Proceedings from the

# Workshop on Research Needs for Assessment and Management of Non-Point Air Emissions from Department of Defense Activities

## 19-21 February 2008
## Research Triangle Park, North Carolina

DoD EPA DOE SERDP

ESTCP

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# Foreword

These proceedings encompass outcomes from the Workshop on Research Needs for Assessment and Management of Non-Point Air Emissions from Department of Defense (DoD) Activities. The proceedings reflect the opinions and views of workshop participants, and not necessarily those of DoD. This document is available in PDF format at www.serdp-estcp.org/workshops.

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# Executive Summary

The Department of Defense (DoD) conducts military training and testing activities on approximately 30 million acres of land. These lands may be far removed from other human inhabitants or may be located in close proximity to populated areas. As it carries out its mission activities, the DoD generates a variety of air emissions, many of which are under regulatory control. Moreover, a number of DoD installations have closed in accordance with the 2005 Base Realignment and Closure initiative and other force redeployments. As a result, more military personnel will be training and testing at fewer installations. In addition, development pressure continues adjacent to many of the installations and places more and more people in proximity to the effects of DoD activities. These factors in combination place tremendous pressure on DoD's ability to continue training and testing without interruption, and to effectively manage its natural resources because of potential air quality-related compliance issues or community complaints.

To address these challenges, DoD's Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) sponsored the Workshop on Research Needs for Assessment and Management of Non-Point Air Emissions from DoD Activities. The workshop was held from February 19-21, 2008 and was hosted by the Environmental Protection Agency (EPA) at its facility in Research Triangle Park, North Carolina. This invitation-only forum of 59 participants included senior researchers and managers from DoD, other federal and state agencies, academia, industry, and the non-governmental organization community.

To assist in designing the workshop purpose and scope a steering committee was formed. This committee developed the workshop charge, identified white paper topics and authors, helped formulate the workshop agenda, and recommended participants for the workshop. To strategically guide future investments and facilitate long-term cooperation and coordination among workshop participants, the steering committee identified five primary objectives for this workshop:

- Assess DoD air quality management needs, focusing on non-point source air emissions.
- Assess the current state of practice relative to these needs.
- Assess the current state of the science and technology related to these needs and practices.
- Identify the gaps in knowledge, technology, and management that, if addressed, could improve DoD's and EPA's ability to address emissions from non-point sources.
- Set priorities for future SERDP and ESTCP investments to address these gaps.

In advance of this workshop, participants were provided white papers on the following topics:

- The U.S. Clean Air Visibility Rule and Military Non-Point Source Emissions
- Emission Measurement and Ambient Air Monitoring in Assessment of Non-Point Sources
- Mitigation Techniques for Fugitive Dust Emissions from DoD Training Activities
- Air Quality Modeling
- Optical Remote Sensing for Assessment of Non-Point Sources

The workshop included a plenary session of presentations highlighting the preceding five white papers, as well as brief perspectives from the participating agencies. To accomplish the workshop objectives, the attendees participated in three breakout sessions: particulate emissions from non-

point sources, gaseous emissions for non-point sources, and sources and activities. During the sessions on particulate and gaseous emissions, workshop participants addressed characterization, monitoring, modeling, and mitigation issues. Those participating in the sources and activities breakout group addressed fire emissions, training range emissions, and fuels, lubricants, and solvents. Emissions from stationary stacks and exhaust emissions from internal combustion engines were not addressed at this workshop. Furthermore, the workshop did not directly address research needs associated with human health effects.

After the formal workshop concluded, a small group consisting of breakout group chairs, white paper authors, and the workshop sponsors engaged in a half-day meeting to review, clarify, and refine the recommendations and 65 priorities expressed during the workshop. Listed below are the top 11 prioritized recommendations (in no particular order) resulting from the workshop:

- Improve characterization, monitoring, modeling, and mapping of fuels to support enhanced smoke management and fire planning at DoD installations.
- Enhance smoke management at DoD installations using advanced monitoring and modeling approaches.
- Quantify, model, and monitor post-fire effects at DoD installations to improve fire management effectiveness.
- Develop surface characterization procedures for determining dust emission potential.
- Improve understanding of the generation and transport of fugitive dust as a function of the interaction between soils, terrain, and mission activity.
- Develop an emissions model broadly applicable to wheeled and tracked vehicle fugitive dust emissions.
- Develop and validate near-field models for fugitive dust emissions.
- Evaluate dispersion models for offsite impact, including evaluation with receptor-oriented source apportionment models.
- Develop monitoring methods to determine source and fence line amounts of fugitive dust emissions for source and ambient compliance monitoring.
- Evaluate fugitive emissions from storage, handling, and transfer of fuels and the effects of these emissions on air quality.
- Develop optical remote sensing methodologies to quantify volatile organic compound emissions at DoD installations.

Working group participants prepared write-ups for each of the priorities that included background, significance, and recommendations. Those write-ups will be evaluated by the SERDP and ESTCP Office to determine how best to invest SERDP and ESTCP funds to address the needs identified during the workshop.

Other priorities identified by workshop attendees that fell outside the scope of the workshop were documented as general findings and recommendations, Focal areas of these recommendations included assessments of other fugitive emission monitoring and dispersion models prepared outside of DoD but applicable to DoD air quality requirements, the need to identify DoD sources and to quantify emissions of greenhouse gases (GHG), and assessments of the environmental effects of a single DoD fuel policy and emissions from alternative fuels.

# Acknowledgements

The sponsors of the Workshop on Research Needs for Assessment and Management of Non-Point Air Missions from Department of Defense (DoD) Activities wish to thank all the white paper authors, plenary and technical session speakers, and technical session chairs for helping make this event a worthwhile and productive endeavor.

The sponsors extend a special thanks to the Environmental Protection Agency (EPA) for hosting this workshop and to the organizers and steering committee members (see table below) who helped formulate the agenda, identified appropriate participants, developed the workshop charge and objectives, and selected white paper topics.

**Table 2. Workshop Steering Committee**

| Name | Organization |
|---|---|
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The sponsors also acknowledge the dedicated efforts of individuals from HGL, including Mr. John Thigpen, Ms. Veronica Rice, Ms. Alicia Shepard, Dr. Robert Holst, Mr. Jeffrey Houff, Ms. Carrie Wood, Ms. Sheri Washington, and Ms. Ashley Cantu. Mr. Kenneth Carey of Noblis led development and completion of this report.

Finally, the sponsors wish to thank all the event's participants (see Appendix A), without whom this workshop could not have happened.

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# List of Acronyms

| | |
|---|---|
| **µg** | microgram |
| **µm** | micron or micrometer |
| **3-D** | three-dimensional |
| **ACE** | Aerosol Characterization Experiment |
| **AERMOD** | AMS-EPA Regulatory Model |
| **ALOHA** | Areal Locations of Hazardous Atmospheres |
| **APIMS** | Atmospheric Pressure Ionization Mass Spectrometry |
| **AP-42** | (Compilation of) Air Pollutant Emission Factors |
| **ASTM** | American Society for Testing and Materials |
| **BART** | Best Available Retrofit Technology |
| **BRAC** | Base Realignment and Closure |
| **BTEX** | benzene, toluene, ethylbenzene, xylene |
| **BXT** | benzene, xylene, and toluene |
| **CAA** | Clean Air Act |
| **CALGRID** | California Photochemical Grid Model |
| **CALPUFF** | California Puff Model |
| **CAM** | Compliance Assurance Monitoring |
| **CAVR** | Clean Air Visibility Rule |
| **CERL** | Construction Engineering Research Laboratory |
| **CFC** | chlorofluorocarbon |
| **CFTS** | Comprehensive Fuel Treatment Strategy |
| **$CH_4$** | methane |
| **CMAC** | Cerebellar Model Articulation Controller |
| **CMAQ** | Community Multiscale Air Quality |
| **CO** | carbon monoxide |
| **$CO_2$** | carbon dioxide |
| **Cr** | chromium |
| **DDT** | dichlorodiphenyltrichloroethane |
| **DIAL** | differential absorption LIDAR |
| **DLSME** | Defense Land Systems and Miscellaneous Equipment |
| **DOAS** | differential optical absorption spectrometer |
| **DoD** | Department of Defense |
| **DOE** | Department of Energy |
| **DRI** | Desert Research Institute |
| **DUSTRAN** | Dust Transport Model |
| **EF** | emission factor |
| **EPA** | U.S. Environmental Protection Agency |
| **ERDC** | Engineering Research and Development Center |
| **ER** | Environmental Restoration |
| **ERT** | Electronic Reporting Tool |

| | |
|---|---|
| **ESA** | Endangered Species Act |
| **ESTCP** | Environmental Security Technology Certification Program |
| **ETV** | Environmental Technology Verification |
| **FCCS** | Fuel Characteristic Classification System |
| **FEIS** | Fire Effects Information Systems |
| **FOFEM** | First Order Fire Effects Model |
| **FTIR** | Fourier Transform Infrared (spectroscopy) |
| **FUWT** | Fire Use Working Team |
| **GACT** | Generally Achievable Control Technology |
| **GHG** | greenhouse gas |
| **GIS** | Geographic Information System |
| **HAP** | Hazardous Air Pollutant |
| **HC** | hexachloroethane |
| **HCFC** | hydrochlorofluorocarbon |
| **HCHO** | formaldehyde |
| **HCl** | hydrochloride |
| **HCN** | hydrogen cyanide |
| **HPAC** | Hazard Prediction and Assessment Capability |
| **HYSPLIT** | HYbrid Single-Particle Lagrangian Integrated Trajectory |
| **IR** | infrared |
| **ISO** | International Organization for Standardization |
| **JFSP** | Joint Fire Sciences Program |
| **JP** | jet propellant |
| **LANDFIRE** | Landscape Fire and Resource Management Planning Tools Project |
| **LBP** | lead-based paint |
| **LCA** | life cycle assessment |
| **LIDAR** | Laser Imaging Detection and Ranging |
| **LPG** | liquid propane gas |
| **MACT** | Maximum Achievable Control Technology |
| **MDC** | Minimum detectable concentration |
| **MM** | Munitions Management |
| **MOU** | Memorandum of Understanding |
| **NAAQS** | National Ambient Air Quality Standards |
| **NARAC** | National Atmospheric Release Advisory Capability |
| **NASA** | National Air and Space Administration |
| **NESHAP** | National Emission Standards for Hazardous Air Pollutants |
| **NFP** | National Fire Plan |
| **NGO** | non-governmental organization |
| **$NH_3$** | ammonia |
| **NIST** | National Institute of Standards and Technology |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **$NO_x$** | nitrous oxide |
| **NSPS** | New Source Performance Standard |

| | |
|---|---|
| **NSR** | New Source Review |
| **NWCG** | National Wildfire Coordinating Group |
| **NWS** | National Weather Service |
| **$O_3$** | ozone |
| **OAQPS** | Office of Air Quality Planning and Standards |
| **OAR** | Office of Air and Radiation |
| **OB/OD** | open burn/open detonation |
| **OBDG** | Ocean Breeze-Dry Gulch |
| **OCONUS** | outside the continental United States |
| **ORD** | Office of Research and Demonstrations |
| **ORS** | Optical Remote Sensing |
| **OSMIS** | Operating and Support Management Information System |
| **OTM** | Other Test Method |
| **PAH** | polyaromatic hydrocarbons |
| **PM** | particulate matter |
| **$PM_1$** | particulate matter with a diameter of 1.0 µm or less |
| **$PM_{2.5}$** | particulate matter with a diameter of 2.5 µm or less |
| **$PM_{10}$** | particulate matter with a diameter of 10 µm or less |
| **POL** | petroleum, oil, and lubricants |
| **QCL** | quantum cascade laser |
| **R&D** | research and development |
| **RACT** | Reasonably Available Control Technique |
| **RCRA** | Resource Conservation and Recovery Act |
| **RDT&E** | Research, Development, Testing, and Evaluation |
| **RH** | relative humidity |
| **SAB** | Science Advisory Board (EPA) |
| **SCICHEM** | SCIPUFF with Chemistry |
| **SCIPAC** | dispersion model |
| **SERDP** | Strategic Environmental Research and Development Program |
| **SI** | Sustainable Infrastructure |
| **SIP** | State Implementation Plan |
| **SON** | statement of need |
| **$SO_x$** | sulfur oxide |
| **SPPD** | Sector Policies and Programs Division |
| **SRS** | satellite remote sensing |
| **SSC** | Services Steering Committee |
| **SVOC** | semi-volatile organic compound |
| **TSP** | Total Suspended Particulate |
| **USDA** | U.S. Department of Agriculture |
| **USFS** | U.S. Forest Service |
| **VCO** | voluntary control organization |
| **VLSTRACK** | Vapor-Liquid-Solid Tracking model |

| | |
|---|---|
| **VOC** | volatile organic compound |
| **VSMOKE** | dispersion modeling system |
| **WEG** | Wind Erodibility Group |
| **WEPS** | Wind Erosion Prediction System |
| **WP** | Weapons Systems and Platforms |
| **WUI** | wildland-urban interface |

# 1 Introduction and Background

The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) are Department of Defense (DoD) programs designed to support research, development, demonstration, and transition of the environmental technologies required by DoD to perform its mission. Assessment and sustainment of training and testing ranges are areas of emphasis for both programs.

DoD conducts military training and testing activities on approximately 30 million acres of land. These lands may be far removed from other human inhabitants or may be located in close proximity to populated areas. As it carries out its mission activities, DoD generates a variety of air emissions, many of which are under regulatory control. Moreover, a number of DoD installations have closed in accordance with the 2005 Base Realignment and Closure (BRAC) initiative and other force redeployments. As a result, more military personnel will be training and testing at fewer installations. In addition, development pressure continues adjacent to many of the installations and places more and more people in proximity to the effects of DoD activities. These factors in combination place tremendous pressure on DoD's ability to continue training and testing without interruption, and to effectively manage its natural resources because of potential air quality-related compliance issues or community complaints.

To address these challenges, SERDP and ESTCP sponsored this Workshop on Research Needs for Assessment and Management of Non-Point Air Emissions from DoD Activities from 19 to 21 February 2008. The Environmental Protection Agency (EPA) hosted this workshop at its facility in Research Triangle Park, North Carolina. This invitation-only forum of 59 participants included senior researchers and managers from DoD, other federal and state agencies, academia, industry, and the non-governmental organization community.

## 1.1 Workshop Focus

This workshop was convened to identify science and technology needs for characterization, monitoring, modeling, and impact assessment and mitigation of non-point source emissions. Emissions from stationary stacks and exhaust emissions from internal combustion engines were not addressed at the workshop, and the workshop did not directly address research needs associated with human health effects.

## 1.2 Workshop Sponsors

The Workshop on Research Needs for Assessment and Management of Non-Point Air Missions from DoD Activities was sponsored by SERDP and ESTCP. The Environmental Protection Agency's (EPA's) Office of Air and Radiation (OAR), Office of Air Quality Planning and Standards (OAQPS) hosted the workshop at its facility in Research Triangle Park, North Carolina.

SERDP is DoD's environmental science and technology program, planned and executed in full partnership with the Department of Energy (DOE) and EPA, with participation by other federal and non-federal organizations. SERDP focuses on four technical areas: Environmental Restoration (ER), Munitions Management (MM), Sustainable Infrastructure (SI), and Weapons Systems and Platforms (WP). To address the highest-priority issues confronting the Army, Navy, Air Force, and Marines, SERDP focuses on cross-service requirements and pursues high-risk/high-payoff solutions to DoD's most intractable environmental problems. The development and application of innovative environmental technologies will reduce the costs, environmental risks, and time required to resolve environmental problems while simultaneously enhancing safety, health, and military readiness. SERDP is using environmental research and development (R&D) to improve mission readiness by (1) ensuring the long-term sustainability of training and testing ranges, (2) improving detection and discrimination of unexploded ordnance, (3) accelerating cost-effective cleanup of contaminated defense sites, (4) reducing defense industrial and operational waste streams through aggressive pollution prevention, and (5) facilitating full compliance with environmental laws and regulations.

SERDP and ESTCP are DoD programs designed to support research, development, demonstration, and transition of environmental methodologies and technologies required by DoD to perform and sustain its mission. Air quality is an important focus area for these two programs. SERDP and ESTCP seek to improve DoD's response to air quality issues through strategic investments that address DoD environmental requirements.

The primary mission of OAQPS is to preserve and improve air quality in the United States. The strategic vision of OAQPS is to lead and manage national air quality programs to protect public health and the environment from air pollution.

# 2 Approach

SERDP and ESTCP sponsored an invitation-only workshop of participants, including senior researchers and managers from DoD, other federal and state agencies, academia, industry, and the non-governmental organization community, to support development of a report that will serve as a strategic plan for SERDP and ESTCP to guide future investments in non-point source air quality science and technologies. To assist in designing the workshop purpose and scope, a steering committee was formed with representatives from the various sectors (public, private, and academic). This committee developed the workshop charge, identified white paper topics, proposed authors, helped formulate the workshop's agenda, and recommended participants for the workshop. The workshop included a plenary session of presentations highlighting five white papers, as well as brief perspectives from the participating agencies. The attendees participated in three breakout sessions: particulate emissions from non-point sources, gaseous emissions for non-point sources, and sources and activities. During the sessions on particulate and gaseous emissions, workshop participants addressed characterization, monitoring and modeling, and mitigation issues; those participating in the sources and activities breakout group addressed fire emissions; training range emissions; and fuels, lubricants, and solvents.

## 2.1 Meeting Objectives

SERDP and ESTCP invest their limited R&D funds to improve DoD's ability to address its air-quality–related environmental requirements while sustaining its military training and testing mission. To strategically guide future investments and to facilitate long-term cooperation and coordination among workshop participants, the workshop steering committee identified five objectives:

- Assess DoD air quality management needs, with a focus on non-point source air emissions.
- Assess the current state of practice relative to these needs.
- Assess the current state of the science and technology related to these needs and practices.
- Identify the gaps in knowledge, technology, and management that—if addressed—could improve DoD and EPA's ability to address their air quality issues.
- Set priorities for future SERDP and ESTCP investments to address these gaps.

