#	Number of Data Points in Hourly CT Average
CT-PR	Estimated Precision of Chamber Temperature
RH	Average Relative Humidity (%)
RH-SD	Standard Deviation of Hourly RH Average
#	Number of Data Points in Hourly RH Average
RH-PR	Estimated Precision of Relative Humidity
N/A	(Not Used)

[1] b_{sp} Interference Code:

Condition	Letter Code														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
RH > RH threshold	X		X		X		X		X		X		X		X
b_{sp} > maximum b_{scat} threshold		X	X			X	X			X	X			X	X
SD/M > uncertainty threshold				X	X	X	X					X	X	X	X
Δb_{sp} > delta threshold								X	X	X	X	X	X	X	X

Z Weather observation between two other weather observations.

Threshold values may be different for each site.

[2] Composite Nephelometer Code Summary:

0123456789	Nephelometer diagnostic code (internal use)
m	Number of missing data points
P	Number of power failure codes
M	Number of manual QA invalidation codes
O	Number of Level-0 invalidated data points
T	Number of times non-serial data were used

Figure 4-13. Level-1 Validated Nephelometer Date File Format.

4.3.4.1 Level-1 Validation Processing Procedures

Level-1 validation of nephelometer data, detailed above, is handled by the NGN_seas.exe software. The procedures for validating data to Level-1 are as follows:

EXECUTE PROCESSING SOFTWARE	Execute the NGN_seas.exe software from the Windows Program Manager. The display will appear as shown in Figure 4-12.
CHECK QA CALIBRATION FILES	The QA calibration files are nephelometer-specific files containing the automatic and manual clean air zero and span calibrations performed on the instrument. The clean air calibrations are used to calculate the calibration line for each nephelometer data point. Invalid calibrations must be coded as invalid in the QA calibration files, as described in the Level-0 validation section of this TI.
CHECK NPROCESS FILE	The nephelometer constants (Nprocess.con) file contains the data validation constants used for Level-0 and Level-1 validation. Verify the constants in the file as described in the Level-0 validation section of this TI.
START LEVEL-1 VALIDATION	Start Level-1 validation as follows: • Click the **Update** button to update the list of available Level-0 validated files. • Highlight the Level-0 validated file(s) to process. • Click the **green light** icon to start Level-1 validation. • Click the **red light** icon to stop any processing in progress. • Each highlighted Level-0 file will be processed in order. The Level-1 validated data will be output to the file shown in the Output File box. • The Status box will show the current processing status. When all the highlighted files have been processed the status box will show DONE. The input, output, QA code, and QA calibration file names being used for processing are updated on the NGN_seas display.

CHECK ERRORS

Any errors encountered by NGN_seas during data validation are recorded in the file NGN_seas.err. The number of errors will be displayed at the bottom of the NGN_seas display.

To check the errors click on **Errors** at the bottom of the display. The Notepad program will be invoked to view the error file. Correct any errors by updating the following files:

- QA code files
- QA calibration files
- Nephelometer constants file

After updated the above files, start Level-0 and Level-1 validation again.

4.3.4.2 Quarterly Summary Plots

Level-1 validated nephelometer and relative humidity data are summarized in quarterly summary plots. Figure 4-14 shows an example quarterly summary plot. The plots are described in detail below:

- **4-Hour Average Variation in Visual Air Quality (Filtered Data)**
  Timeline of 4-hour average scattering data filtered to remove data affected by meteorological interference. The data are plotted as b_{scat} (km^{-1}).

