Nitrogen Deposition Reduction Plan for Rocky Mountain National Park

Presentation to MANE-VU 2009 Science Meeting

July 29, 2009
Air Quality Issues at Rocky

- For Rocky Mountain National Park, there is concern about:
  - Visibility degradation
  - Increasing tropospheric ozone concentrations
  - Nitrogen deposition

- CDPHE, NPS and EPA began a process for addressing these concerns
  - The “RMNP Initiative” began
  - Nitrogen deposition is the focus of the Initiative
Ecosystem Impacts

High elevation lakes have shifted from natural undisturbed systems to disturbed systems; changes in aquatic plant species have occurred.

Soils are soaking up nitrogen; excess nitrogen is accumulating.

Shift from alpine flowers to grasses likely occurring; nitrogen helps sedges and grasses outcompete flowering plants.

Changes to tree and soil chemistry are beginning.
Deposition of Nitrogen at RMNP

- Current wet and dry nitrogen deposition averages 4.0 kilograms per hectare per year

- Wet nitrogen deposition averages 3.1 kg/ha/yr

- The pre-industrial or “natural” levels of nitrogen deposition are estimated to be around 0.2 kg N/ha/yr

- This increased nitrogen loading is unnaturally changing high elevation ecosystems at RMNP
Critical Load and the Resource Management Goal

- RMNP Superintendent identified 1.5 kg/ha/yr wet deposition as the critical load for eutrophication (N fertilization), and as a park resource management goal.

- RMNP has adopted a wet nitrogen deposition resource management goal of 1.5 kg N/ha/yr.

- CDPHE, the Colorado Air Quality Control Commission, and EPA have endorsed this goal.
Collaborative Process to Address Air Quality Concerns for Rocky

- MOU (2005) between NPS, EPA Region 8 and Colorado’s Air Pollution Control Division: to develop “air quality management policies and programs to address harmful impacts to air quality and other natural resources occurring in Rocky Mountain National Park.”

- Colorado Air Quality Control Commission subcommittee

- Participants and stakeholders have reviewed the research, identified information needs and have begun to discuss options for improving conditions

- “Weight of the evidence” approach to consider reductions
  - Monitoring/trends
  - Attribution studies
  - Planned reductions

- A Plan has been developed
Highlights of the RMNP Nitrogen Deposition Reduction Plan
Goals Have Been Established

Rocky Mountain National Park
2032 Glidepath for Nitrogen Deposition Reduction

- Interim Resource Goal (Target Load): 2.7 kg N/ha/yr - wet deposition
- Aquatic Management Resource Goal (Critical Load): 1.5 kg N/ha/yr - wet deposition
- Natural Conditions: 0.2 kg N/ha/yr

Year:
- 2006
- 2008
- 2010
- 2012
- 2014
- 2016
- 2018
- 2020
- 2022
- 2024
- 2026
- 2028
- 2030
- 2032
- 2034
NOx Control Options Have Been Developed

- A list of possible control options to reduce NOx emissions are provided for numerous source types
  - Stationary sources
  - Mobile sources
  - Area sources
- A general overview of each with emission reductions and cost estimates are provided
Ammonia Reduction Options Have Been Developed

- A list of possible best management practices to reduce ammonia emissions are discussed
  - BMPs for crop production
    - Tillage and fertilizer management
  - BMPs for livestock production
    - Feed, livestock, facility, wastewater, manure management
- A general overview of each with emission reduction potential and implementation issues are provided
- Research needs and plans are also presented
- BMPs for domestic fertilizer and controls for stationary sources will be investigated
Mandatory Emission Reduction Measures Have Not Been Proposed

- Voluntary reductions, best management practices, and benefits from current programs will be emphasized

- Future air quality regulatory efforts are anticipated
  - MOU agencies commit to develop NOx reduction measures for consideration during the Regional Haze SIP process
  - Contingency plan measures will be developed by 2010 through a public process

- For water quality, restoration of waters using a collaborative, community-based approach will be utilized
Deposition, Emissions and Transport and Attribution

• Deposition monitoring and trends data are presented
• Colorado emissions of N from NOx and ammonia are estimated
  – 34% mobile sources
  – 23% agriculture
  – 24% area sources
  – 19% point sources
  – Trends in activities and emissions are presented
• Anticipated NOx reductions may result in achieving the 2012 target load of 2.7 kg N/ha/yr if ammonia emissions remain constant
Deposition, Emissions and Transport and Attribution

• Further research will better help determine source regions and emission reduction benefits
  – Regional Haze visibility modeling work
  – ROMANS study over the next 1-2 years
• Metro-area, in-Park, in-State and out-of-State culpability will be better defined
• Attribution of N deposition by source category will be possible
• The ozone/N deposition interplay will be examined
Implementation Strategy and Continuing Evaluation

• Near term:
  – Existing and planned NOx reduction measures will be implemented
  – NOx strategies will be developed
  – Agricultural BMPs accepted by the industry will be broadly implemented in Colorado
  – Ammonia emissions will be better characterized
  – Modeling and assessment activities will proceed