## 2.2 Participants

A list of workshop participants is provided in Appendix A.

## 2.3 Agenda Elements

The workshop agenda is provided in Appendix B.

## 2.4 Workshop Charge

The workshop charge is provided in Appendix C.

## 2.5 Read-Ahead Materials

Background white papers were prepared and distributed prior to the meeting to communicate the state of the science in sampling and analysis methodologies and management strategies (Appendix D: Background Papers).

## 2.6 Supplemental Materials

The Department of Transportation provided additional materials after the workshop. The following documents can be found referenced in Appendix E:

- Strategic Plan for Particulate Matter Research: 2005 to 2010
- Strategic Workplan for Air Toxics Research, 2005
- Air Quality Research Subcommittee Particulate Matter Research Plan.

## 2.7 Formation of Breakout Groups

To accomplish the workshop objectives, the attendees participated in the three breakout groups. Table 3 illustrates how the workshop discussions and focus areas were organized.

**Table 3. Workshop Breakout Groups**

| Session Number/Name | Breakout Group 1 | Breakout Group 2 | Breakout Group 3 |
|---|---|---|---|
| **I. Particulate Emissions from Non-Point Sources** | Characterization | Monitoring and Modeling | Mitigation |
| **II. Gaseous Emissions from Non-Point Sources** | Characterization | Monitoring and Modeling | Mitigation |
| **III. Sources and Activities** | Fire Emissions | Training Range Emissions | Fuels, Lubricants, and Solvents |

***Breakout Session I: Particulate Emissions from Non-Point Sources***

***Breakout Session II: Gaseous Emissions from Non-Point Sources***

The first two breakout sessions addressed three key workshop objectives as they related to non-point source emissions:

- Review the current state of management practices relevant to these sources.
- Assess the current state of the science and technology relevant to these issues.
- Identify the gaps in knowledge and technology that—if addressed—could improve DoD's and EPA's ability to address emissions from non-point sources.

Discussions on these issues were addressed in the following breakout groups:

- The *Characterization* group addressed the state of practice and science relevant to characterizing non-point source emissions. Issues addressed included the technologies and measurement protocols needed to determine amounts and composition (chemical and physical properties) of non-point sources to support compliance, management, development of regulations, standards, emission factors, methodologies, and impact assessments.
- The *Monitoring and Modeling* group addressed the state of practice and science relevant to monitoring non-point source emissions and modeling their fate, transport, and impact at both the local and the regional scale. Issues addressed included both the technologies and the

measurement protocols needed to assess regulatory compliance and the impact of non-point source emissions.

- The *Mitigation* group addressed the current state of practice and supporting science needed for management and mitigation of non-point source emissions.

***Breakout Session III: Sources and Activities***

The third breakout session built on the discussions of the first two sessions by focusing on the activities and sources that led to both particulate and gaseous non-point source emissions. For each activity, the breakout groups were asked to accomplish the following:

- Assess DoD's air quality management needs
- Review and assess the state of science and technology discussed in first two breakout sessions
- Review and assess the gaps in science and technology discussed in first two breakout sessions
- Recommend priorities for future SERDP and ESTCP investments to address these gaps.

Discussions on these issues were addressed in the following breakout groups:

- The *Fire Emissions* group addressed issues associated with emissions from both prescribed burns and wild fires on DoD installations.
- The *Training Range Emissions* group addressed issues associated with non-point source emissions from the direct use of military vehicles and weapons and indirect emissions due to their impact on the landscape, such as by increasing windblown fugitive dust.
- The *Fuels, Lubricants, and Solvents* group addressed issues associated with evaporative emissions from the use and storage of fuels, lubricants, and solvents on DoD installations. Activities of interest included distribution, storage, refueling, use, and disposal, as well as any leakages associated with each activity as they commonly occur on military bases.

During the breakout session, the chairs guided the discussion to identify areas of uncertainty where additional R&D or field demonstrations would improve the group's understanding of the issue.

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# 3 Establishing a Common Perspective: Plenary Session

## 3.1 Welcome by the Host EPA

**Mr. Richard "Chet" Wayland**, EPA OAQPS Director, welcomed the workshop participants by providing the following opening remarks:

> "The EPA is especially pleased to host this workshop because we believe that our partnership with SERDP/ESTCP is beneficial to both of us. This workshop, with its distinguished participants, will build upon previously, successful efforts between DoD and EPA over the past several years. We are excited about the partnerships that have evolved and from which we are already seeing tangible results. SERDP/ESTCP came to us with specific needs, and we were able to participate in an advisory capacity on projects that met DoD environmental needs and which also resulted in knowledge valuable to us.
>
> This workshop, which will focus on identifying science and technology needs for characterization, monitoring, modeling, and impact assessment and mitigation of non-point source emissions, will continue this partnership, and broaden the circle to include distinguished academicians and researchers. By working with you to identify important technology gaps, we hope to assist you in prioritizing your environmental R&D budget. In turn, we can incorporate your findings in our emissions quantification and modeling programs such that they are consistent throughout the nation for everyone.
>
> We hope that today, our EPA participants from both OAQPS and ORD can help provide you with a framework and vision of environmental concerns and activities that need to be addressed over the next few years.
>
> In summary, I congratulate your gathering here and applaud your efforts to find better ways in which our military installations can meet their environmental challenges. This partnership is a perfect example of how we can work with each other and with external stakeholders to achieve better air quality management with less cost and duplication."

## 3.2 Welcome by SERDP, the Workshop Sponsor

**Mr. Bradley Smith**, Executive Director of SERDP, thanked the attendees for their participation in this workshop. He then described the SERDP and ESTCP programs in detail.

Mr. Smith explained that the overarching environmental drivers for both programs are the sustainability of ranges and range operations and the reduction of current and future liabilities. He added that projects funded by SERDP and ESTCP are grouped into one of four programmatic areas: Munitions Management, Environmental Restoration, Weapons Systems and Platforms, and Sustainable Infrastructure. Mr. Smith highlighted the key differences between the SERDP and ESTCP Programs. SERDP funds basic and applied research and accomplishes its programmatic goals by conducting annual solicitations to meet DoD needs, selecting projects for funding through a competitive award process, and transitioning completed projects into demonstration/validation efforts. ESTCP funds technology demonstration and validation projects and accomplishes its programmatic goals through partnering with stakeholders to test the technologies at DoD facilities, validating the technologies' operational cost and performance, and identifying appropriate DoD market opportunities for those technologies.

Mr. Smith next described SERDP and ESTCP's interest in air quality. He mentioned that the air quality mission of both programs is to develop and demonstrate technologies to monitor air emissions, determine their composition, predict their dispersion, and assess and reduce their environmental impacts. He then described the many air quality projects funded by SERDP and ESTCP over the years. These projects are further grouped into four specific DoD air quality needs: training-range fugitive emissions, DoD impact analysis, tools, and methods for air quality monitoring, and emissions reduction and control.

Mr. Smith closed by mentioning the 2008 SERDP and ESTCP Partners in Environmental Technology Technical Symposium & Workshop, which is scheduled for December 2-4, 2008, at the Marriott Wardman Park Hotel in Washington, D.C.

## 3.3 General Overview of Regulatory Issues

**Mr. Bob Schell**, EPA Office of Air Quality Planning and Standards; **Dr. Kim Teal**, EPA Office of Air Quality Planning and Standards; **Dr. Eric Ginsburg**, EPA Office of Air Quality Planning and Standards; **Mr. John Bosch**, EPA Office of Air Quality Planning and Standards

**Mr. Schell** and **Dr. Ginsburg** presented an overview of measurement policy issues in FY 2008 and a "new" road to cleaner air.

Mr. Schell focused his talk on three challenges:

- **Emissions Factors**. This is a major management challenge in the FY 2009 Congressional Justification. A recent Inspector General's evaluation found the emissions factor program lacking in a number of areas. EPA is developing a self-sustaining emissions factors program that will be designed to produce high-quality emission factors, quantify the uncertainty of emissions factors, and ensure the appropriate use of emissions factors. EPA has developed Electronic Reporting Tool (ERT) and WebFIRE and is revising emissions factor procedures document. Both of these elements are expected to be fully operational in FY 2009.
- **Emissions Monitoring**. A review of New Source Performance Standard (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations identified a significant number of monitoring deficiencies; EPA is working with their rule writers and also developing revisions to the Compliance Assurance Monitoring (CAM) rule.
- **Condensable Emissions**. Particulate Matter (PM) fine implementation rules were promulgated on April 25, 2007, with a deadline of April 5, 2008 (condensables are required). There is a transitional period until January 2011 for developing emissions limits and regulations for condensable particulate matter 2.5 microns or less in diameter ($PM_{2.5}$). EPA is committed to improving the available test methods for condensable PM. As a result, EPA will be proposing amendments to several promulgated test methods: Method 201A of 40 CFR Part 51, Appendix M–Determination of $PM_{10}$ Emissions (Constant Sampling Rate Procedure), and Method 202–Determination of Condensable Particulate Emissions from Stationary Sources.

Dr. Ginsburg discussed progress on developing new approaches to needed emissions reductions. He first highlighted the traditional approach, where control requirements have been implemented by individual regulations or programs on criteria pollutants (e.g., State Implementation Plans [SIP], Reasonably Available Control Technique [RACT], New Source Review [NSR], Best Available Retrofit Technology [BART], NSPS) and hazardous air pollutants (HAP) (e.g., NESHAPS, Maximum Achievable Control Technology [MACT], Generally Achievable Control Technology [GACT], Residual Risk). Lessons learned from this approach include possible results of conflicting or redundant programmatic elements and impact on other emissions of concern; this approach does not always result in the most cost-effective approach, and it could produce mismatched compliance timing requirements.

Dr. Ginsburg then outlined a new direction for EPA where they were encouraged by the National Academy of Sciences Clean Air Act (CAA) Advisory Committee to move toward multi-pollutant, sector-based approaches. This redirection led to a recent OAQPS reorganization, resulting in the Sector Policies and Programs Division (SPPD). SPPD's philosophy is aimed at meeting statutory requirements while streamlining inefficiencies and developing new approaches to needed emissions reductions. This move was focused on an initial "bigger" picture view for overall sector assessment instead of on piecemeal regulations.

EPA is working with stakeholders to understand priorities and trade-offs and is also exploring alternative approaches that better address costs. EPA is developing a consolidated emission-reduction, sector-based strategy that would potentially address both criteria and toxics' pollutants, taking into consideration multiple emission sources and program impacts, administrative and compliance complexities, and existing regulatory requirements. An assessment to define potential sector-based approach is being undertaken to establish an industry footprint, determine the potential for environmental improvements and program implications, and evaluate emission reduction options and related benefits. However, potential challenges include working through and being consistent with the CAA; developing a better understanding of regulations' causes and effects, including potential effects on media other than air; developing a better understanding of industry-specific and sector-specific economic motivations or drivers; and addressing the need for a techno-economic model.

Dr. Teal presented a discussion on a new emissions source category called Defense Land Systems and Miscellaneous Equipment (DLSME). DLSME includes printing, coating, and dyeing of fabric and other textiles; metal furniture; plastic parts and products; miscellaneous metal parts and products; wood building products; aerospace manufacturing and rework; and shipbuilding and ship repair.

Her presentation highlighted DLSME emission reduction options, such as the following:

- Traditional MACT rulemaking for DLSME surface coating operations
- Traditional MACT rulemaking (fallback) and a Memorandum of Understanding (MOU) pilot for DLSME surface coating operations
- MOU only for DLSME surface coating operations
- MOU for all surface coating operations
- MOU for all media-specific pollutants
- MOU for all emissions.

Finally, Dr. Teal outlined implementation- and enforcement-level considerations for DLSME emissions. Implementation and enforcement emissions enforcement could come from the Headquarters Level (e.g., DoD and the National Air and Space Administration [NASA]), the service level (e.g., Army, Navy, Marine, Air Force, Coast Guard, National Guard), NASA, as well as the installation level (e.g., Anniston Army Depot, Hill Air Force Base, Puget Sound Naval Air Station, Kennedy Space Center, etc.).

## 3.4 Military Air Quality Issues

**Mr. Felix Mestey**, Navy/DoD Clean Air Act Services Steering Committee

Mr. Felix Mestey, Naval Facilities Engineering Command, presented general overview of military air quality issues.

Mr. Mestey began his presentation by describing his work as chair of the DoD CAA Services Steering Committee (SSC). He indicated that the CAA SSC provides multi-service review and input on proposed CAA rules to minimize the impact on DoD's mission and operations, and provides Service-interface on CAA issues promoting cost-effective compliance across DoD. The U.S. Navy has been designated the DoD Executive Agent for CAA Implementation, with the CAA SSC consisting of Headquarters representatives with the following responsibilities:

- Monitor EPA rulemaking
- Identify and interact with EPA on issues of concern to military
- Share information and resources
- Develop and recommend policy and guidance.

One of the major activities of the CAA SSC is to implement the new $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS) promulgated in April 2007. The annual and 24-hour standards were revised, with nonattainment designation implications. Mr. Mestey said that DoD sources located in areas not attaining the standard could be subject to more stringent controls of PM and precursors such as nitrous oxide ($NO_x$), sulfur oxide ($SO_x$) and volatile organic compounds (VOC). In fact, many more DoD installations are now required to consider PM emissions. DoD requested that EPA emphasize the unique nature of military readiness activities and indicate that regulation of military activities is not necessary to achieve reductions of transported $PM_{2.5}$. The preamble to the final rule clarifies that EPA is not granting exemptions to DoD for military training activities, but indicates that individual states should work with DoD to better understand these emissions.

The rest of the Mr. Mestey's presentation focused on military non-point sources of PM, such as military readiness activities, engine emissions, munitions, open burn/open detonation (OB/OD), prescribed burns, and engine emissions from ships, aircraft, vehicles, and other mobile tactical equipment.

- Military readiness activities:
  - Live-fire training, training with smoke and obscurants, maneuver training, and munitions-related testing
  - What we think we know:
    - Largest component is crustal dust (relatively small component is $PM_{2.5}$).
    - Crustal dust emissions do not share the suspension and transport characteristics associated with emissions from industrial operations.
    - Crustal dust emissions are localized and of short duration.
    - Research, Development, Testing, and Evaluation (RDT&E) needed to characterize emissions and justify the items identified above.

- Munitions OB/OD
- Prescribed burning
- Engine emissions from ships, aircraft, vehicles, and other mobile tactical equipment
  - Primarily $PM_{2.5}$; currently not subject to emission limits for national security reasons; could become larger percentage of emissions as emissions from other sources are reduced
  - RDT&E needed to characterize emissions and identify practical alternatives for reducing $PM_{2.5}$ emissions from ships, tactical and deployable vehicles, and other mobile tactical equipment.

## 3.5 Regional Haze and Visibility

To help attendees better understand the U.S. Clean Air Visibility Rule (CAVR), **Dr. John Watson,** Research Professor at the Desert Research Institute (DRI) of the University of Nevada, provided an overview of the CAVR and its implications for air emissions from military facilities.

Haze is caused by the scattering and absorption of visibility light by particles and gases. Light is an electromagnetic wave; just as a plane water wave is deflected by a barrier from its original direction, light waves are scattered when they encounter particles and gas molecules that are approximately the same size as the light's wavelength. The sky is blue because particle-free air also scatters light, but the gas molecules are so small that they scatter the shorter wavelength blue light more than they scatter the longer wavelength red light.

Reducing regional haze requires emission reductions that cross local, regional, and international boundaries. The United States has established five regional planning organizations with different states as members to track progress toward natural background levels at 156 national parks and wilderness areas where the air pollutants that cause haze are measured. At each of these areas, contributions to light extinction from these components will be tracked for the next 60 years relative to a baseline for the poorest 20 percent of the days established by measurements between 2000 and 2004. A linear glide path toward natural visibility conditions will be used to determine progress that will be evaluated at 10-year intervals. There are differences in the rate of progress depending on how poor the initial visibility is and what are considered to be natural conditions for an area. Defining natural conditions is a scientific challenge. Annual average estimates are currently in use, but these will eventually need to be made more event-specific. Wildfires, dust storms, and other natural events will affect visibility on a case-by-case basis. Transport from outside of the United States will also need to be considered because this is largely beyond the control of national authorities.

Other important topics require further review and evaluation:

- Practical methods for sampling and analyzing organic and elemental carbon
- Scientific validity and practical requirements for integrating continuous particle monitoring technology into ongoing networks
- North American and global emissions from natural and anthropogenic sources
- Satellite technology for tracking haze, emission sources, and pollution levels
- Non-road emission source identification and estimation methods
- Chemical markers for natural and anthropogenic sources
- Air-quality trend detection and tracking methods

- Integration of source and receptor models.

Urban and regional haze are important indicators of air pollution in many cities throughout the world. Quality of life and enjoyment of majestic vistas will improve only when serious emission reductions are undertaken by all emitters, including the military, to improve visibility. These have the added benefit of improving public health and reducing property damage due to excessive air pollution.

## 3.6 Status of Available Technologies for Characterization and Monitoring

**Mr. Dennis Mikel**, EPA Office of Air Quality Planning and Standards

Mr. Dennis Mikel from OAQPS discussed areas where DoD can work closely with EPA/OAQPS to develop new and emerging technologies for quantifying emissions. DoD has partnered with OAQPS in the past to develop new technologies that are currently being used to fulfill the regulatory needs. However, new federal regulations are being written, and regulatory needs and recently developed technologies may not yet be fully integrated for a number of reasons. A white paper on this topic, "Emission Measurement and Ambient Air Monitoring in Assessment of Non-Point Sources—White Paper for Department of Defense Workshop: Assessment and Management of Non-Point Air Emissions from Department of Defense Activities" is provided in Appendix C. The presentation and white paper addressed six areas of concern:

- Fugitive/Area Emission Modeling
- Wildfires and Prescribed Burns
- Particulate Matter: Coarse Particles (between 10 µm and 2.5 µm particle diameter)
- Single Particle Monitoring
- Opacity
- Greenhouse Gases.