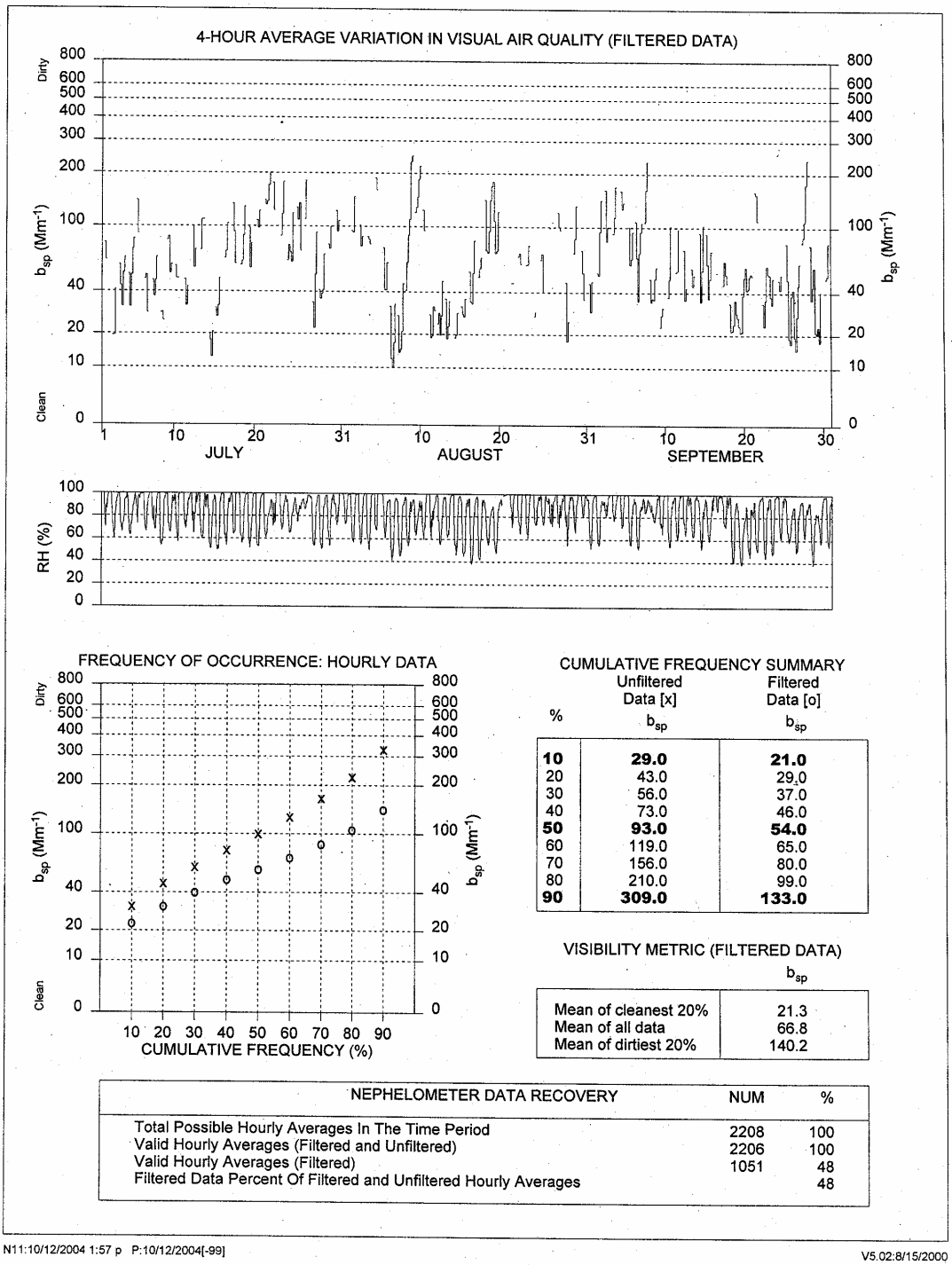
- **Relative Humidity**
  Timeline of hourly relative humidity. Note that periods of high scattering are often associated with periods of high relative humidity.

- **Frequency of Occurrence and Cumulative Frequency Summary**
  Frequency of occurrence distribution of hourly scattering data, both unfiltered and filtered for meteorological interference. The 10% to 90% values are plotted in 10% increments and are summarized in the table next to the plot. The 50% values represents the median of the valid hourly averages.

- **Visibility Metric**
  Visibility statistics for data filtered for meteorological interference, including:
  - Mean of the cleanest 20% of valid data
  - Mean of all valid data
  - Mean of the dirtiest 20% of valid data

- **Nephelometer Data Recovery**
  Data collection statistics, including
  - Total number of hourly averages possible in the period
  - Number of valid hourly averages including filtered and unfiltered data
  - Number of valid hourly averages including filtered data only
  - Filtered data as percent of unfiltered and filtered data

MAMMOTH CAVE NATIONAL PARK, KENTUCKY
IMPROVE Nephelometer Data Summary
Fall Season: July 1, 2004 - September 30, 2004



FREQUENCY OF OCCURRENCE: HOURLY DATA

CUMULATIVE FREQUENCY SUMMARY

%	Unfiltered Data [x] b_{sp}	Filtered Data [o] b_{sp}
10	**29.0**	**21.0**
20	43.0	29.0
30	56.0	37.0
40	73.0	46.0
50	**93.0**	**54.0**
60	119.0	65.0
70	156.0	80.0
80	210.0	99.0
90	**309.0**	**133.0**