• Longer term:
  – Ammonia-reducing agricultural BMPs will be researched, field tested
    • MOU agencies will work with producers to implement BMPs that are shown to be cost-effective
  – Ammonia-reducing BMPs and emission reduction programs for urban sources and water treatment facilities will be researched and implemented
    • Urban fertilizer usage research began this Spring
  – Education/outreach to the agricultural sector, industrial groups and the public will occur
  – Additional NOx strategies, voluntary and regulatory, will be considered
The Website for the Nitrogen Deposition Reduction Plan, the Options and Technical Papers, and additional information about the RMNP Initiative

http://www.cdphe.state.co.us/ap/rmnp.html
RoMANS
Rocky Mountain Atmospheric Nitrogen and Sulfur Study

March, 2009
ISSN 0737-5352-84
Increasing Wet Nitrogen Deposition Trends

Wet nitrate concentration deposition trends

Wet ammonium concentration deposition trends
Contribution of Dry and Wet Deposited N Species to Total Measured N depositions

- N Deposition is ~2/3 wet (rain and snow) and 1/3 dry (particles and gases).
- ~1/2 of N deposition is due to reduced N; 1/3 oxidized; and 15% organic N
- Over 30% of N deposition is not being measured in the current monitoring programs (NADP & CASTNET).
East Winds = High Concentrations

The graph shows the concentration levels of sulfate ($SO_4^{2-}$), nitrate ($NO_3^-$), and ammonium ($NH_4^+$) over time, with different wind directions represented by the wind direction arrows. The precipitation is indicated by a blue arrow pointing right. The x-axis represents the dates from April 20th to April 27th, and the y-axis shows the concentration levels in neq/m$^3$. The graph includes lines for each of the three chemical components and a line for wind direction.
Apportionment Strategy (Weight of Evidence)

- Concentration gradients
- Pollution roses: Which way does the wind come from?
- Simple back trajectories
- Statistical trajectory analyses
- Residence time Analysis
- Trajectory receptor models
- Receptor models
- Source oriented chemical transport
Colorado NO$_X$ and NH$_3$ Emission Budgets

- NO$_X$ emissions are from a diverse set of sources
- Many of these sources are regulated

- NH$_3$ emissions are primarily due to agricultural activities
Wet + Dry Deposition for Spring and Summer (in state vs. out of state)
### Detailed Deposition Source Attribution

#### Budgets

- **Spring N deposition** is primarily from northeastern CO and Denver.

- **Summer N deposition** is from a diverse set of sources.
  - Local sources contribute ~15% of summer NH$_3$ deposition.

<table>
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<tr>
<th>Nitrogen Deposition, mg/m$^2$</th>
<th>Reduced</th>
<th>Oxidized</th>
<th>Reduced</th>
<th>Oxidized</th>
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**Legend:**
- Other Non-CO
- Four Corners
- S. NV - N. AZ
- California
- Southwestern WY
- Eastern WY
- Other Colorado
- Local
- Western CO
- Northwestern CO
- Denver
- Northeastern CO
Trace Gas Samplers
(off the shelf and custom)

Sample Pumps
Moly Converters (825C, 315C)
Zero Air Generator
Dilution Calibrator
NO/CO
NH₃
NPN
1 Minute Data Acquisition With Labview For all Instruments

Moly (285C)
Nylasorb Filter

URG HNO3 Glass Denuder

Calibration Gas Injection Line
Online N measurements: Two 3 Channel Instruments

**DIRECT**

1. NO\textsubscript{Y} (inlet moly 285\textdegree}C
2. NO\textsubscript{Y}'(denuded/filtered inlet moly 285\textdegree}C
3. NO

**BY DIFFERENCE**

1. HNO\textsubscript{3} + pNO\textsubscript{3}⁻
2. pNO\textsubscript{3}⁻

(NO\textsubscript{Y} analyzer)

1. ‘Total’ Gas Phase Nitrogen (moly 815\textdegree}C)
2. ‘Traditional’ NO\textsubscript{x} (moly 315\textdegree}C)
3. NO

(NH\textsubscript{3} analyzer)

1. ‘NH\textsubscript{3}’
2. ‘NO\textsubscript{2}’
Clean conditions prevailed most of the winter and occasionally in spring

NH\textsubscript{3} was the dominant nitrogen species often showing a midday peak
Nitrogen Species Conc (ppb)

- CO (ppb)
- CO
- NH₃
- NO
- NO₃/pNO₃
- NO₃
- NH₃ typically leads events beginning in mid-morning
Winter Overnight NO$_y$ Event

- Dominated by NO$_y$ plus smaller contributions of NH$_3$ and particulate NO$_3^-$
- Low NO: not a locally driven event
Starting in spring, daytime events more common and higher concentrations

Oxidized species trend with carbon monoxide
• Outside of high concentration events, NO\textsubscript{Y}, filtered NO\textsubscript{Y}, denuded NO\textsubscript{Y}, and NO\textsubscript{x} equivalent

• Suggests NO\textsubscript{2} dominance of NO\textsubscript{Y}

• Just starting the high summer HNO\textsubscript{3} season
Source regions of NH$_3$ and NO$_y$ at RMNP are quite different
RMNP NH$_3$ Denuder Comparisons

- Poor agreement between online and denuder
- Volatilization artifact of NH$_4$NO$_3$ seems unlikely
- Likely interference of other gas phase nitrogen species
- Implementing several additional online NH$_3$ methods

Order of magnitude lower concentrations than urban site