There are a number of external factors that workshop participants might consider in regard to environmental monitoring. Many factors are qualitative in nature at this time. For example, emissions quantification is rapidly shifting away from single emission factors and towards site-specific measurements. The field is also shifting towards more temporal detail (minutes and hourly), automation (removal of the human interface), and continuous quality controls. These shifts are further forced by new regulatory drivers which, in turn, are responding to new or unanticipated political and public policy issues.

## 3.7 Remote Sensing Applications: Fugitive Emissions Monitoring and Modeling

**Dr. Robert Spellicy**, Industrial Monitor and Control Corporation, presented an overview of Optical Remote Sensing (ORS) capabilities.

Dr. Spellicy introduced his presentation by summarizing the following issues:

- Non-point (distributed) sources require monitoring of large spatial extents, inhomogeneous plumes, and temporally varying plumes.
- This approach is incompatible with conventional point monitoring methods.

- ORS techniques have unique characteristics qualifying them to address this type of monitoring.
- While ORS methods have seen steady advancement, to address future DoD needs, various systems require improvements in a number of areas:
  - Detection sensitivity
  - Speciation capability
  - Temporal resolution
  - Range capability
  - Portability
  - System cost.
- From the perspective of measurement strategies, demonstration and validation studies are required for specific applications, along with development of formal measurement protocols or test methods for the applications.
- Some systems can reach the desired goals with short-term developments; others may require longer-term R&D.
- The white paper produced for this workshop serves three primary purposes:
  - Outline the current state of the art of ORS techniques
  - Show examples of current non-point source monitoring in industry and government
  - Introduce some possible development areas to initiate discussion.

Dr. Spellicy provided an overview of the basics of ORS, including a brief discussion on monostatic, bistatic, and laser systems. The presentation concluded with a discussion of technology and method development opportunities in the areas of measurements of speciated air toxics and greenhouse gases, as well as improvements in PM/opacity measurement capability. The presentation highlighted the following application research areas:

- Information exchanges and collaborations among agencies: necessary to avoid duplication of efforts in all areas
- Fire Emission and Modeling: generation of Laser Imaging Detection and Ranging (LIDAR) data for development and validation of smoke dispersion models
- Investigation of Airborne differential adsorption LIDAR (DIAL): extension of EPA Other Test Method (OTM)-10 methods to larger area or macro-scale monitoring of source emissions
- Investigation of Fugitive Dust Opacities: application of low-cost, easily applied imagery to measurement of mass concentrations and emission factors from fugitive dust events.

## 3.8 State of the Modeling: Fugitive Emissions and Ozone

**Dr. Steven Hanna**, Harvard University School of Public Health

To help attendees better understand the state of modeling fugitive emissions and ozone, Dr. Steven Hanna, Harvard University School of Public Health, described the background and categories of ongoing modeling work that would impact DoD activities.

Dr. Hanna opened his presentation by stressing that managing air quality requires modeling tools that connect among three scales:

- Global—e.g., climate change, stratospheric ozone, intercontinental transport
- Regional—e.g., ozone, fine particles health, acid rain, visibility
- Local—e.g., ozone, PM health, air toxics.

Dr. Hanna reviewed the categories of air quality models by scenario of interest, distance scale, type of air quality model, meteorological input, chemical reaction mechanism, and degree of hybridization, then provided a survey and comparison of widely used air quality models (developed in the United States). He contrasted Gaussian plume and puff models for short distances (< 10 km) with Lagrangian puff model for 10-200 km to three dimensional (3-D) regional grid models.

Dr. Hanna provided the following summary and recommendations:

- Information exchanges and collaborations among agencies are necessary to avoid duplication of efforts in all areas.
- Further research should attempt to improve and refine these hybrid approaches, especially to allow large point and area sources to be simulated on small scales and then to be handed off to a 3-D Eulerian model.
- Model outputs should move towards being expressed in probabilistic form rather than as a single deterministic estimate.
- For DoD emissions scenarios, there is a need to quantify uncertainties in the magnitude and the time and space distribution of emissions, as well as in the estimation of the buoyancy of the source.
- Many DoD source scenarios—such as wildfires and munitions tests—take place in areas without detailed local meteorological observations.
- As always, field experiments are needed for the short-term scenarios of interest, as well as monitoring of routine release scenarios.

## 3.9 Mitigation Techniques

**Dr. Dick Gebhart**, U.S. Army Corps of Engineers, Engineering Research and Development Center—Construction Engineering Research Laboratory (ERDC-CERL)

To help workshop attendees better understand some of the techniques for mitigating fugitive dust emissions from DoD training activities, Dr. Dick Gebhart, U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL), described several current and promising future chemical, physical, and biological approaches for dealing with this problem.

Because military training produces dust that can cause health, safety, and regulatory concerns, DoD needs to understand and implement technologies to mitigate these emissions. Chemical dust control technologies are widely available and have been evaluated for performance and durability under several ERDC RDT&E verification efforts. These efforts have documented performance across multiple soil types and training scenarios and ultimately resulted in the development of an interactive dust-control technology selection key that allows selection of the most appropriate chemical agent based on site-specific factors such as climate, soil type, traffic type, and traffic volume. Physical dust control technologies consist of utilizing (1) sound road/trail construction designs and practices that may include admixing of water attracting compounds; (2) berming, furrowing, wind fencing, blast matting, and other similar types of practices for both open-field and firing-point emission sources; and (3) waste products such as compost, wood chips, or processed solid waste as site-specific surface treatments to minimize dust generation. Biological dust control technologies with the greatest potential for widespread utilization involve planting prescriptive vegetative arrays so that near-source vegetation capture of dust particles is maximized. Vegetative factors affecting capture efficiency include height, density, and leaf area index. Initial tests of several vegetation or plant community types—including tall grass prairie and coniferous and deciduous trees of varying height—indicated that upwards of 35 to 65 percent of particulate matter 10 microns or less in diameter ($PM_{10}$) plume loss can be attributed to vegetation. These results were larger than anticipated, suggesting that this previously unrecognized form of natural mitigation should studied in greater detail and also be accounted for in future air-quality compliance models.

Chemical, physical, and biological control technologies are important, but they are only a part of the solution. Accurate characterization and monitoring methodologies are required to provide information for comprehensive and cost-effective decisions regarding strategies for mitigation of fugitive emissions. An increased focus on mitigation technologies utilizing sustainable installation resources such as wood chips, compost, and processed solid waste should also be pursued. Lastly, an increased focus on R&D of vegetative prescriptions that maximize near-source particulate capture and prevent regional transport should be aggressively investigated.

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# 4 Particulate Emissions from Non-Point Sources: Breakout Session 1

## 4.1 Characterization

**Chairs**: Dr. Ram Hashmonay, ARCADIS; Dr. Bryce Bird, Utah Division of Air Quality

**Scribe**: Dr. Robert Holst, HydroGeoLogic, Inc.

### 4.1.1 Background

This breakout group addressed the characterization of particulate emissions from non-point sources. The specific charge for this group was to address the state of practice and science relevant to characterizing non-point source emissions. Issues addressed included the technologies and measurement protocols needed to determine amounts and composition (chemical and physical properties) of non-point sources to support compliance, management, development of regulations/standards/emission factors/methodologies, and impact assessments.

Definitions of PM emissions and of characterization were offered in order to focus the discussion and to ensure that all of the participants were "on the same page" as to these discussions.

**Particulate Emission.** A particulate emission is an aerosol or particle that can be carried by the air currents and is anywhere from a few nanometers to more than 100 micrometers in diameter. Particulate emissions can be either liquid or solid. Normally, an aerosol or particle can be captured by means of a non-reactive or inert filter. Particles can deflect or reflect light beams. Specific size classes and characteristics of interest with respect to PM are listed below:

$PM_{10}$—those PM that are $\leq$10 µm in diameter
$PM_{2.5}$—those PM that are $\leq$2.5 µm in diameter
PM coarse—the difference in mass concentration between $PM_{10}$ and $PM_{2.5}$
$PM_1$—ultrafine particulates $\leq$1 µm in diameter
Speciated PM—those particulates with characterized chemical and optical properties (density is included).

**Characterization of Emissions.** Characterization is the ability to determine/differentiate between the various constituents/components of the atmosphere including PM and gaseous matter. The quantification and qualification of these components are important factors for understanding the physics and chemistry of the atmosphere.

### 4.1.2 Session Summary

DoD is faced with a number of PM sources. The following is a general list of those sources.

- Fugitive dusts at training ranges from vehicles, low-flying aircraft, artillery, and disturbed landscapes
- Emissions from prescribed and wildland fires
- OB/OD of munitions and fuels
- DoD-unique sources, such as smokes and obscurants (including fog oil and graphite)
- Contaminated dusts (re-entrained dust/road dust: asbestos, lead, silica)

- Distributed sources, such as industrial sites/maintenance activities and construction sites (including painting, welding, and demolition)
- Mobile Sources—such as ships, aircraft, and vehicles—where PM is generated in fuel combustion (no additional discussion was undertaken)
- Urban/residential sources, such as fireplaces and heating, food industry, public works activities.

In addition to the general listing of the sources, the following are breakouts of the sources of PM noted above with respect to the possible means of generating the respective PM.

- Prescribed burns—emission production and downwind movement of those emissions are the primary issues
  - Area burned, fuel characteristics, and fuel consumption by combustion are key components that lead to differences in PM generated
  - Ecological restoration, driven in part by the Endangered Species Act (ESA) compliance, which can require large areas to be burned
  - Fuel hazard reduction to reduce wildland fire potential
  - Logging operations—cleaning up unwanted debris after logging
- Wildland fires are uncontrolled fires occurring generally under dry conditions
  - Often higher intensity, longer duration fires than prescribed fires resulting in more fuel consumed, more emissions generated, and a higher plume rise
  - Possible differences in physical and chemical properties as compared to prescribed fires
- OB/OD
  - Munitions disposal—usually short duration with large quantities of weapons
    - Soil entrapment, when explosion is conducted on covered soil and/or munitions, adds to the development of the plume
    - Can involve a mix of munitions
  - Fuels and propellants (open burns that can be of long duration)
- Role of precursors for PM
  - Gases can be the nuclei or the chemical initiators in the development of PM
  - Sources can include fuel emissions, ammonia from waste operations, and biogenic sources.

The group also addressed PM that does not “fit” into the above source categories, otherwise termed “oddball source PM”; this generally PM that has not been characterized.

Current management practices and burning techniques have been explored for their abilities to reduce overall emission production by reducing fuel consumption during the higher polluting, smoldering combustion stage. For fugitive dust, wheeled and tracked vehicles use formulae to calculate emission factors (EF). For aircraft, EFs are just being generated while artillery and disturbed landscapes have no EFs available. For prescribed burning, EFs are generally available—a primary issue is determining the extent of plume rise.

A looming management issue is the measurement and regulation of fugitive particulate emissions, particularly dust, by states with the increased imposition of reducing emissions through mitigation practices that reduce the emissions or reduce or end activities that cause the emissions, including training and testing at DoD sites.

As an introduction to the discussion of the gaps in knowledge, four items were identified as general problem areas that were cross-cutting to the types of PM:

- What are the physical and chemical properties—How are they characterized?
- PM-Gas Interactions—How do these two phases interact in the development or dispersion of the emissions?
- Environmental Factors—How do the specific environment parameters interact with the development and sustainability of the PM both at the ground level and in the air column(s)?
- Of these previous three items, how do they relate to EFs? What, if any, are the site-specific issues with respect to EFs?

One overlapping issue with respect to all of these sources and management practices is the fact that AP-42 (Compilation of Air Pollutant Emission Factors) is not current and is very incomplete, which can lead to erroneous assessments based on the AP-42 information. Measuring and monitoring the presence of PM as an opacity factor—especially where Method 9 is being instituted—is another knowledge gap that must be resolved. This measurement function is not addressing the needs or the problems associated with the generation or presence of fugitive emission, specifically dust.

Looking at the sources, the group then discussed the technical gaps. Gaps not noted above or captured in the prioritized outcome section are listed below:

- Fugitive Dusts
  - Reformulation of the definition of measurement-based EFs for AP-42
    - Need measurable parameters (measurement-based?) of the site and relevant to the activity (usable surrogates)—silt is a poor surrogate
    - Need an emissions model
    - Need inverse modeling to determine if the EFs are correct based on boundary-line monitoring
  - Emission inventory for near-source removal processes (vegetation)
  - Source profile (size and chemical composition, optical properties)
  - Cost-effective, reliable, portable instrumentation with standard/acceptable protocols/approaches
  - Characterization of the dusts and the meteorology (site-specific conditions)
  - Lack of capability to measure plumes with temporal and spatial variability.
- Prescribed Burning
  - Six pieces of information are required to model emissions and air quality impacts from prescribed fires and wildfires. These include: 1) area burned, 2) fuel characteristics and loading, 3) fuel consumption, 4) emission factors for actual vegetation and other site conditions (relative humidity [RH], etc.), 5) emission production and plume rise, and 6) weather information along with a dispersion model to calculate dispersion dynamics, including fate and transport of the emissions. The U.S. Department of Agriculture (USDA) Forest Service has developed ways to account for each piece of information.
  - Feedback loop from satellite in real-time for fire characterization; detection resolution is an issue.

- Wildland Fires (other than as noted for Prescribed Burning)
  - Limited information on crown burns and fuels in areas—remote sensing
  - Climate change effects due to large fires
  - Forecasting models—air-quality impact models
- Contaminated Dust
  - Inventory of sites for ascertainment of chemical contaminants (e.g., metals)
  - EFs needed for specific species, also as function of meteorological conditions
  - Fate and transport, especially organics, for on-site versus off-site impacts (personnel)
- Cross-Cutting Gap Issues (Technologies)
  - Exploitation of remote-sensing technologies (both satellite and ground-based)
  - Integration of measurement techniques and processes
  - Anticipated climate change impacts due to PM (droughts, floods, global warming)
  - Cost-effective measurement tools (opacity/extinction)
  - Assessment of air quality impact (keeping the modelers honest).

### 4.1.3 Prioritized Outcomes

The discussion group identified the R&D priorities for these PM emissions as they may relate to the various sources.

**Fugitive Dust**. Most of the participants felt that this is a greater area of concern for western states than for eastern states. The following relate specifically to dust emissions and generally to most other fugitive emissions.

- A new paradigm for emission estimation models derived by measurement and modeling working in concert is needed. In the meantime, the data are available to be reworked to generate better EFs using more current processes to interpret the data.
- Measure the fluxes (at source) using more measurement sites with inexpensive but reliable instrumentation and good cost-effective protocols (less manpower-intensive). Two points to be measured include emissivity and chemical composition.
- Better define the observables on which EFs are based; when collecting PM information, one of the key items is to better measure the full particle size distribution because measuring $PM_{10}$ or $PM_{2.5}$ is insufficient.
- Obtain and define the emission matrices for fugitive emissions.
- Better define the hazardous pollutants in the matrices in order to determine the human and ecological risk.

**Prescribed Burns and Wildland Fires**. In general, the problems need to be addressed on a regional basis because the issues include the development of databases that contain such information as fuel type and load, after-burn statistics identifying fuel consumed, EFs for the specific fuels and the emissions production. DoD is particularly interested in developing models that illustrate plume rise and dispersion and air-quality models that illustrate the effects of plume dispersion.

A question arose as to whether DoD will be responsible for the life-cycle of products to the extent of destroying the products, usually on site, rather than returning the waste or unused items either to the vendor or, in the case of waste materials generated overseas, back to the United

States. This was discussed with respect to PM production. There was a question as to whether DoD will have to backhaul waste from Iraq and other overseas operational areas or whether it will be allowed to burn the material in place. Another issue related to the cleanup of environmental problems, such as trash and general building waste that may be a result of natural phenomena such as hurricanes.

## 4.2 Monitoring and Modeling

**Chairs:** Dr. Mark Rood, University of Illinois; Mr. Tyler Fox, EPA Office of Air Quality Planning and Standards

**Scribe:** Mr. Jeffrey Houff (HydroGeoLogic, Inc.)

### 4.2.1 Background

The overarching goal of this session was to discuss the areas of monitoring and modeling of PM emissions from non-point sources and determine DoD research needs in this area. This session addressed the state of practice and science relevant to monitoring non-point source particulate emissions and modeling their fate, transport, and impact at both local and regional levels. Specifically, the session set out to answer the following questions:

- What are the current and future management practices and needs for non-point PM source emissions?
- What are the current technical capabilities to support management practices at local and regional scales?
- What are the unmet scientific and technology needs in monitoring and modeling non-point sources to support current and future management practices?
- What are the high-priority gaps in knowledge and capabilities that need to be addressed to drive our R&D activities?

PM emissions are one of the main air-quality compliance issues faced by DoD facilities; non-point sources are a significant contributor to these PM emissions. For the purpose of the session, the term PM refers to near-field, non-reactive, inert particles and non-point sources (as defined by EPA), encompasses any source other than an exhaust stack or duct, and does not include emissions that are directly emitted from mobile sources. The scope of this session was limited to air quality issues related to PM emissions that were formed within the boundaries (fence line) of DoD facilities. Situations where PM emissions originated outside a DoD facility but ultimately affected the air quality within the fence line of the facility would be noted but were not the focus of this session. It was noted that the main concerns for DoD facilities are issues with encroachment on the surrounding communities.

### 4.2.2 Session Summary

Several important drivers force DoD to take measures to maintain compliance with the NAAQS, including federal, state, and local regulations. NAAQS are set for each of the six criteria air pollutants, but because air quality varies greatly across the country, the state and local requirements for control needed to attain each NAAQS will also vary. Therefore, DoD facilities have a variety of requirements that they must meet to help maintain the attainment of the area in which they are located. New or modified DoD facilities located in non-attainment areas must complete an NSR and must employ the best available technologies to reduce their contribution of criteria pollutants in that area. State and local opacity regulations must also be met by DoD facilities at the fence line of that facility. In addition, DoD facilities take measures to reduce the emission of air pollutants to avoid complaints and lawsuits from the local population in nearby communities. Finally, the exposure of workers within the facility to regulated air pollutants also drives DoD to seek an overall reduction in PM emissions.