VISIBILITY METRIC (FILTERED DATA)

	b_{sp}
Mean of cleanest 20%	21.3
Mean of all data	66.8
Mean of dirtiest 20%	140.2

NEPHELOMETER DATA RECOVERY	NUM	%
Total Possible Hourly Averages In The Time Period	2208	100
Valid Hourly Averages (Filtered and Unfiltered)	2206	100
Valid Hourly Averages (Filtered)	1051	48
Filtered Data Percent Of Filtered and Unfiltered Hourly Averages		48

N11:10/12/2004 1:57 p P:10/12/2004[-99]

V5.02:8/15/2000

Figure 4-14. Example Level-1 Quarterly Summary Plot.

Quarterly summary plots are generated using the NGN_nsum.exe software. The following procedures describe the operation of the software:

EXECUTE PROCESSING SOFTWARE

Execute the NGN_nsum.exe software from the Windows Program Manager. The display will appear as shown in Figure 4-15.

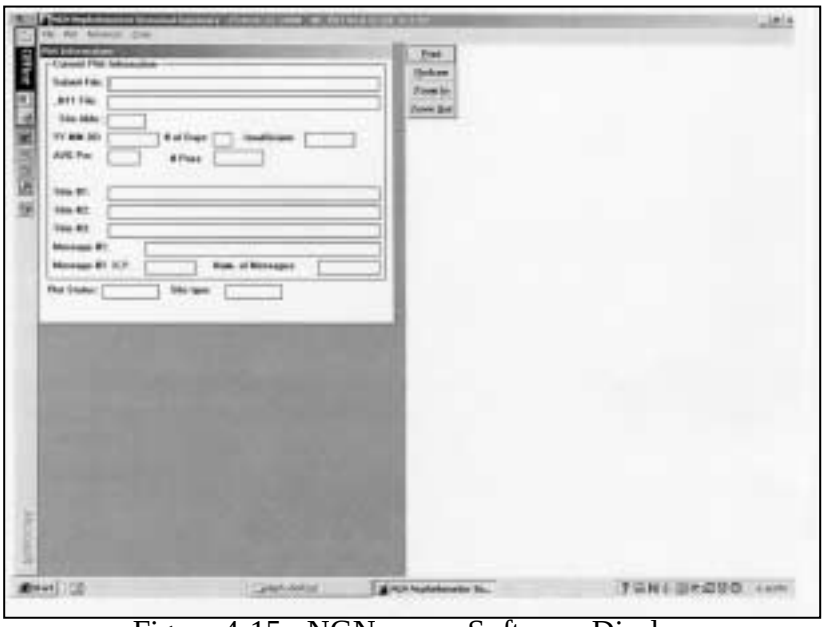


Figure 4-15. NGN_nsum Software Display.

EDIT THE SUBMIT FILE

The submit file defines the Level-1 validated data files and associated parameters used to generate the plots. Figure 4-16 details the format of the submit file. The following procedures are used to edit the submit file:

- Click on **File**. Click on **Edit Submit File**. The Windows Notepad program will be launched.
- Open an existing submit file or create a new one in Notepad.
- Save the submit file and exit Notepad.

GENERATE THE PLOTS

The plots defined in the submit file can be plotted to the screen or to any Windows-compatible printer attached to the system. The following procedures are used to generate the plots:

- Choose the submit file to use by clicking **File** and then **Choose Submit File**. Select the submit file to use from the file selection box.
- Generate the plots defined in the submit file by clicking **Plot** and then **Plot All Plots** (printer) or **Plot To Screen** (screen).
- The plots defined in the submit file will be sent to the printer selected by the user after clicking Plot All Plots.

Figure 4-16. NGN_nsum Software Submit File Format.

Quarterly summary plots of Level-1 validated data are reviewed by the data analyst and project manager to identify the following:

- Data reduction and validation errors
- Instrument operational problems
- Calibration problems

Problems identified in the Level-1 quarterly summary plot review are resolved by editing the QA code and/or calibration files to identify additional data as valid or invalid and performing the Level-0 and Level-1 validation procedures again.

When the Level-1 quarterly summary plots have passed the review process, the raw through Level-1 validated data and associated QA files are archived as described in TI 4600-5000, *Nephelometer Data Archiving*.