Given these drivers, DoD is making a significant effort to reduce PM emissions at its facilities. In order to reduce PM emissions, DoD must quantify what is currently being released through emissions monitoring and must predict and understand the behavior of the emissions through modeling. DoD uses a number of management practices to monitor and model PM emissions from non-point sources. Because of the differences in regulations from one locality to the next, no standard practices are employed across DoD in this area. It is essentially up to the individual facility to maintain compliance with the air quality requirements for their location. For example, some facilities have EPA emission monitoring programs, while others do not. Most of the facilities that do monitor PM emissions do not do so continuously. Opacity, a widely used metric for air-quality compliance, is also a requirement that varies from area to area. Some locations have an actual opacity value that must be met, while others have only a subjective requirement based on visibility as perceived by the human eye. Modeling is also currently employed on certain DoD facilities to better understand the PM emissions that are released, but the modeling is typically performed by contractors on an as-needed basis. Overall, there is a lack of DoD-wide knowledge on air quality issues despite the fact that many DoD facilities face the same types of problems.

There are a wide range of issues associated with modeling and monitoring PM emissions. In terms of modeling, issues arise regarding a lack of data that can be input into emissions models. Some efforts attempt to collect data, but the information is not comprehensive. In addition, a variety of models are used at DoD installations—such as Operating and Support Management Information System (OSMIS), Atmospheric Pressure Ionization Mass Spectrometry (APIMS), Dust Transport Model (DUSTRAN), Hazard Prediction and Assessment Capability (HPAC), SCIPAC, SCIPUFF with Chemistry (SCICHEM), Community Multiscale Air Quality (CMAQ) model, and others—to manage a number of different issues and problems. In all of these models, the issue of reducing uncertainty is critical to the validity of the information provided by the model. The data used in these models—including emissions data and environmental conditions—need to be validated in order to reduce uncertainty. The models themselves also need to be validated by comparing them to the actual measured behavior of the emissions obtained through emissions monitoring campaigns. Monitoring PM emissions has its own set of issues. Variables such as unexploded ordnance located in prescribed burn sites and fugitive dust deposits can alter PM measurements. The fact that monitoring is typically not performed continuously means that the data do not give a complete picture of the PM emitted from a facility.

### 4.2.3 Prioritized Outcomes

Given the standard practices and issues discussed above, additional research in the following areas will help DoD facilities improve modeling and monitoring of PM emissions from non-point sources.

**Modeling**

- Define “scenarios” of interest based on regulatory and other drivers (spatial and temporal timescales that will determine appropriate modeling approach)

- Improve near-field modeling science, especially deposition
- Develop, test, and evaluate hybrid modeling approaches
  - Use regional model for background
  - Use near-field models for sub-grid results
- Use inverse modeling to improve source/emissions characterization in air quality models
- Use more source/receptor models to determine contributions that stress the need for improved source characterization (source profiles and parameterization)
  - Existing databases: EFs (e.g., WebFIRE) and speciation profiles (e.g., SPECIATE)
- Integrate validation of models with measurements to improve input (emissions and meteorology) and modeling science; comparison across alternative models and hybrid approaches.

**Monitoring**

- Improve coordination among agencies, develop means to make databases more readily available, and integrate databases from monitoring (e.g., WebFIRE for EFs, or SPECIATE database)
- Develop effective and less subjective methods to monitor opacity along facility fence lines at short timescales (hours to minutes) (e.g., quantify plume opacity with digital cameras)
- Characterize large-scale plumes that could be aloft at much lower cost (e.g., optical remote sensing)
- Use/develop monitors to evaluate closure between hybrid models and measurements (e.g., monitors located along fence lines and at regional/federally relevant locations)
- Implement both baseline routine monitoring and specialized vertical resolution and shorter timescales (e.g., help separate urban/regional/local scales)
- Develop continuous monitors that speciate PM (e.g., prescribed burning).

## 4.3 Mitigation

**Chairs**: Dr. Dick Gebhart, U.S. Army Corps of Engineers, Engineering Research and Development Center—Construction Engineering Research Laboratory (ERDC-CERL); Ms. Julie McDill, Mid-Atlantic Regional Air Management Association.

**Scribe**: Mr. John Thigpen (HydroGeoLogic, Inc.)

### 4.3.1 Background

The charge for this breakout group was to address the current state of practice and supporting science needed for management and mitigation of non-point source particulate emissions. Specifically, this session was asked to review the current state of management practices relevant to non-point sources of particulate emissions, assess the current state of the science and technology relevant to non-point source particulate emissions mitigation, and identify the gaps in knowledge and technology that, if addressed, could improve DoD’s and EPA’s ability to mitigate particulate emissions from non-point sources.

### 4.3.2 Session Summary

The group began by listing the various major military operations that generate non-point sources of particulate emissions:

- Transportation

- Construction
- Land management
- Weapons
- Materials handling
- Other sources and activities that fall outside of the SI focus area of SERDP and ESTCP.

Once an agreeable list of major dust-generating operations was compiled, the group identified more specific sources and activities within each major category, selected those sources and activities that contribute the most to particulate emissions from each major operational category, and discussed various mitigation tools, options, and needs for each of these sources and activities. Below is an annotated outline of the discussion from that session, organized by major military operation.

#### 4.3.2.1 Transportation

Unpaved developed surfaces/staging and maneuver areas (e.g., airstrips, helicopter landing zones, wheeled and tracked vehicle use on unpaved roads) were identified as the major source relating to non-point source emissions stemming from transportation activities. The major take-home messages for mitigation of these particulate emissions related to chemical mitigation strategies and physical mitigation strategies are listed below:

- Chemical
  - DoD must stay abreast of what the chemical dust suppressant industry is really using by continually testing chemical dust suppressants. The EPA's Environmental Technology Verification (ETV) program has a protocol for objectively testing performance and durability of chemical dust suppressants (for road applications). There is a need to expand the ETV protocol to include impacts to ground/surface water and cultural resources.
  - Research is needed to assess the secondary effects of chemical dust suppressant application (effects on cultural resources, effects on runoff/water quality).
  - Looking at the Chesapeake Bay protocols in terms of preventing polluted runoff could prove useful for circumventing any secondary effects of chemical dust suppressant application relating to runoff/water quality.
  - The overarching need is a robust protocol for evaluating dust suppressants and their impacts on other resources.
- Physical
  - There is a need to develop EFs for roads, which can be affected by atmospheric stability, terrain, etc.
  - Research is needed to evaluate physical barriers adjacent to roads as a dust suppressing technology and to understand why certain barriers are more effective under certain circumstances.
  - Physical barriers will likely be different when attempting to mitigate PM coarse emissions versus PM fine emissions.
  - Physical barriers will likely be different, with different performance characteristics, for geologically and climatically distinct regions of the world.
  - Physical and biological mitigation strategies must be compatible with military training occurring in that area as well as with security requirements.

Other sources of non-point source particulate emissions stemming from transportation activities include spray/mist from watercraft, off-road training (trails, open ranges), and vehicle track-out onto paved roads (dust and soil movement from unpaved to paved roads).

#### 4.3.2.2 Construction

Particulate emissions from deconstruction and site remediation activities, exacerbated by BRAC, were identified as the primary contributors to non-point source particulate emissions from military construction activities. The major needs and research gaps and overall take-home messages for mitigation of dust emissions from these sources are listed below:

- Emission factors are largely absent for these sources of particulate emissions. In addition, there is a lack of local standards for toxics (lead-based paints [LBP], asbestos, dichloro-diphenyltrichloroethane [DDT]).
- Mitigation strategies currently employed include wetting, bagging before implosion, and air curtains.
- There is a need for real-time on-site characterization for deconstruction activities that can provide quality data regarding the use of proper mitigation tools for varying circumstances, as well as the development of more efficient and cost-effective analysis tools.
- The main problem with effective mitigation of deconstruction activities is poor characterization. Given that limitation, a one-size-fits-all strategy for outside the continental United States (OCONUS) deconstruction activities should be developed. This makes it easier to implement good mitigation strategies in underdeveloped regions where accessibility to technology is limited. This would include software that provides meteorological data and site condition data to determine if deconstruction activities are favorable/unfavorable for dust generation.
- Alternative particle capture techniques also represent a research need.
- Alternative construction materials and assembly was suggested, such that product recycling/reuse is encouraged and facilitated, and disassembly is facilitated, thereby reducing dust generation and the need for imploding contaminated buildings.

Other construction-related activities, primarily regarding architectural repair and maintenance (e.g., sandblasting) were recognized as other sources of particulate emissions (especially toxics) generated from military construction activities.

#### 4.3.2.3 Land Management

Particulate emissions from wind erosion and from range burning (wildland and prescribed fires) were both highlighted as key contributors to an installation's particulate emissions stemming from its land management activities. Separate discussions on priority needs from each of these two sources are captured below.

- Wind Erosion
  - Soil stabilizers emerged as the most used and effective mitigation tool for particulate emissions from land management activities. Improperly sited and unprotected disposal of dredge spoil creates a large source of potential particulate emissions from winds; there is a need to characterize the particulates in dredge spoil and to develop an optimal dredge spoil stabilizer.
  - Biological soil stabilizers were also discussed, primarily in their use for restoring desert plant communities (soil crusts). Re-establishing desert plant communities with these biological soil stabilizers would anchor the desert soils and thus reduce the magnitude of

particulate emissions generated in these regions. Use of such stabilizers should avoid introducing non-native invasives for restoration.

  - Another biological mitigation approach mentioned was the use of invasive species to quickly restore a tract of land to control dust/wind erosion and ultimately to serve in the production of biofuels. As a control mechanism, the group recommended this mitigation tool only be used on federally managed land and that the plants be harvested prior to producing seed so that reproductive spread is limited.
  - Physical barriers (primarily vegetation) are another frequently used mitigation tool for controlling dust emissions. The group felt that research was needed to understand the fate of dust captured by these physical barriers (e.g., Is it re-suspended? Are there any impacts on other resources?). Computational modeling for designing windbreaks, mentioned as a possible solution, could lead into a temporally based decision support system for end users. It might also be useful to examine the mitigation strategies employed by other countries facing serious dust issues (such as Mongolia).
  - Installation waste products were also highlighted as a mitigation tool because of their dust prevention capabilities and reduction of waste generated on base. Woodchip berms, which have proven effective at stopping sand flow, were cited as an example of this.
  - Climate change was also a prevalent theme during this discussion, as it has the potential to drastically increase the amount of particulate emissions through the drying of lake beds, desertification, and vegetation—and therefore pest—changes. Adaptation to these changes emerged as a priority research and management need.

- Range Burning
  - EFs were a big theme during the range burning discussion. The group agreed that EFs from fires are largely outdated, only developed for certain types of vegetation, yet applied broadly. There is a pressing need to improve EFs so the best time(s) to burn can be determined. The group also discussed the need to create emission estimation techniques via open path monitoring.
  - A need for evaluating smoke management practices also emerged. The group felt that a better understanding of which practices work best under which conditions was needed. This could be enhanced with a regular interagency exchange of best smoke/fire management practices. Related to this idea, the group thought it useful to adapt best practices from forestry to military bases located in areas with little U.S. Forest Service (USFS) presence.
  - The group cited a need to evaluate the emissions resulting from pile burns versus those resulting from broadcast burns and to subsequently establish burning methods that have the least emissions.
  - The group discussed ways to reduce fuel loads in systems that we do not want to burn through the eradication and/or prevention of invasive species.
  - Another mitigation tool that was highlighted was green stripping, which has proven useful in containing the spatial extent of fires.
  - Discussing other alternatives, the group agreed that looking to other uses of biomass (rather than pile burning) could reduce particulate emissions and increase, for example, fuel generation. The group also mentioned the use of goats for land management as opposed to limiting one’s land management options to burning.

The group also mentioned agriculture outleasing as a source of particulate emissions generated from historic and current military land management activities, such as grazing, logging, and crop production.

#### 4.3.2.4 Weapons

OB/OD, impact points, and firing points were highlighted as the primary source of non-point source particulate emissions stemming from weapons-related activities.

- The group concluded that an optimal design of OB/OD pits—such as through the use of alternative caps (construction debris or other waste products) is a research need that, if addressed, would minimize emissions from this source.
- The group agreed that overall waste reduction would inherently reduce emissions. Designing new munitions that can be reworked (into new munitions or for other unrelated uses) when their shelf life expires—rather than disposed of via OB/OD—would be a valuable capability that should be researched.
- Developing blast mats for muzzle backblast was mentioned as a research need, but some in the group noted that existing research is underway to meet this need.
- Alternatives were also mentioned in regard to munitions constituents. Munitions currently contain heavy metals that can eventually become part of the topsoil of firing ranges and may be picked up and become a component of windblown dust. The group felt that alternatives to these munitions constituents represented an important research area. Regular maintenance of firing ranges—through vegetation maintenance and cleanup—was also cited as a method to reduce windblown dust emissions from these sources.
- Studying impact areas via computational modeling was highlighted as an area that could use some additional R&D. This could help in monitoring pollutant migration downwind and ultimately help develop software that can determine the best times to conduct exercises in impact areas.

Smokes and obscurants were also cited as a source of particulate emissions from weapons use; however, the group was informed that a great deal of this research has been done, and the impacts from these sources were found to be negligible.

#### 4.3.2.5 Materials Handling

Solid-waste handling emerged as the primary contributor to non-point source particulate emissions resulting from the handling of various materials, particularly waste materials.

- Composting was discussed first as a mitigation tool for waste management but also cited as a potential source for particulate emissions. The group felt that research on additives that can minimize windblown transport of particulates from compost would be useful.
- Sewage was viewed as another waste stream that can generate particulate emissions. The group felt adapting package plant technologies for use in generating energy from sewage (e.g., methane) would be a valuable research topic.
- Using treated sewage as a soil stabilizer was also mentioned as a possible mitigation technique that takes advantage of reusing items typically treated as waste. This idea was expanded to water recycling from various sources for using graywater or blackwater in dust control and suppression.
- Reduction and reuse of solid-waste materials was a general theme of this discussion relating to mitigating and minimizing particulate emissions. Alternatives to open pit burning in OCONUS installations during base camp setup are needed, but reducing the solid waste that

is burned—through use of an on-site incinerator or through better packaging materials—would also reduce emissions. Shredding solid waste would also reduce the volume of waste, and the products could be used in dust suppression.

Materials movement and storage, as well as surface mining, were also mentioned as sources of particulate emissions on DoD installations resulting from materials-handling activities. In particular, the group felt as though development of computational models that allow on-site decision makers to determine dust migration from quarries would help control dust emissions from surface mining operations.

##### 4.3.2.6 Other

Other potential sources of non-point source particulate emissions identified by the group fall outside the scope of the SERDP and ESTCP SI focus area:

- Paints
- Mobile sources, specifically tailpipe emissions
- Vehicle maintenance activities (break linings can contribute to emissions)
- Pesticides, herbicides, and fertilizers (which can contribute to both particulate and gaseous emissions).

The group also mentioned a more overarching need to determine a subset of domestic best management practices that are transferable to OCONUS locations to help with the emissions issues those locations are experiencing.

### 4.3.3 Prioritized Outcomes

- Unpaved Developed Surfaces/Staging and Maneuver Areas
  - Develop broad-based protocol for evaluating dust suppressants, including their secondary impacts on other resources
  - Conduct basic research on the physics of near-source dust deposition
- Dust Emissions from Building Deconstruction/Demolition
  - Employ safer technologies for deconstruction/disassembly as opposed to demolition of contaminated buildings
  - Evaluate demolition control techniques to determine efficacy; collect monitoring data
- Computational Modeling and Data Management for Field Decision Making
  - Model prescribed burns, demolition, live-fire training, OB/OD, wind breaks (erosion control)
- Wind Erosion
  - Use biological and physical mitigation strategies to control dust
    - Short- versus long-term strategies
    - Adaptation to climate change
- Range Burning
  - Exchange best practices among agencies to improve transferability and identify research gaps
  - Develop alternative uses of biomass rather than pile burning (e.g., biomass to fuels)
- OB/OD and Impact Points/Areas
  - Design optimal OB/OD process to minimize emissions

- Explore potential reuse of explosives components of munitions
- Identify long-term alternatives to OB/OD.

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# 5 Gaseous Emissions from Non-Point Sources: Breakout Session 2

## 5.1 Characterization

**Chairs**: Dr. Ram Hashmonay, ARCADIS; Dr. Bryce Bird, State of Utah, Division of Air Quality

**Scribe**: Dr. Robert Holst, HydroGeoLogic, Inc.

### 5.1.1 Background

This breakout group addressed the characterization of gaseous emissions from non-point sources, particularly the state of practice and science relevant to characterizing non-point source emissions. Issues to be addressed include the technologies and measurement protocols needed to determine amounts and composition (chemical and physical properties) of non-point sources to support compliance, management, development of regulations/standards/EFs/methodologies, and impact assessments.

The terms "gaseous emission" and "characterization" were defined in order to focus the discussion and to ensure that all of the participants were on the same page during the discussion:

- **Gaseous Emission—**Any matter that cannot be captured by a non-reactive (inert) filter material. A gas can deflect (bend) light beams and can alter the physical properties of the light beam.
- **Characterization—**The ability to determine and differentiate between the various constituents or components of the atmosphere including PM and gaseous matter. The quantification and qualification of these components are important factors for understanding the physics and chemistry of the atmosphere.

### 5.1.2 Session Summary

The second breakout was to address the characterization of gaseous emissions. Three main areas of gaseous emissions were identified:

- VOCs
- Semi-volatile gases such as acrolein, naphthalene, benzene, and benzo(a)pyrene
- Greenhouse gases, which are not part of this discussion.

The discussion addressed the sources of these non-point gaseous emissions, management practice issues, and the state of knowledge and the gaps in that knowledge with respect to characterization.

Nine operations were identified as being sources of gaseous emissions within DoD installations, facilities, and ranges:

- Maintenance facilities
- Oil products storage
- Refueling operations
- Training ranges from mobile and stationary sources
- Solvents and cleaning agents outside of maintenance facilities
- Prescribed and wildland fires
- Biogenic sources

- Domestic uses, including public works operations
- General and accidental releases.

The group discussed management practices that either control the release of fugitive gaseous emission, such as inventory control, or monitor the movement of emissions. The group noted the general lack of continuous air monitoring in any of the above source locations. Periodic and as-needed monitoring does occur.

Though there are many deployed and developed technologies (see white paper by Bosch et al., and the plenary presentation by Mikel), many current test methods still require high minimum detectable concentrations (MDC)—1 ppb is the current demarcation point; parts per trillion is not readily attainable with affordable instrumentation. Passive monitors are available as a first line/supplemental (warning) of monitoring (chronic measurements) for higher MDCs and episodic events.

An extensive list was generated as to the extent of the gaps in technology with respect to characterizing gaseous emissions, leading to the prioritization of research needs below:

- VOC losses are about a magnitude greater than estimated or measured; there is a question as to the accuracy of either the prediction or the actual amounts.
- The mixing and interaction processes of installation emissions (of all sorts) with other sources downwind—biogenic, urban VOCs, sea salts, etc.—is not well understood.
- Measurement processes are not readily available to the general user.
- Uniform meteorological stations are needed at all DoD installations with the possible use of phased array or other means of detection for meteorology.
- Speciated air toxics need lower MDLs, longer optical paths, and brighter sources.
- Leak detection imaging systems need both speciated and geo-location.
- DIAL serves as a compact special purpose LIDAR for one wavelength.
- A more compact, more efficient, inexpensive version of infrared (IR) laser monitor (quantum cascade lasers [QCL])—for chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC), fluorocarbons, VOCs, etc.—is needed.
- Some example candidates for metal atom gases include lead, copper, chromium, and strontium.
- Some candidates for molecule gaseous compounds include acrolein, naphthalenes, formaldehyde, benzene, and benzo(a)pyrene.
- Some evaluation protocols exist and are being developed for instrumentation and processes.
- Sun photometers improvements are necessary for firefighting plume detection.
- Hand-held instruments for carbon monoxide (CO) are needed to characterize and monitor plumes (for forest firefighters).

### 5.1.3 Prioritized Outcomes

A number of areas were identified as R&D priorities for gaseous emissions:

- Better characterization of the source(s):
  - Develop inventories on the gaseous emissions on an installation-by-installation basis of suspected fugitive gases so as to better target the technologies and methods, particularly VOC fugitive emissions. Start with the pharmacy inventories on the installations and

  - develop a tiered approach for characterizing specific emissions that may be unique to DoD operations and installations or for which DoD is a major source.
  - Improve methods and instruments and make them more field-usable. The instruments may include those that are IR source, open path, or compact DIAL which are low-cost and reliable. There is also need to marry technologies in order to detect or monitor a wider variety of emissions.
- Develop and refine protocol(s) (e.g., TO-16) for regulated measurements using reference materials with the development of established methodologies through organizations that will provide the background data used to verify the instrumentation/protocols. The organizations include EPA, the American Society for Testing and Materials (ASTM), OTM, the National Institute of Standards and Technology (NIST), American Petroleum Institute, and the International Organization for Standardization (ISO)

Some in EPA are advocating a Center of Excellence for Non-Point Source Effluent Testing for environmental testing to be located at a university.

## 5.2 Monitoring and Modeling

**Chairs**: Dr. Mark Rood, University of Illinois; Mr. Tyler Fox, EPA Office of Air Quality Planning and Standards

**Scribe:** Mr. Jeffrey Houff (HydroGeoLogic, Inc.)

### 5.2.1 Background

The overarching goal of this session was to discuss the areas of monitoring and modeling gaseous emissions from non-point sources and determine DoD research needs in this area. This session addressed the state of practice and science relevant to monitoring non-point source gaseous emissions and modeling their fate, transport, and impact at both local and regional scales Specifically, the session aimed to answer the following questions:

- What are the current and future management practices and needs for non-point source gaseous emissions?
- What are the current technical capabilities to support management practices at local and regional levels?
- What are the unmet scientific and technology needs in monitoring and modeling non-point gaseous sources to support current and future management practices?
- What are the high-priority gaps in knowledge and capabilities that need to be addressed to drive our R&D activities?

The scope of the discussion for this session was the same as in the modeling and monitoring of the PM session in that non-point sources encompass any source other than an exhaust stack or duct and do not include emissions from mobile sources. The discussion in this session was limited to air-quality issues related to gaseous emissions that were formed within the boundaries (fence line) of DoD facilities. The main sources of gaseous emissions on DoD facilities were identified as prescribed burns and wildland fires, refueling and operations dealing with solvents, and OB/OD of energetic materials. In addition, it was noted that the overall gaseous emissions measured on a DoD facility could be influenced by gaseous emissions released outside the fence line. Examples of these emissions include prescribed burns or wildland fires on private lands or emissions from feedlots or other agricultural operations. For this session, since OB/OD locations were outside the scope of the workshop and since another session would focus on fuels and solvents, the group focused on monitoring and modeling gaseous emissions from prescribed burns and wildland fires.

### 5.2.2 Session Summary

The drivers for reducing gaseous emissions from DoD facilities are the same as those for PM emissions, specifically federal, state, and local regulations; worker safety issues; and avoiding conflict with surrounding communities. These drivers have led to a number of management practices that DoD facilities use when dealing with the emissions from prescribed burns. When a facility is preparing to initiate a prescribed burn, several conditions must be met in order to get permission to burn. First a burn plan—outlining the details of area to be burned and the burn itself—must be filed up to a year in advance. Once the plan is approved, the state department of environmental quality will use PM forecasts and meteorological data to assign a date for the burn to take place. While the burn is taking place, some monitoring of PM emissions occurs. Models are currently available for use on prescribed burns; however, there are a wide range of models available, and there is no standard model for use across DoD. As in the case of monitoring and modeling PM emissions, because of the variability in air quality around the country, different measures are taken at each facility in order to maintain the overall attainment in that area.

In terms of monitoring gaseous emissions from prescribed burns, there is currently no routine monitoring performed because the emissions standards are so high that by the time the emissions plume reaches a receptor, the concentration of emissions has been diluted. In addition, routine monitoring is difficult because sensors would have to be placed in a variety of locations in order to get the complete picture of emissions released by an entire facility. It has been found to be difficult to get DoD facility managers to implement more than one sensor for monitoring emissions in the first place. A single sensor is not very effective for routine monitoring as it would not always be positioned at the correct location. Monitoring emissions at the source can provide data, but this method fails to give a complete picture of gaseous emissions released into the environment. In addition to the emissions themselves, other factors such as environmental and fuel conditions have to be monitored. This information is useful in preparing for and executing the burn, as well as for modeling the emissions of the burn.

There are a wide variety of models available for prescribed burns, including the California Puff Model (CALPUFF), California Photochemical Grid Model (CALGRID), Cerebellar Model Articulation Controller (CMAC), Blue Sky, VSMOKE, Hazard Prediction and Assessment Capability (HPAC), AMS-EPA Regulatory Model (AERMOD), and others. Many of these models are used to predict the results of a burn prior to the burn taking place, but models are also available for real-time decision making during a burn although these real-time models are not widely used.

In general, it is not widely known which models are used at the various DoD facilities. While different models may be needed for areas that have vastly different types of terrain and vegetation, it is likely that different models are used in areas where the same model could have been used. Understanding the implications of using different models in similar situations could help the community as a whole better manage emissions from prescribed burns.

A final issue dealing with modeling is the validity of the data that are input into models. In the area of modeling gaseous emissions from prescribed burns, there are some questions about the accuracy of the meteorological data that are provided for the models. The quality of the data has to be ensured before it is used for decision making.

### 5.2.3 Prioritized Outcomes

Given the standard practices and issues discussed above, additional research in the following areas would help DoD facilities improve monitoring and modeling of gaseous emissions from non-point sources.

**Overall**

- Develop critical state-of-the-science document describing monitoring and modeling available to meet DoD's needs in conjunction with regulatory agency needs (stress needs of the facility managers)
- Document DoD research pertaining to fire activities
- Foster better interagency cooperation
- Evaluate best modeling systems for gaseous and PM emissions and transport for widespread uniform use
- Implement workshop to discuss commonality of facility needs and generalization of tools and training available for widespread use.

**Modeling**

- Develop real-time modeling capabilities for managers to determine plume transport
- Utilize National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS) ozone ($O_3$) and PM forecasting capabilities to help managers determine how and when to implement prescribed burning
- Improve back-trajectory models to better assess what is coming from particular sources
- Develop models that can handle chemical interactions from other sources, regional consideration ($O_3$ potential and total $PM_{2.5}$)
- Conduct closure evaluation of transport models, monitoring measurements, and use of markers/tracers
- Develop better understanding nighttime/stable atmospheric conditions pertaining to prescribed burning
- Establish capabilities to provide modeling results that are needed to evaluate impacts on sensitive ecosystems
- Develop better understanding of interactions of prescribed and wildland-fire burning and the boundary layer (influence transport); test, evaluate, and implement in models to improve predictions
- Analyze fluid dynamics of fire-related plumes (plume rise from multiple sources).

**Monitoring**

- Develop low-cost and portable monitoring methods and relate them to EPA reference methods (ORD and OAQPS are working on this area) (e.g., real-time air toxics, polyaromatic hydrocarbons [PAH], and terpenes as tracers for prescribed burning, $O_3$ to describe spatial resolution at receptors, CO/carbon dioxide [$CO_2$]), low power
- Conduct ammonia ($NH_3$) monitoring

- Implement smart-target deployment of monitoring networks
- Develop monitoring networks for gases combined with PM
- Monitor prescribed burning/wildland fire-induced VOC emissions (e.g., isoprene, terpene)
- Monitor fire-related markers (e.g., levoglucosan) and secondary aerosol formation.

## 5.3 Mitigation

**Chairs:** Dr. Dick Gebhart, U.S. Army Corps of Engineers, Engineering Research and Development Center—Construction Engineering Research Laboratory (ERDC-CERL); Ms. Julie McDill, Mid-Atlantic Regional Air Management Association

**Scribe**: Mr. John Thigpen (HydroGeoLogic, Inc.)

### 5.3.1 Background

The charge for this breakout group was to address the current state of practice and supporting science needed for management and mitigation of non-point source gaseous emissions. Specifically, this session was asked to do the following:

- Review the current state of management practices relevant to non-point sources of gaseous emissions
- Assess the current state of the science and technology relevant to non-point source gaseous emissions mitigation
- Identify the gaps in knowledge and technology that, if addressed, could improve DoD's and EPA's ability to mitigate gaseous emissions from non-point sources.

### 5.3.2 Session Summary

The group began by listing the major gaseous emissions DoD deals with, which include $NO_x$, $SO_x$, $NH_3$, HAPs, VOCs, water vapor, greenhouse gases, and terpenes. The group then listed the various major military sources and operations that generate non-point sources of gaseous emissions. These activities included the following:

- Range burning
- Training range activities
- Gas/fuel tanks and farms
- Storage facilities
- Land management
- OB/OD
- Other sources and activities that fall outside of the SI focus area of SERDP and ESTCP.

Once the group compiled a list of major operations generating gaseous emissions, they identified more specific sources and activities within each major category, selected those sources and activities that contribute the most to particulate emissions from each major operational category, and discussed various mitigation tools, options, and needs for each of these sources and activities. Below is an annotated outline of the discussion from that session, organized by major military operation or source.

#### 5.3.2.1 Range Burning

Prescribed and wildland fires produce both gaseous and particulate emissions. The group believed that the biggest research need was in developing emission factors for different vegetation types that are frequently burned.

Another research need discussed was related to temporally based approaches to mitigating gaseous emissions from burning. Better characterization of the gaseous emissions during different times or seasons may inform decisions on when best to burn in order to limit gaseous emissions. Improved characterization of ozone seasons versus non-ozone seasons also emerged as a research need.

The group suggested stronger interactions between land management decisions and biogenic terpene.

#### 5.3.2.2 Training Range Activities

The group cited smokes and obscurants—as well as fog oil—as key contributors to gaseous emissions, primarily VOCs. The formulations of smokes and obscurants have been modified in recent years to minimize this emission source. However, VOCs still remain in fog oils, so the group suggested research to look at the timing of the use of fog oils to minimize reactions with $O_3$.

The use of light and heavy munitions on DoD training ranges is seen as less of a contributor to emissions relative to the other gaseous non-point sources. The use of these munitions generates more particulate emissions than gaseous emissions.

#### 5.3.2.3 Gas/Fuel Tanks and Fuel Farms

Fuel handling during training activities represents a major source of fugitive gaseous emissions, primarily as a result of fuel waste and loss. The group suggested evaluating current mitigation practices available for curtailing fuel loss to see which of those practices would be compatible with realistic training scenarios. The group identified developing additional fuel-loss prevention measures compatible with DoD training activities as a priority research need.

Airfield and port emissions were discussed as another major source of fugitive gaseous emissions, particularly from fuel leaks from aircraft while they are grounded. Several mitigation techniques and research needs were offered to address this non-point source of gaseous emissions.

- Implementation of fuel-tank balances and refrigeration devices can minimize fuel loss from leaks and evaporative emissions.
- Keeping fueled aircraft off runways when not in use represents a simple solution for reducing such fuel losses.
- IR cameras and DIAL can be used to identify operational fugitive gaseous emissions. DoD would be able to survey large regions of interest and pinpoint where the bulk of the fugitive emissions are originating.
- Development of alternatives for deicing fluids and halon are needed to reduce gaseous emissions from these sources.
- Adjusting ground equipment operations can also mitigate non-point gaseous emissions (e.g., towing planes to the runways versus having them use jet fuel to drive themselves to the runway).

For fuel farms, the group suggested evaluating the tradeoffs between using bladder tanks versus using standard fuel storage tanks.

Ship operations were also highlighted as a source of gaseous emissions from gas/fuel tanks and fuel farms, but there was no additional discussion on the topic.

#### 5.3.2.4 Storage Facilities

Gaseous emissions resulting from leaks from storage tanks (55-gallon drums) vary depending on the types of waste stored in those drums. The emissions themselves are not well characterized given the diversity of wastes stored in such drums; however, there is a good inventory of what waste items are there because of Resource Conservation and Recovery Act (RCRA) regulations.

IR cameras were mentioned as a useful application to this non-point source of gaseous emissions to quantify the amount of emissions from this source and to pinpoint their exact origin.

The group saw a need to develop sound 55-gallon drum waste storage protocols to minimize such leakages (e.g., storage under a roofed structure to minimize temperature changes versus fire and safety concerns resulting from enclosing this waste).

#### 5.3.2.5 Land Management

Pesticide, herbicide, and fungicide application and residuals were identified as the primary gaseous emission source resulting from DoD land-management activities. Several mitigation techniques and research needs were offered to address this non-point source of gaseous emissions.

- Substituting lower toxicity materials in the development of pesticides, herbicides, and fungicides that are less persistent in the environment could cut gaseous emissions. The same is true of the development of fumigants for termite and mosquito control. Brominated compounds and defoliants were singled out as key ingredients in pesticides, herbicides, and fungicides that need to be replaced in order to cut gaseous emissions from this source.
- The group suggested developing certified pesticide applicators that reduce the fugitive emissions resulting from spraying pesticides. Research is needed to determine the amount of pesticide waste generated from its overapplication and to develop approaches to minimize this type of gaseous emission.
- Gaseous emissions resulting from pesticides, herbicides, and fungicides are not a DoD-unique issue. Thus, there should be a move towards interagency sharing of best application practices in similar ecosystems. Such collaboration could lead to a more integrated form of pest management that would subsequently reduce gaseous emissions from this source.
- Agricultural outlease areas are another source of gaseous emissions. Because of the rapid land-use changes those properties experience, legacy contaminants continue to resurface (e.g., Fort Campbell). DoD could benefit from research that characterizes what is in the soil, thereby providing a clearer picture of what types of gaseous emissions originate from this source. This soil characterization need can also be applied to impact areas; these areas represent a major source of chlorinated solvents, which can be volatized if disturbed by training activities.

The group also cited a need for improved interaction between land-management decisions and biogenic terpene, particularly as it relates to regional haze.

#### 5.3.2.6 OB/OD

The discussion for this source of gaseous emissions followed the same logic as the discussion of OB/OD as it relates to particulate emissions.

- The group concluded that an optimal design of OB/OD pits—such as through the use of alternative caps (construction debris or other waste products)—is a research need that, if addressed, would minimize emissions from this source.
- The group also felt that overall waste reduction would inherently reduce emissions. Designing new munitions that can be reworked (into new munitions or for other unrelated uses) when their shelf life expires—rather than disposed of via OB/OD—would be a valuable capability that should be researched.
- Studying impact areas via computational modeling was highlighted as an area that would benefit from additional R&D. Such research could help monitor pollutant migration downwind and ultimately help develop software that can determine the best times to conduct exercises in impact areas.

In addition to the items discussed above, which mirrored discussions from the particulate emissions breakout session, the group also suggested developing additives to put into OB/OD pits that can act as a sponge to absorb gaseous pollutants. A more integrated approach to mitigating both particulate and gaseous emissions resulting from OB/OD activities was also suggested.

#### 5.3.2.7 Other

Other potential sources of non-point source particulate emissions that were identified fall outside the scope of the SERDP and ESTCP SI focus area. The key recommendations and research needs are described below.