APPENDIX A

IDENTIFICATION OF DATA AFFECTED BY METEOROLOGICAL INTERFERENCE

Nephelometer data are filtered to identify periods likely affected by meteorological interference. The following filter criteria (defined in the nephelometer constants file, Nprocess.con) are used to identify these periods:

- **Rate of Change** - If the rate of change between nephelometer hourly b_{scat} data exceeds the following threshold, the b_{scat} value is coded as filtered:

  Nephelometer b_{scat} rate-of-change threshold: 0.05 km^{-1}

- **Maximum** - If the nephelometer b_{scat} data exceeds the following threshold, the b_{scat} value is coded as filtered:

  Nephelometer b_{scat} maximum threshold: 5.0 km^{-1}

- **Relative Humidity** - If the relative humidity corresponding to the nephelometer b_{scat} value exceeds the following threshold, the b_{scat} value is coded as filtered:

  Nephelometer b_{scat} RH threshold: 95%

- σ/μ - If the standard deviation of the hourly raw nephelometer data divided by the mean of the hourly raw nephelometer data exceeds the following threshold, the value is coded as filtered:

  Raw nephelometer σ/μ threshold: 10%

Nephelometer data identified as affected by meteorological interference is still considered valid. An additional validity code is assigned to the hourly average data point in the Level-1 file as shown in Figure 4-13.

APPENDIX B

ESTIMATING PRECISION IN NEPHELOMETER DATA VALIDATION AND PROCESSING

The following methods are used to estimate the precision of Level-1 validated data.

- The precision of meteorological data are defined by the factory specified precision for the sensors. These precision are recorded in the site-specific QA code files. Typical precisions of meteorological sensors are detailed in Table B-1.

Table B-1

Typical Factory-Defined Precisions of Meteorological Sensors

Sensor	Precision
Rotronics Ambient Temperature	± 0.5 °C
Rotronics Relative Humidity	± 2%
Optec NGN-2 Nephelometer Chamber Temperature	± 2°C

- The estimated precision of nephelometer data for a given time period is based on calibrations performed during that time period. The precision estimates for are recorded in the site-specific QA code files and are automatically placed in the Level-1 data files. The relative error (uncertainty) in scattering due to drift of the slope of the calibration line is evaluated based on the instrument-specific zero and span checks performed. The following statistical analysis was applied to calculate potential uncertainty:

V(t) =	Normalized nephelometer reading at time t
$V_o(t)$ =	Normalized clean air reading at time t
$V_s(t)$ =	Normalized SUVA 134a reading at time t
$b_{scat,o}$ =	Scattering coefficient for clean air
$b_{scat,s}$ =	Scattering coefficient for SUVA 134a
V_o =	Average normalized clean air reading
V_f =	Average normalized SUVA 134a reading
$b_{scat}(t)$ =	Theoretical scattering coefficient at time t
m =	Slope of the calibration line used to calculate the theoretical scattering coefficient $b_{scat}(t)$

$$m = \frac{(b_{scat,\,s} - b_{scat,\,o})}{(V_s(t) - V_o(t))}$$

Given a normalized nephelometer reading $V(t)$, the theoretical b_{scat} at time t is:

$$b_{scat}(t) = b_{scat,o} + m\,(V(t) - V_o(t))$$

Assuming that $V_o(t)$ and $V(t)$ are known without error.

The slope of the calibration line is not constant as defined above, but changes (drifts) with time. Figure B-1 illustrates the drift in the clean air and span values with time. Figure B-2 illustrates how these drifting values cause the slope of the calibration line to drift.

The actual slope of the calibration line at time *t* is:

$$m(t) = (b_{scat,s} - b_{scat,o}) / (V_s(t) - V_o(t))$$

The actual b_{scat} (denoted b'_{scat}), given a nephelometer reading $V(t)$, is:

$$b'_{scat}(t) = b_{scat,o} + m(t)\ (V(t) - V_o(t))$$

The relative error between the theoretical b_{scat} and actual b'_{scat} is:

$$- ((m - m(t))\ (V(t) - V_o(t))) / (b_{scat,o} + m\ (V(t) - V_o(t)))$$

$$relative\ error = (b_{scat}(t) - b'_{scat}(t)) / b_{scat}(t)$$

$$= (m - m(t)) / (b_{scat,}o / (V(t) - V_o(t)) + m)$$

$$= |\ (m\text{-}m(t)) / (b_{scat,o} / (V(t) - V_o(t)) + m)\ |$$

The magnitude of the relative error is:

$$|\ relative\ error\ | = |\ (b_{scat}(t) = b'_{scat}(t)) / b_{scat}(t)\ |$$

The magnitude of the relative error is bounded by the slopes such that:

$$|\ relative\ error\ | \leq |\ (m - m(t)) / m\ |$$

Assuming that the calculated slopes, $m(t)$, of the calibration lines are normally distributed about the average slope m with a standard deviation s, then for a probability (confidence level) of 95%:

$$|\ m - m(t)\ \backslash \leq 2s$$

so that

$$|\ (b_{scat}(t)) - b'_{scat}(t)) / b_{scat}(t)\ | \leq |\ 2s / m|$$

Assuming that $_s$ is estimated by s_m with k degrees of freedom, based on k+1 sample values of $m(t)$, and using the two-tailed t distribution, the relative error at a 95% confidence level (which for a two-tailed t distribution is read from the 97.5 column of the t table) is:

$$|\ relative\ error\ | \leq t_{k,0.025} * s_m / m$$

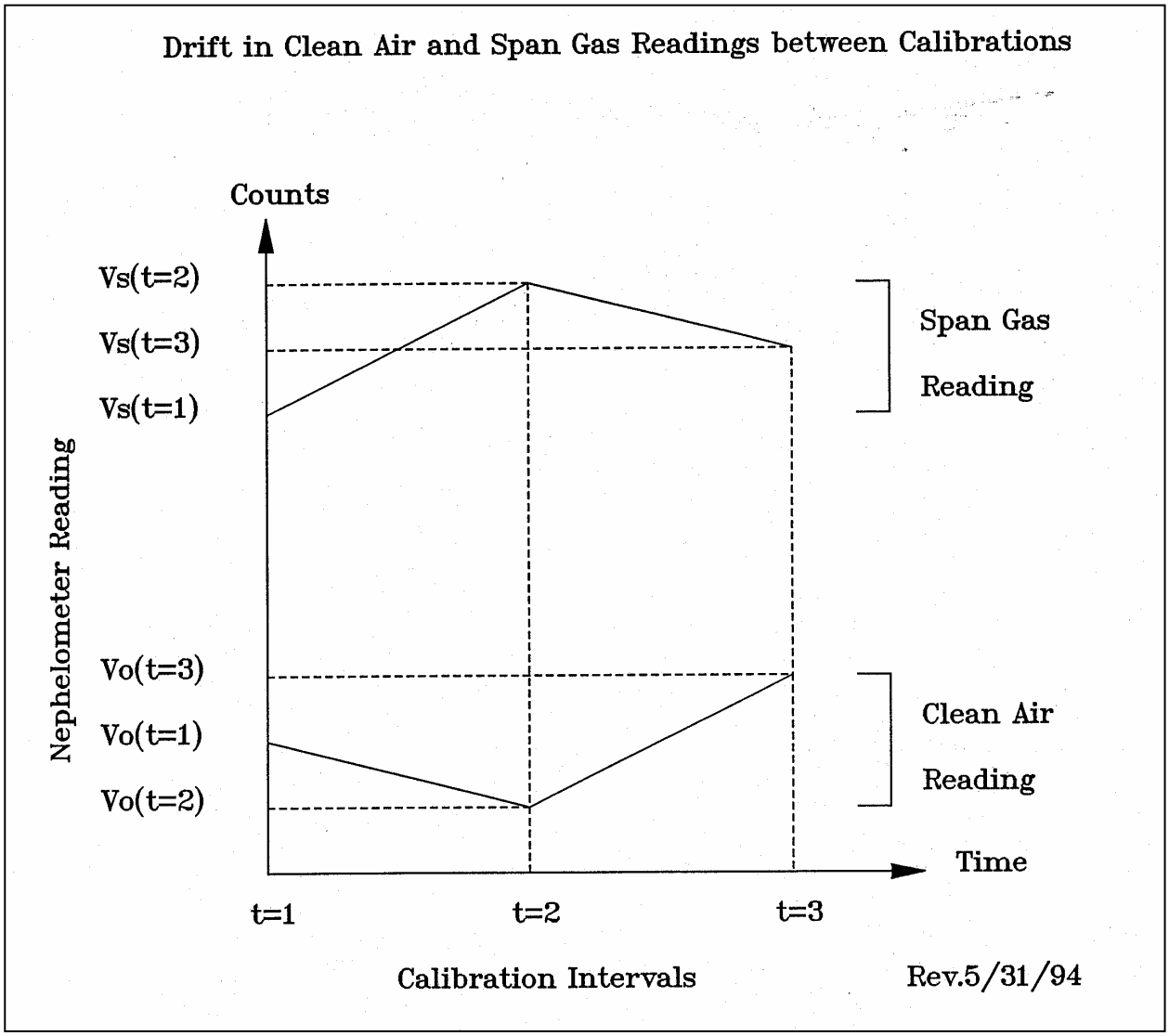


Figure B-1. Drift in the Clean Air and SUVA 134a Values With Time.