- DoD should continue to strive toward more improved fuel conservation and more efficient fuel use by engines. Less refilling will lead to less fugitive gaseous emissions. In addition, reducing vehicle miles traveled will reduce VOC emissions.
- Low sulfur fuels are also needed. Developing portable de-sulfur devices for fueling operations (bypass for high-sulfur fuels) would significantly reduce fugitive gaseous emissions.
- Institutional barriers exist that prevent incorporation and implementation of new science into rulemaking (e.g., opacity rules, prescriptive state implementation plans, and cultural barriers). New mitigation techniques must be faster, cheaper, and easier than the current standard or practice in order to circumvent these institutional barriers.
- Compliance in $O_3$ and fine particulate non-attainment areas is an emerging issue, especially given the shift in base populations resulting from BRAC. The inevitable increase in the volume of regulated emissions generated at bases selected for expansion will require reductions in other emissions sources in order to comply with the stringent requirement for controls and offsets in nonattainment areas.
- Historical spills represent an acute issue. Spills that occurred in the past drastically outnumber spills that occur today. These historical spills have led to surface contamination. The group suggests phytoremediation as a mitigation technique to control these potential gaseous emissions.

### 5.3.3 Prioritized Outcomes

- Range Burning
  - Temporally optimize burning schedules to minimize air impacts (such as ozone versus regional haze)

- Integrate land management with air quality (such as mechanical treatment versus fire to encourage preferred vegetation)

- Training-Range Activities (less of a concern relative to particulate emissions—major source is vehicle emissions-mobile sources)
- Fuel Handling
  - Use IR camera or DIAL to identify operational emissions to survey where problems lie
  - Apply integrated approach to emissions reduction using standard reduction techniques
  - Study sensitivity to training compatibility
- Storage Facilities
  - Use IR camera to identify "low-hanging fruit"
  - Design protocols in partnership with state and federal environmental agencies so that emission credits can be realized and continuous emission monitoring can replace some point-by-point periodic monitoring (LIDAR)
- Land Management
  - Integrate pest-management pollution-prevention to reduce and document reductions
  - Encourage interagency coordination and cooperation
  - Monitor emission from changes in land use; study legacy issues for all media/pollutants
- OB/OD
  - Design optimal OB/OD process to minimize emissions (limit burn variability)
  - Explore potential reuse of explosives components of munitions
  - Develop long-term alternatives to OB/OD (e.g., hydrochloride [HCl] from large solid-rocket motors)
  - Identify additives to put in OB/OD pits to act as sponge to absorb gaseous pollutants.

# 6 Sources and Activities: Breakout Session 3

## 6.1 Fire Emissions

**Chairs**: Dr. William Sommers, George Mason University; Dr. Allen Riebau, U.S. Forest Service (retired)

**Scribe**: Mr. John Thigpen (HydroGeoLogic, Inc.)

### 6.1.1 Background

The charge for this breakout group was to address the issues associated with emissions from both prescribed burns and wildland fires on DoD installations. This group built on the discussions from the first two breakout sessions by focusing on the activities and sources that lead to both particulate and gaseous non-point source activities. With respect to fire emissions, the group was asked to assess DoD's air-quality management needs, to review and assess the current state and the gaps in science and technology discussed in the first two breakout sessions, and to recommend priorities for future SERDP and ESTCP investments to address these gaps.

### 6.1.2 Session Summary

Drs. Riebau and Sommers did a great deal of preliminary work to prepare for this session. Ten questions were prepared to guide the discussion and help narrow the fire emissions research priorities. The discussion is organized by question. Not all questions generated discussion. The general consensus of the group was that fire emissions management can improve with a more holistic, integrated approach by enhancing and exploiting the advantages offered by the wide variety of characterization, monitoring, modeling, and mitigation tools currently in existence.

- What type of fire emissions on DoD installations (prescribed, wildland, structural) are of most concern? Why? Where (e.g., in what region or locations) do they occur?
  - The group felt that both prescribed and wildland fires were significant concerns on DoD installations in terms of fire emissions. Dr. Sommers showed several slides on fire data which indicated a steady increase in the number of acres burned in the United States since 1986 (almost 10 million acres burned each year in 2006 and 2007), although the number of annual fires has remained about the same since that time. The slides also indicated the importance of fires in the east, from demographic, ecosystem, and wildland-urban interface (WUI) perspectives.
- Does DoD have a current baseline (inventory) of fire (prescribed, wildland, WUI, structural) emissions from all DoD installations? If yes, please describe. Has DoD performed any risk, or prioritization analysis that identifies which installations are likely to be of greatest concern in regard to fire emissions and the basis for concern? If yes, please describe.
  - The group agreed that DoD does a thorough job of documenting the size, location, and frequency of their prescribed burns. It is a critical management tool. These answers led the group to recommend that all DoD bases with legitimate concerns about fire emissions and smoke actively refine their fuel-bed characterizations and develop fuel characteristics maps. The maps might additionally provide information on how much fuel was consumed and in which stage of combustion (such as flaming, smoldering) realizing that in most cases such information may only be best estimates. These maps should be

regularly updated as an exercise in adaptive management and will help identify those installations of greatest concern in regard to fire emissions.

- What wildland fuel analyses have been done for DoD installations? Are there fuel maps for DoD installations? Please describe and reference.
  - As a part of the Aerosol Characterization Experiments (ACE), the group felt that a national DoD data/information repository would be a useful tool for military land managers. This repository could include all fuel analyses and fuel maps completed for DoD installations.
- What types of wildland fire fuels are of most concern on DoD installations? Why? Where are they?
  - The group felt that further research is needed to evaluate the benefits and tradeoffs between prescribed burns and wildland fires. What impact do they have on biomass carbon sequestration? How much do these events (prescribed burns and wildland fires) contribute to overall greenhouse gas emissions? There were also concerns as to what influence a changing climate might have on fire ecology and fire dynamics (including occurrence and intensity), especially on DoD lands, especially in the southwest.
- What factors (fuel-loading, fuel consumption, fire intensity, rate of spread, plume height, etc.) influence wildland fire emissions from DoD installations? Which of them are the most important for DoD installations? Which do we know the least about?
  - The group identified plume-rise characterization as the clear research gap for fire emissions. By improving our understanding of the distribution of various pollutants (both primary and secondary) in the plumes, our land managers could be better equipped to determine the best times to burn, under what conditions to burn, and how much fuel to burn.
  - The group felt that further research is needed to distinguish the emissions originating from flaming and smoldering phase fire emissions.
- What tools do DoD installations employ for modeling fire emissions and their fate? Why are they used? What are their strengths? What are their weaknesses?
  - The group agreed that the fate of wildland fire emissions would best be modeled through an approach similar to the ACE (http://saga.pmel.noaa.gov/Field/ace1/). This approach involves integrating field experiments and incorporating the results into the design and complexity of subsequent experiments. The group also agreed that any experiments involving constructing and validating fate and transport models should follow the methods described by the Joint Fire Science Program Smoke Roundtable (http://www.firescience.gov/documents/Smoke_Management_Air_Quality/Smoke%20Roundtable%20Review%20Summarizations%20August%2013%202007.pdf).
  - The group recommended improving on existing emissions models so that meteorological conditions, plant/fuel conditions, and fire behavior are incorporated into model simulations and output.
  - The group suggested pursuing more robust modeling for understanding fire emissions. The ideal models would be more real-time and more physics-based and would account for the various processes (including $O_3$ development) occurring during a fire event. An example of such modeling—termed “hybrid” modeling—has been employed successfully for point sources.

  - It was also discussed that one model may not suit all needs or fire configurations. A modeling framework might be developed in which fire managers would have a series of model choices that all work from a common database of fire and meteorology information, and that provide tabular and geographically displayed results linked within a single operating environment. An example of such a framework is the current Forest Service BlueSky modeling framework used in the Pacific Northwest.
- What tools do DoD installations employ for measuring fire emissions and their fate (such as concentrations away from the fire)? What are their strengths? What are their weaknesses?
  - The group agreed that increased monitoring will directly lead to improved management of fire emissions, and that this could best be accomplished through the development, refinement, and ultimately implementation of low-cost monitoring devices. These monitoring devices should measure a wide range of pollutants and cover varying spatial ranges. Examples of such low-cost monitoring devices include optical devices, such as digital cameras and passive samplers.
  - The group felt that by integrating remote-sensing technologies (including satellite, air platform, and ground-based remote sensing) data and including the data in model comparisons, land managers could better quantify the fire emissions originating from their burns.
- Is long-range or short-range transport of wildland fire smoke onto DoD installations a concern? If so, what are these concerns? What do we need to know or do to alleviate such concerns?
  - The group felt that development of very specific tracers for biomass burning would help DoD determine the origin of wildland fires and whether or not they originated from DoD land management activities or from another non-point source.
- Do DoD installations with wildland fire concerns tend to work with local/regional and non-DoD wildland fire entities and other DoD installations in nearby areas within a national DoD framework of resource sharing and allocation? If so, how?
  - The group agreed that DoD and other land management and regulatory agencies could improve their coordination. They felt that a good start would be to conduct a thorough literature review of air quality modeling and subsequently develop a comprehensive modeling framework for the installation/state/region/country.
- After answering all of the previous questions, what are the top five R&D needs we have identified? How much might we roughly estimate each one might cost? How long might such research take? Who might do it best (national labs, universities, NOAA, etc.)?
  - The group generated several items that were considered priorities. They are described in the section below.

### 6.1.3 Prioritized Outcomes

- Key DoD bases that have a real concern with prescribed fire and smoke need to have refined fuel beds and fuel characteristics maps.
- Remote-sensing technologies (satellite, air platform, and ground-based) should be integrated and included in model comparisons.
- Plume-rise characterization should be improved, particularly to discern the distribution of materials with plume height. This should be accomplished through a combination of LIDAR and other methodologies and should include a comparison to models.

- Integrated field experiments like ACE are recommended for looking at wildland fire emissions and fate. The experiments should follow the Joint Fire Sciences Program (JFSP) Smoke Roundtable methods for building and validating models, and potentially develop a project in partnership with JFSP.
- Emissions models should be developed that consider meteorological conditions, plant conditions, and fire behavior; they should also include emissions profiles for receptor models.
- Low-cost monitoring devices should be developed and implemented. They can be routine or specialized monitors depending on the particular event being monitored (e.g., optical devices such as cost-effective digital cameras and passive samplers).
- Development of very specific tracers for biomass burning, including emissions profiles for receptor models, is needed.
- Research is needed to distinguish between flaming and smoldering phase emissions.
- A DoD national data/information repository would be a useful tool and could probably be a component of an ACE type of effort.
- Real-time and more complex (e.g., hybrid) modeling of the various processes occurring in wildland fires, including $O_3$ generation, is needed (compare with ACE).
- A comprehensive literature review of air-quality modeling is needed to provide DoD with a modeling framework for their needs.
- The benefits and tradeoffs of prescribed fire vis-à-vis carbon sequestration and greenhouse gases should be evaluated.

## 6.2 Training Range Emissions

**Chairs**: Dr. John Watson, Desert Research Institute; Mr. Robert Lacey, U.S. Army Corps of Engineers, Engineering Research and Development Center—Construction Engineering Research Laboratory (ERDC-CERL).

Scribe: Dr. Robert Holst (HGL, Inc.)

### 6.2.1 Background

A breakout group was convened after the discussions as to particulate and gaseous non-point source emission characterization, monitoring and modeling, and mitigation to address training range emissions. They were specifically charged to address issues associated with non-point source emissions from the direct use of military vehicles and weapons and indirect emissions due to their impact on the landscape, such as by increasing windblown fugitive dust.

A definition of training range emissions was offered in order to focus the discussion and to ensure that all of the participants were “on the same page” as to these discussions.

**Training Range Emissions**. Air pollution sources at DoD training ranges include fugitive dust, smoke and obscurant training, artillery/bombing practice, weapons impact testing, OB/OD, range fueling operations, and range maintenance activities. Fugitive dust is created by vehicle and aircraft maneuvers, artillery/missile backblast, range maintenance and construction activities, and wind erosion. Military ordnance includes large- and small-caliber weapons, the propellant used to launch the ordinance, and explosive chemicals used in the warheads. Small to moderate amounts of excess propellant is typically disposed of through OB during the training activities. Any significant amount of propellant or explosive in unused or obsolete munitions is disposed of at specific locations designated for such purposes. Obscurants include handheld grenades, smoke pots, and larger smokescreens created through smoke-generation devices.

### 6.2.2 Session Summary

The group discussed training range emissions to determine the magnitude of the issue. The major issues discussed included emissions inventory by location with more exacting numbers; better understanding and management of operations to reduce fugitive dust and other emissions; better monitoring of dust movement with mobile, less-expensive systems; better mitigation practices; OB/OD emissions in general; understanding of the movement of dust in the near field distances; and understanding of the various air regulations and the related issues surrounding permits versus the real world.

In addition, the development and verification of EFs was a major concern. The following items were noted during the discussion:

- EPA EFs will be coming up on WebFIRE. WebFIRE will be used to access AP-42 information (data, test context, performance tests). WebFIRE access will be made available so that holders of the information can upload this data/information.
- DoD's CAA subcommittee wants to verify the AP-42 information so that the data is accepted by the states.
- EPA has a grading system for EFs but at this point the EPA Science Advisory Board (SAB) and Congress have expressed concerns about the confidence levels associated with this system.

EPA participants pointed out that EPA is being required by Congress—in the Fiscal Year 2008 appropriations—to generate a greenhouse gas rule; a proposed rule is expected within 9 months, and a Final Rule will be rolled out in 18 months.

#### 6.2.2.1 Sources

The breakout group identified five non-point source emissions that can occur on DoD training and testing ranges:

- Fugitive dusts from training and testing using wheeled and tracked vehicles, rotary aircraft (fixed winged is not a major concern except on unpaved short take off and landing surfaces), and artillery backblast (backblast areas can be a small to moderate source; over-pressure from the gun tube firing was considered a non-significant source)
- Secondary emissions from surfaces due to wind erosion
- Land management actions, including positive and negative effects of vegetation
- OB/OD—Gas, dusts, metals from propellants (OB), waste munitions (fixed sites)—mixes of munitions (OD), static firing of rockets/missiles (OB), and pits covered with soil that is then entrained in the plume (OD)
- Smokes and obscurants localized; limited use due to state restrictions
- For each source, the following were needed:
  - Bound each source with specific methods, for example, as for a management need
  - Provide minimum requirements/criteria for each method.

#### 6.2.2.2 Cradle-to-Grave Management and Gaps in Knowledge

The breakout group then discussed the present management practices on training and testing ranges and suggested that case studies would enable them to study the magnitude of this issue. The case studies would look at the management practices in a cradle-to-grave approach. These points also were discussed as gaps in the technical knowledge.

- **Wheeled Vehicles and Fugitive Dust**
  - Sources must be characterized with credible methods to measure and model the effects. This characterization requires knowledge of where the vehicles are being used and associated land characteristics—miles traveled, vehicle speed, and road surface. Better maneuver statistics for training activities and inventories are needed. Surface conditions are important—micrometeorology (seasonal), soil type (soil classification), RH, wind erosion index, etc.
  - Case studies should be performed in order to gain an understanding of the total activities in at least five different sites, noting episodic source versus long-term effects. The information obtained must be transferable to most sites. The SERDP-sponsored study at Fort Bliss is a good example; this case study showed that vehicle speed and weight accounts for 90 percent of dust emission. Methods need to be verified along with the roadside emissions and vegetation/physical barrier (mitigation) effects for use in models.
  - The EFs should be scaled to understand the road to the grid boundary (scaling factor for first 200 meters) effects with respect to realistic emission and near-field mitigation.
  - Mitigation by soil roughness and vegetation as a near-source mitigation practice is not well defined or accepted; the critical issue is understanding the porosity of barriers and vegetation. Methods and instruments are available but require data under controlled conditions. Field studies are preferred over a lab or wind-tunnel study because the scaling issue does not work in sand and silt movement dynamics. Additional materials under development need to be tested, such as waste (glycerin from biodiesel generation) and biomaterials.
  - Long-range transport of fugitive emissions modeling must be supported with particle-size distributions rather than just $PM_{2.5}$ and $PM_{10}$ alone. An empirical base of information of size distribution (wind-tunnel studies) with respect to soil classifications will be needed to verify the results through field tests.
- **Tracked Vehicles**
  - The primary issue is the difference between tracked vehicles and wheeled vehicles.
  - Track entrainment of dust particles is the major issue that needs instrumented measurements.
  - Generally one can go from wheeled to tracked vehicles to gain EF information, but there are assumptions that need to be verified.
- **Rotary-Winged Aircraft**
  - The primary issue for rotary-winged aircraft is dust-plume generation.
  - Dust-plume generation is dependent on aircraft dynamics, such as altitude, hover, and speed forward. A study of aircraft activity—how often and where the operations are taking place—is needed to quantify the dust plume as a source. The plume then needs to be studied as to height and mass of cloud through the use of remote sensing flux plane

measurements using instruments such as LIDAR and Fourier Transform Infrared (FTIR) spectroscopy.
- Replication and verification of data from existing/past field efforts will be required to support potential predictive models.

- **Wind Erosion**
  - Better instruments and methodologies are needed to study the microclimate of the soil, such as temperature (freeze/thaw effect) and soil moisture. The surface roughness and strength of the crust texture need to be studied, along with the recovery period and conditions of the crust.
  - Wind-to-entrain thresholds need to be identified to trace the routes of sand flow. The effect of sandblasting—sand lifted up to 1 meter height—is the telling force.
  - Satellite data and other data should be used to focus studies on large-scale, specific sites and issues.
- **Smokes and Obscurants**
  - Many aspects of smokes and obscurants are known, including chemical compositions, droplet size distributions at the source, and the fact that they are normally used under controlled conditions, which are easily modeled.
  - Activity assessment is one area that could be improved relative to types, use patterns/conditions.
- **OB/OD**
  - It is harder to determine the source emissions for OD because of the mixed munitions profile. In most instances, OB is also considered to be a point source for pit burns.
  - The development of EFs is in progress. Activity assessments are key to EF determinations; they have been done, but there is some question of whether they are current.
  - OD generates large plumes that need to be modeled better, including plume-height source injection and dust entrainment from overlaid soils.
  - Better mitigation practices are needed to contain the explosions (OD) and to predict times to undertake OB. Alternatives for scrubbing the plume (water curtains) must be addressed because the static fire of rockets and missiles may generate HCl and other noxious gases.
- Artillery backblast exhibits a very low impact (source) as compared to vehicle dust generation. One telling issue is the variability in construction of firing points, which leads to the large variability in dust generation, which is of greater concern to local personnel.

### 6.2.3 Prioritized Outcomes

The training and testing range emission breakout group provided a total listing of priorities for R&D investment. It was group consensus that the principle means to address these issues would be through empirical case studies and field data collection involving actual training and testing activities.

- Fugitive Dusts
  - Evaluation and standardization of methods and protocols for emission potentials, especially for soil characterizations
  - Survey of activities that generate dust
  - Emission measurement protocols

  - Source signatures to determine the sources of dust in order to control dust generation at the source
  - Emission factors scaling
  - Determine the processes that are instrumental in deposition of dust
  - Verification of models for off-site transport
- OB/OD
  - Emissions methodology is needed.

## 6.3 Fuels, Lubricants, and Solvents

**Chairs:** Mr. John Bosch, EPA Office of Air Quality Planning and Standards; Ms. Elizabeth Hill, Research Triangle International

**Scribe:** Mr. Jeffrey Houff (HydroGeoLogic, Inc.)

### 6.3.1 Background

The objective of this session was to identify areas where additional R&D can help DoD reduce air emissions from activities relating to the storage, transport, and use of fuels, lubricants, and solvents. In this session, the discussion of fuels was limited to emissions from fuels as liquids and did not include emissions from burned fuels. In addition, it was determined that an emission from lubricants was not a major issue with respect to air emissions, so the discussion focused on fuels and solvents.

### 6.3.2 Session Summary

Several drivers have made it necessary for DoD to take steps to reduce evaporative losses and air emissions from fuels and solvents, including federal, state, and local regulations for air quality as well as cost savings benefits since emissions from solvents and fuels mean losses in material. In general, there are technologies currently available that can reduce or eliminate evaporative losses from fuels and solvents. However, these technologies are not likely to be used or purchased unless the extent of evaporative losses are quantified and their locations are fully characterized . Studies performed on several petroleum refineries have discovered that only a fraction of evaporative losses are being accounted for and that implementation of  additional maintenance measures can reduce evaporative losses by as much as two-thirds. A similar approach is needed at DoD facilities. Because of the nature of fuel-handling and storage and solvent use, points of evaporative losses can be numerous and widespread depending on the nature of fuel-handling and storage and solvent use. Prior to initiating such a study, protocols will need to be developed on what would be measured and how the emissions measurements would be taken. The results of such a baseline survey would be a necessary starting point for DoD to assess the evaporative losses of fuels and solvents from their facilities.

Emissions are able to be quantified using currently available open-path techniques, such as FTIR, differential optical absorption spectrometer (DOAS), and DIAL, along with the use of IR cameras. Once leaks have been identified using a combination of these methods, a standard should be developed that DoD can incorporate into their regular maintenance procedures to minimize evaporative losses from fuels and solvents. After a set period of time, the emissions survey can be repeated to gauge the success of such maintenance programs on overall reduction of emissions for that particular facility. There are, in general, five types of installations within DoD: depots, training installations, logistical installations, operational installations, and super depots. Each would need its own emissions survey protocol. Each facility would likely have to perform a slightly different survey due to the different operations that are conducted at that location.

It is important to understand both the overall picture of emissions from fuels and solvents at DoD facilities and the specific gaps. The specific knowledge gaps in fuel and solvent use within DoD are identified below.

#### 6.3.2.1 Fuel Use Needs

- Characterize the VOCs being emitted at DoD installations
- Determine the losses of fuel over entire life cycle (production to final use)
  - Improve system designs and processes
  - Determine liquid losses versus VOC emissions
- Perform life-cycle assessment (LCA)—from the time DoD gains possession of fuel until it is placed into the weapon system—on fuel used in DoD using new open-path technologies
  - Assess the efficiency of the fuel-handling infrastructure
  - Consider the difficulty of doing mass balance in DoD strategic storage of fuels (large amounts of fuel stored for later use)
- Improve accounting methodology of liquid losses (especially fuels stored in large tanks for a long time)
- Develop an understanding of emissions from alternative fuels
  - Determine new emission factors (in storage and distribution—not following combustion)
  - Consider blending operations as possible emissions source
  - Consider possibility of on-base production of bio-fuels
- Consider Otto fuel used in torpedoes as a special case
  - Very specialized
  - Very hazardous—produces hydrogen cyanide (HCN) when burned
- Monitor (precursors) and model ($O_3$ formation) $O_3$ and other gaseous emissions from installations
- Speciate emissions from refinery processes
- Quantify methane emissions from refineries and fuel storage
- Understand/quantify emissions from cleaning fuel tanks for repair
  - VOCs from solvents
  - VOCs from fuel waste and residue
  - State of practice across DoD
- Define uses of gaseous fuels on DoD installations (liquid propane gas [LPG], propane)
  - Amounts used and emissions from gaseous fuels
  - Fuel losses
- Determine accuracy of current emissions inventories
- Determine the root cause of leaks that contribute to VOC emissions
  - Leak detection system being developed/demonstrated
  - Looks at systems to determine where leaks are likely before they occur
- Increase monitoring to get better picture of fugitive emissions
  - Monitor at fence line

  - Start with broad area monitoring, then step down to local source of emissions
- Recognize that reduced leakage is another benefit to installations increasing their knowledge of their VOC emissions
- Evaluate the environmental effects of single fuel policy in the Army.

#### 6.3.2.2 Solvent Use

- Quantify/understand VOC emissions from solvent use in DoD (cleaning, surface preparation, painting equipment, etc.)
- Consider pharmacy inventory practices applied to DoD use of solvents
  - Study use at selected installations
  - Consider expanding service-wide
- Reduce use of solvents through increased nondestructive inspection methods
- Evaluate work practices to determine if changes could be made to reduce solvent loss
- Perform studies to find new sources of VOC emissions that have been overlooked in the past
  - Use new and improved technologies.

#### 6.3.2.3 General

- Apply meteorological data to open path FTIR to better monitor emissions
  - Determine whether current wind monitors are providing the best information for measurement of emissions
  - Combine meteorological data input with pollutant concentration data to completely monitor emissions
- Determine whether major source of fugitive emissions are acute or chronic
- Identify greenhouse gas emissions from DoD sources
  - Estimate amounts
  - Create new emission factors specific to DoD.

#### 6.3.2.4 Out of Scope

- Study VOC emissions resulting from remediation of spilled/leaked fuels and other liquids that emit VOC
- Study emissions from vehicles/weapons systems/other mobile sources
- Understand emissions from fire-fighting drills/training
- Label solvents to indicate the "green-ness" of the product
- Establish criteria first.

### 6.3.3 Prioritized Outcomes

Of the gaps in knowledge listed above, the following recommendations are seen as the most important in the effort to reduce emissions from fuels and solvents at DoD facilities:

**Fuels**

- Evaluate the environmental effect of fuel changes
  - Understand emissions from alternative fuels
  - Study environmental effects of single fuel policy in the Army
- Develop a methodology to quantify volatile organic emissions from DoD installations (Bubble Approach)

  - Use open-path techniques and visual camera techniques (IR and open-path FTIR).

**Solvents**

- Consider pharmacy inventory practices applied to DoD use of solvents
- Evaluate work practices to determine if changes could be made to reduce solvent loss.

**General**

- Apply meteorological data to open path FTIR to better monitor emissions
  - Are current wind monitors providing the best information for measurement of emissions?
  - Obtain input of meteorological data combined with pollutant concentration data to completely monitor emissions
- Understand greenhouse gas emissions from DoD sources
  - Estimate amounts
  - Make new EFs specific to DoD.

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# 7 Synthesis of Priorities by Emission Source

One of the objectives of the workshop was to create a list of the highest priority needs. Participants in each of the breakout sessions were asked to select the top needs identified in earlier sessions. The outcome objective was to further refine and prioritize these needs with each breakout group developing a list of high-priority objectives relevant to their respective topic areas. Table 4 is a synthesis of the list aligned with the emission source.

**Table 4. Priorities Listed by Emission Source**

| Priority |
|---|
| **Particulate Emissions–Characterization** |
| Exploit ORS technologies (both satellite and ground-based) |
| Integrate remote and point measurements |
| Anticipate climate-change impacts (droughts, floods, global warming, invasive species) |
| Develop cost-effective measurement/monitoring tools (e.g., opacity) |
| Assess air-quality impact (vet the models) |
| Derive new paradigm for EFs with measurement methods (validated and demonstrated protocols) for flux and opacity measurements |
| Study regional emphasis of prescribed and wildland fires |
| Investigate risk of hazardous pollutants (hazardous constituents of the dust) |
| **Particulate Emissions–Monitoring/Modeling** |
| Define “scenarios” of interest based on regulatory and other drivers (spatial and temporal time scales that will determine appropriate modeling approach) (modeling) |
| Improve near-field modeling science, especially deposition (modeling) |
| Develop, test, and evaluate hybrid modeling approaches (modeling)<br>• Use regional model for background<br>• Use near-field models for sub-grid results |
| Use inverse modeling to improve source/emissions characterization for use in air-quality models (modeling) |
| Use more source/receptor models to determine contributions that stress the need for improved source characterization (source profiles and parameterization) (modeling)<br>• Existing databases: EFs (WebFIRE), Speciation profiles (SPECIATE) |
| Integrate validation of models with measurements to improve inputs (emissions and met) and modeling science; compare across alternative models and hybrid approaches (modeling) |
| Improve coordination among agencies, develop means to make databases more readily available, and integrate databases from monitoring (e.g., WebFIRE for EFs, or SPECIATE database) (monitoring) |
| Develop effective and less subjective methods to monitor opacity along facility fence lines at short time scales (hours to minutes) (e.g., quantify plume opacity with remote sensing technology such as digital cameras) (monitoring) |
| Characterize large-scale plumes that could be aloft at much lower cost (e.g., optical remote sensing) (monitoring) |
| Use/develop monitors to evaluate closure between hybrid models and measurements (e.g., monitors located along fence lines and at regional/federally relevant locations) (monitoring) |
| Implement baseline routine monitoring and specialized vertical resolution and shorter time scales (help separate urban/regional/local scales) (monitoring) |
| Develop continuous monitors that speciate PM (e.g., prescribed burning) (monitoring) |
| **Particulate Emissions–Mitigation** |
| **Unpaved Surfaces**<br>• Develop broad-based protocol for evaluating dust suppressants, including their secondary impacts on other resources<br>• Conduct basic research on the physics of near-source dust deposition |
| **Dust Emissions from Building Deconstruction/Demolition**<br>• Safer technologies for deconstruction/disassembly as opposed to demolition of contaminated buildings<br>• Evaluating demolition control techniques to determine efficacy; collection of monitoring data |

| Priority |
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| **Computational Modeling and Data Management for Field Decision Making**<br>• Model prescribed burns, demolition, live-fire training, OB/OD, and wind breaks (erosion control) |
| **Wind Erosion**<br>• Use biological and physical mitigation strategies to control dust (short-term versus long-term strategies; adaptation to climate change) |
| **Range Burning**<br>• Exchange best practices among agencies to improve transferability and identify research gaps<br>• Develop alternative uses of biomass rather than pile burning (e.g., biomass to fuels) |
| **OB/OD; Impact Points/Areas**<br>• Design optimal OB/OD process to minimize emissions<br>• Explore potential reuse of explosives components of munitions<br>• Identify long-term alternatives to OB/OD |
| **Gaseous Emissions–Characterization** |
| Better characterize sources:<br>• Develop inventory of DoD bases/suspected fugitive gases so as to better target the technologies/methods, in particular VOC fugitive emissions. Start with pharmacy inventories<br>• Develop tiered approach of monitoring for specific species at certain installations<br>• Research of sources (emissions characterization) (suspects in red)<br>– Refueling/transfer operations VOC, semi-volatile organic compound (SVOC), hexachloroethane (HC)<br>– Storage/transfer operations—diesel, solvents, gasoline, jet propellant (JP)-5, JP-8, etc. benzene, toluene, ethylbenzene, xylene (BTEX), VOC, SVOC, HC, ketones, aldehydes<br>– Fires (prescribed burn, wildland fire, OB/OD) and other combustion scenarios VOC, SVOC, HC, Acrolein, formaldehyde (HCHO), CO, $CO_2$, HCN, HCl, NOx, SOx<br>– Industrial rework/maintenance: electroplating, welding, painting chromium (Cr) (VI) (as particle), ketone, benzene, xylene, and toluene (BXT), HCN, HCl<br>– Landfills, wastewater (IWTP), refuse disposal VOC, methane ($CH_4$), HC, $NH_3$<br>– Mobile sources CO, $CO_2$, HCN, HCl, $NO_x$, $SO_x$ |
| Develop Technology of Methods/Instruments<br>• IR sources<br>• Open path (FTIR)<br>• Sun photometers—need improvements<br>• Handheld instruments for CO (for firefighters, also characterize/monitor plume)<br>• Leak Detection Imaging systems—need speciation as well as geolocation<br>• Compact DIAL LIDAR compact special purpose Lidar for one wavelength—one species (group)<br>• More compact, more efficient, cheaper version of IR laser monitor (QCLs), e.g., for CFCs, HCFCs, fluorocarbons, VOCs, etc. VOCs currently underestimated by VOC losses ~1 order magnitude |
| Develop/refine (and acceptance of) a protocol (e.g., OTM-16) for regulated measurements via use of reference materials.<br>• Established Methodologies or Organizations<br>• EPA methods<br>• ASTM<br>• OTM, e.g., OTM-10 (verify/develop TO-16 for each compound?)<br>• NIST—allows voluntary control organizations (VCO)<br>• ISO<br>• American Petroleum Institute |
| Develop approaches for the installations based on what protocols are available, but tailored to individual effluents |
| Develop approaches for installations (similar to Rainbow series at USFS) series of how-to document to monitor fires<br>– Easily accessible management document for guidance |
| **Gaseous Emissions–Monitoring/Modeling** |
| Develop critical state-of-the-science document describing monitoring and modeling available to meet DoD's needs in conjunction with regulatory agency needs (stress needs of the facility managers) (general) |
| Document DoD research pertaining to fire activities (general) |

| Priority |
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| Foster better interagency cooperation (How to do it?) (general) |
| Evaluate best modeling systems for gas and PM emissions and transport for widespread uniform use—two or three recommended models (general) |
| Implement workshop to discuss commonality of facility needs and generalization of tools and training available for widespread use (general) |
| Develop real-time modeling capabilities for managers to determine plume transport (modeling) |
| Utilize NOAA/NWS $O_3$ and PM forecasting capabilities to help managers determine how/when to implement prescribed burning (modeling) |
| Improve back-trajectory models to better assess what is coming from particular sources (modeling) |
| Develop models to handle chemical interactions from other sources, regional consideration ($O_3$ potential and total $PM_{2.5}$) (modeling) |
| Conduct closure evaluation of transport models, monitoring measurements, and use of markers/tracers (modeling) |
| Develop better understanding nighttime/stable atmospheric conditions pertaining to prescribed burning (modeling) |
| Establish capabilities to provide modeling results that are needed to evaluate impacts on sensitive ecosystems (modeling) |
| Develop better understanding of interactions of prescribed and wildland-fire burning and the boundary layer (influence transport); test, evaluate, and implement models to improve predictions (modeling) |
| Analyze fluid dynamics of fire-related plumes (plume rise from multiple sources) (modeling) |
| Develop low-cost and portable monitoring methods and relate them to EPA reference methods (Office of Research and Development [ORD] and OAQPS are working on this area) (e.g., real-time air toxics, PAHs, terpenes as tracer for prescribed burning, $O_3$ to describe spatial resolution at receptors, $CO/CO_2$), low power (monitoring) |
| Conduct $NH_3$ monitoring (monitoring) |
| Implement smart target deployment of monitoring networks (monitoring) |
| Develop monitoring networks for gases combined with PM (monitoring) |
| Monitor prescribed burning/wildland fire induced VOC emissions (e.g., isoprene, terpene) (monitoring) |
| Monitor fire-related markers (e.g., levoglucosan?) and secondary aerosol formation (monitoring) |
| **Gaseous Emissions–Mitigation** |
| **Fires (Prescribed and Wildland)**<br>• Temporally optimize burning schedules to minimize air impacts (e.g., ozone versus regional haze)<br>• Integrate land management with air quality (e.g., mechanical treatment versus fire to encourage preferred vegetation) |
| **Training Range Activities**<br>• Less of a concern relative to particulate emissions (major source is vehicle emissions-mobile sources) |
| **Fuel Handling**<br>• Use IR camera or DIAL to identify operational emissions to survey where problems lie<br>• Apply integrated approach to emissions reductions using standard reduction techniques<br>• Study sensitivity to training compatibility |
| **Storage Facilities**<br>• Use IR camera use to identify "low-hanging fruit"<br>• Design protocols in partnership so that emission credits can be realized |
| **Land Management**<br>• Integrate pest management to reduce and document reductions<br>• Encourage interagency coordination/cooperation<br>• Monitor emission from changes in land use; study legacy issues for all media/pollutants |
| **OB/OD**<br>• Design optimal OB/OD process to minimize emissions (limit burn variability)<br>• Explore potential reuse of explosives components of munitions<br>• Develop long-term alternatives to OB/OD (e.g., HCl from large solid-rocket motors)<br>• Identify additives to put in OB/OD pits to act as sponge to absorb gaseous pollutants |

| Priority |
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| **Sources and Activities—Fires** |
| Key DoD bases that have a real concern with prescribed burns and smoke need to have a refined fuel beds and characteristics map. |
| Remote-sensing technologies (satellite, air platform, and ground-based) should be integrated and included in model comparisons. |
| Plume-rise characterization should be improved, particularly to discern the distribution of materials with plume height. This should be accomplished through a combination of Lidar and other methodologies and should include a comparison to models. |
| Integrated field experiments like ACE are recommended for looking at wildland fire emissions and fate. The experiments should follow the JFSP Smoke Roundtable methods for building and validating models. |
| Emissions model should be developed that consider meteorological conditions and plant conditions; they should also include emissions profiles for receptor models. |
| Low-cost monitoring devices should be developed and implemented. They can be routine or specialized monitors, depending on the particular event being monitored (e.g., optical devices such as cost-effective digital cameras and passive samplers). |
| Development of very specific tracers for biomass burning, including emissions profiles for receptor models, is needed. |
| Research is needed to distinguish between flaming and smoldering phase emissions. |
| A data/information repository would be a useful tool and could probably be a component of an ACE type of effort. |
| Real time and more complex (e.g., hybrid) modeling of the various processes occurring in wildland fires, including $O_3$ generation, is needed (compare with ACE). |
| A comprehensive literature review of air-quality modeling is needed to provide DoD with a modeling framework for their needs. |
| The benefits and tradeoffs of prescribed fire vis-à-vis carbon sequestration and greenhouse gases should be evaluated. |
| **Sources and Activities—Training Range** |
| Evaluation and standardization of methods and protocols for emission potentials, especially for soil characterizations |
| Survey of activities that generate dust |
| Emission measurement protocols |
| Source signatures to determine the sources of dust in order to control dust generation at the source |
| Emission factors scaling |
| Determine the processes that are instrumental in deposition of dust |
| Verification of models for off-site transport |
| Apply through example case studies—activity-based |
| Emissions methodology is needed (OB/OD) |
| **Sources and Activities—Fuels, Lubricants, and Solvents** |
| Evaluate environmental effect of fuel changes (fuels)<br>• Understand emissions from alternative fuels<br>• Study environmental effects of single fuel policy in Army |
| Develop methodology to quantify volatile organic emissions from DoD installations (Bubble Approach) (fuels)<br>• Use open-path techniques and visual camera techniques (IR and open-path FTIR) |
| Consider pharmacy inventory practices applied to DoD use of solvents |
| Evaluate work practices to determine if changes could be made to reduce solvent loss (solvents) |
| Apply meteorological data to open-path FTIR to better monitor emissions (general)<br>• Are current wind monitors providing the best information for measurement of emissions?<br>• Obtain input of meteorological data combined with pollutant concentration data to completely monitor emissions |
| Identify greenhouse gas emissions from DoD sources (general)<br>• Estimate amounts<br>• Identify new EFs specific to DoD |