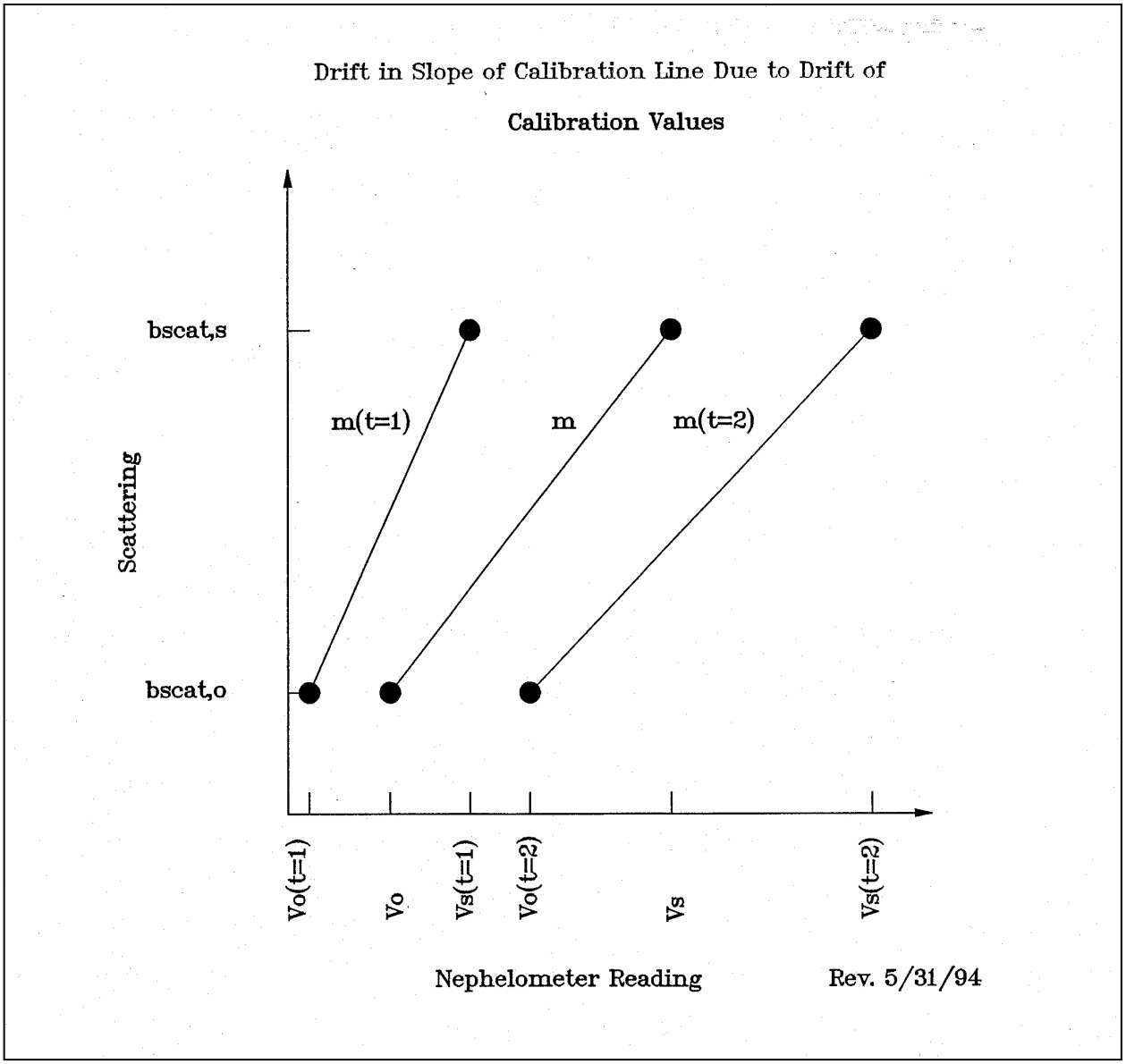


Figure B-2. Drift in Slope of Calibration Line Due to Drift of Calibration Values.