Note: Abbreviations and acronyms used in Table 4 are defined in the List of Acronyms

# 8 Priority Outcomes

After the formal workshop concluded, a small group consisting of breakout group chairs, white paper authors, and the workshop sponsors engaged in a half-day meeting to review, clarify, and refine the recommendations and priorities expressed during the workshop. This section discusses the prioritized outcomes of this session.

## 8.1 Improve characterization, monitoring, modeling, and mapping of fuels to support enhanced smoke management and fire planning at DoD installations

### 8.1.1 Background

Large tracts of lands managed by DoD require fire to be applied to maintain ecosystems, treat fuel accumulation, and manage sites for military operations (Figure 1). When applying fire, however, various emissions are produced including criteria pollutants of $PM_{2.5}$, CO, and $O_3$. These particulates and gaseous compounds can be hazardous to human health, threaten human welfare and ecosystems, degrade visibility, and contribute to greenhouse gas emissions (Sandberg and Dost, 1990; Sandberg et al., 1999; Hardy et al., 2001; Battye and Battye, 2002; Sandberg et al., 2002). To mitigate the human health and welfare hazards, wildland fire emissions are regulated under the NAAQS and Regional Haze Rule by EPA and by SIPs. As the NAAQS $PM_{2.5}$ ambient 24-hour standard drops from 65 to 35 $\mu g\ m^{-3}$ and EPA proposes tightening the ambient NAAQS ozone standards (8-hour average), the regulatory atmosphere will require DoD land managers to quantitatively predict, report, and manage wildland fire emissions generated on their lands (Environmental Protection Agency 2006, Environmental Protection Agency 2008). This will require explicit knowledge of the emission source including size of the area burned, characteristics of the fuel, the amount of fuel consumed, and emission factors for specific pollutants. Although many errors and uncertainties arise in all phases of estimating emissions, the largest errors are related to the characteristics of the fuels and amount of fuel consumed (Figure 2; Peterson and Sandberg, 1988). Consequently, it is suggested that new smoke management research should be directed toward improving the ability to monitor, model, and map fuelbed characteristics, continued development of a fuelbed building and cataloguing system, and improving the ability to predict fuel consumption by the combustion phase.

**Figure 1. Prescribed Burn on Eglin Air Force Base March 2008.**

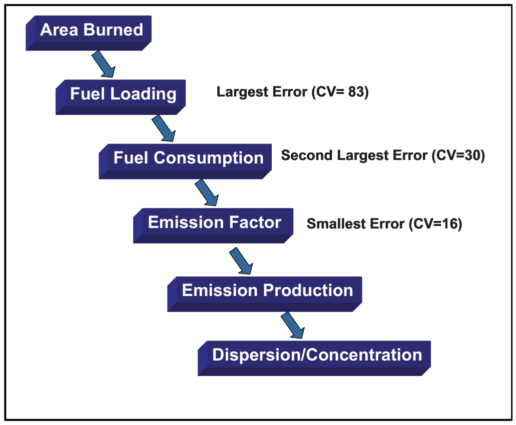


**Figure 2. Input variables and errors associated with predicting emissions from wildland fires**

### 8.1.2 Significance

Knowing characteristics of a fuelbed including what fuelbed components exist, the species composition, and fuel loading are critical to improving the estimation of wildland fire emissions from DoD-administered properties. Although significant advances in characterizing and cataloguing fuelbeds have occurred over the past 20 years, this research has been directed toward fuel loading of the small and large sound (not decomposed or rotten), dead woody fuels remaining after logging operations or following an ice storm or wind event. Minimal research has been directed toward other fuelbed categories, such as tree crowns, shrubs, grasses, large rotten woody fuels, litter, and duff, to model and predict wildland fire emissions and possible impacts (Ottmar et al., 2007). Furthermore, the mapping of fuelbeds has only occurred at extremely large scales (LANDFIRE 2005) and has not been routinely applied at the project or unit scale required for managing wildland fire smoke. Further development of analytical and monitoring techniques for characterizing all fuelbed components, constructing representative fuelbeds for DoD managed lands, and mapping those fuelbeds across DoD installations would improve smoke management and fire management planning and assist in assessing areas for ecological health and carbon stores.

Characterizing fuels for DoD properties for smoke management planning will require the building of many representative fuelbeds and the development of a system to house those fuelbeds. Attempts have been made to develop systems that construct and catalogue fuelbed components and properties with differing degrees of success (Deeming et al., 1977; Anderson, 1982; Hirsch, 1996; Cheney and Sullivan, 1997; Reinhardt et al., 1997; Ottmar et al., 1998). Because these systems were designed for specific software applications, they included only that portion of the fuelbed components, characteristics, and properties required by the software they were designed to support. Consequently, the early systems did not capture certain important fuelbed categories required by models to estimate emissions production and impacts. The Fuel Characteristic Classification System (FCCS) (Ottmar et al., 2007) was developed to provide users with a tool that enables the creation and cataloguing of fuelbeds and the ability to classify those fuelbeds for their capacity to support fire, consume fuels, and generate emissions. The FCCS could be modified and adapted for all DoD fuelbed types and characteristics.

Fuel consumption by combustion stage is another critical component needed to estimate smoke generated from wildland fires and assessing fire impacts. Generally, two to four times more smoke is produced during the smoldering stage than flaming stage and quantifying the fuel consumed by combustion phase is critical for estimating smoke produced (Hardy, 2001). Significant research has been carried out over the past 30 years to develop models for estimating fuel consumption including the First Order Fire Effects Model (FOFEM; Reinhardt et al., 1997) and Consume 3.0 (Ottmar et al., 2005). This research, however, was confined to flaming and smoldering consumption of grasses and down, dead, sound (not decomposed or rotten) woody material. Minimal research has been conducted to evaluate the consumption of tree crowns, shrubs, rotten logs, litter, and the organic layer during the flaming and smoldering combustion phase. For managers to develop improved wildland fire plans that will meet specific smoke management guidelines, research will be required to improve fuel consumption software equations currently in existence. This research would improve fuel consumption models for the estimation of fuel consumption during the flaming and smoldering stage for tree crowns, shrubs, down, rotten wood, litter, and duff.

The significance of these areas of research will be to (1) advance the science and technology in quantifying fuelbeds and fuelbed consumption for improved wildland fire emissions prediction for input into emission production and dispersion models; (2) provide fuel characteristics and fuel consumption outputs for ecological planning, fire effects and fire behavior estimates; (3) advance the science of modeling fuel consumption during wildland fires; (4) provide the air quality regulators and land managers at DoD installations with improved technology for assessing the impact of fires on air quality and public health; (5) assist DoD bases in obtaining the prescribed burning permits based on the best science and technology; and (6) estimate carbon stores and carbon emissions.

### 8.1.3 Recommendations

The following described work would improve the characterization, monitoring, modeling, and mapping of fuels and fuel consumption on DoD lands. Accomplishing these objectives will provide an improved source characterization for determining emissions generated from wildland fires, improve fire and smoke management planning, and improve ecological assessments. There are three major suggested tasks:

- Further the development of the science and technology necessary to characterize and map fuelbeds for smoke and fire management, as well as for habitat management planning on DoD installations.
- Provide a fuelbed modeling framework that will enable managers to create and catalogue fuelbeds and to classify those fuelbeds based on their capacity to support fire, consume fuels, and generate smoke.
- Improve the science and technology necessary to predict fuel consumption for critical fuelbed components including trees, shrubs, grasses, downed, dead woody fuels, litter, and duff during wildland fires on DoD installations.

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## 8.2 Enhance smoke management at DoD installations using advanced monitoring and modeling approaches

### 8.2.1 Background

During the past three decades, tremendous progress has been made to understand the emissions of trace gases and aerosols from fires in different ecosystems and their impacts on the environment. Pressure is increasing recently on air quality regulators and land managers to assess quantitatively the environmental and regulatory impacts of smoke emitted by fires on air quality and public health. The major regulations pertinent to fire emissions are the Regional Haze Rule and the NAAQS for $PM_{2.5}$ and $O_3$. Recent NAAQS $PM_{2.5}$ reduction of the ambient 24-hour standard from 65 to 35 µg $m^{-3}$ and EPA's proposed tightening of the ambient NAAQS $O_3$ standards (8-hour average) have required air quality regulators and land managers to quantitatively address the role of fire emissions in air pollution. We will summarize the current knowledge and major issues on characterization, monitoring, and modeling of smoke emissions, dispersion, and transformation from prescribed fires and wildfires at DoD installations.

**Characterization**. Significant research has been carried out to determine the EFs of atmospheric pollutants from prescribed fires and wildfires in various ecosystems. Most of the field experiments of biomass burning often were carried out near the end of the dry season with low fuel moisture content. These combustion conditions favor flaming combustion and are characterized by low emissions of carbon monoxide, PM, and hydrocarbons, which are ozone precursors. Most of prescribed burning, however, occurs at the beginning of the dry season, with relatively high fuel moisture content and probably higher emission factors of CO and hydrocarbons. These measurements were also taken with limited information on vegetation (e.g., fuel moisture content, elemental composition) and meteorological (e.g., temperature, humidity, wind velocity) conditions. To apply the emission factors to a variety of combustion conditions at different DoD installations, a dynamic model of emission factors must be developed to relate the EFs to a wide range of fuel and weather conditions at major DoD installations where fires occur. In addition, most of the previous measurements were made by taking grab samples at a fixed location. The current work seeks improved analytical techniques for measuring more representative time- and space-integrated atmospheric pollutants using ground- or airborne-based optical remote sensing instruments during the flaming and smoldering combustion of vegetation fires.

**Monitoring**. Fires are episodic events that emit a large amount of pollutants within a short time period of several hours or days. The concentrations of pollutant levels have to be monitored continuously in real-time at DoD installations during the fire season in order to assess in a timely manner the impacts of these pollutants on air quality and public health. New in-situ monitoring instruments should be developed to measure time- and space-integrated concentrations of major pollutants (e.g., CO) over a large area. These instruments must be fast-response, portable, compact, low power usage, and cost effective, so they can be installed at major DoD installations in the Southeast, Southwest, and Northwest where most of the fires occur. Satellite remote sensing should be used to provide large-scale measurements that place DoD emissions within a regional air quality framework.

**Modeling**. The impact of fires on air quality and public health in communities adjacent to DoD installations or over an area from a few kilometers to several hundred kilometers away from the installations can be evaluated quantitatively by linking the emission source models and plume rise models with the atmospheric transport-chemistry models. Although several state-of-the-art plume dispersion and transport models are available, their applications to prescribed fires and wildfires have not been rigorously validated. The behavior of fire smoke plumes varies with the combustion process that depends on the biomass burned, fire intensity, topography, and changing atmospheric conditions (e.g., temperature, humidity, wind velocity). In addition, fires, especially wildfires, usually have multiple cores produced during the combustion process, introducing additional complications for smoke plume dispersion modeling.

The validity of using these models for assessment or forecasting purposes relies on the accuracy of pollutant concentrations estimated by the models in different scales and scenarios. Few observational datasets of fire smoke plumes are available to properly evaluate these models. A series of well-coordinated prescribed fire experiments at DoD installations, complemented by satellite remote sensing measurements, should be carried out to validate the individual or integrated models of fire emissions, plume dynamics, and long-range transport and photochemical processes. For example, the plume rise and dispersion models should be validated by continuous in-situ measurements using ground-based remote sensing instruments (e.g., lidar) over an area affected by smoke in daytime and nighttime. Airborne measurements of pollutant concentrations close to the source and in the plumes downwind from the fires would enable validation of the emission source models and the long-range transport and chemistry/aerosol models. Experimental fires from several hundred to thousand acres in different ecosystems at DoD installations may be burned from several hours to days. The field experiments should enable a rigorous validation of current fire emissions, smoke plume dynamics, long-range transport, and transformation models and facilitate the modification and improvement of these models into the decision support tools for DoD land management. Validation of these models provides the accuracy of the model calculation under various scenarios, which would give air quality and land managers the confidence for using the model results. In addition, satellite remote sensing measurements of burned area, the soil and fuel moisture content, and smoke transport should provide the estimation of smoke emissions, transport, and transformation over a large area.

### 8.2.2 Significance

The outcomes of this research will advance the science and technology for quantifying smoke emissions, monitoring pollutant concentrations, and modeling smoke plume rise, dispersion, and transformation; provide air quality regulators and land managers at DoD installations with the technology for assessing the impact of fires on air quality and public health; and assist DoD installations in obtaining prescribed burning permits based on the best science and technology.

### 8.2.3 Recommendations

The research should address the following areas:

- Characterize and quantify the emissions of atmospheric pollutants from fires spatially and temporally in a variety of ecosystems at various DoD installations. This research should focus on using ground- or airborne-based optical remote sensing instrumentation to measure the gaseous chemical composition and the physical, optical, and chemical properties of particulate matter emitted from prescribed fires and wildfires. In addition, a dynamic emission model should be developed to predict the emission factors as a function of vegetation and meteorological conditions.
- Monitor in real-time the gaseous and particulate pollutant levels either inside or in close proximity to DoD installations. This research requires development of portable, fast-response, low-power, compact, and cost-effective monitoring instrumentation.
- Validate the models of smoke plume rise, heights, diurnal cycles, transport, and chemical transformation. This project requires conducting comprehensive field experiments to measure smoke plume dynamics and a variety of atmospheric trace gases and aerosol particles adjacent to or downwind from the fires at DoD installations. Satellite remote sensing can be used for monitoring and validating large fires.

## 8.3 Quantify, model, and monitor post-fire effects at DoD installations to improve fire management effectiveness

### 8.3.1 Background

The February 2008 DoD/EPA Workshop on Research Needs for Assessment and Management of Non-Point Air Emissions from DoD Activities convened a session on sources and activities associated with Wildland Fire Emissions. Session participants were charged to address the issues associated with emissions from both prescribed burns and wildfires on military installations. They were asked to build on the discussions from two previous sessions by focusing on the activities and sources that lead to both particulate and gaseous non-point source activities. With respect to fire emissions, the group was asked to assess DoD's air quality management needs; review and assess the state of science and technology discussed in the first two breakout sessions; review and assess the gaps in science and technology discussed in the first two breakout sessions; and recommend priorities for future SERDP and ESTCP investments to address these gaps. The Fire Emissions session proposed 12 recommended research priorities. The 12 Fire Emissions priorities were considered in a follow-up working group session and assigned to three overarching categories: Fuels Characterization, Monitoring, Modeling, and Mapping (generally pre-fire); Smoke Management Monitoring and Modeling Approaches (generally during-fire); and Fire Effects Quantification, Modeling and Monitoring (generally post-fire). The Post-Fire Effects category was assigned two of the original 12 priorities: 9—Data/Information depository (cf ACE type of project) and 12—Benefits/tradeoffs of prescribed fire vis-à-vis carbon sequestration and greenhouse gas (GHG), with the intent of documenting the tradeoffs between prescribed fire and wildfire in terms ecosystem sustainability objectives, fuel consumption, hazard reduction, smoke generation, carbon sequestration and GHG, and wind/water erosion, among a range of fire effects.

Fire use is a principal tool for fuel (vegetation) management as described in the Comprehensive Fuel Treatment Strategy (CFTS) under the National Fire Plan (NFP). Fire use is justified to reduce the potential hazard of future wildfires, to help sustain ecosystems and, most recently, to enhance carbon sequestration. The main public impacts of fire are personal injury or death, property damage or loss, and air quality and transportation system effects associated with smoke from wild and prescribed fires. Wildland fire smoke is subject to federal, state, and local air quality regulations. The effectiveness of fire use in reducing hazards and sustaining ecosystems can only be quantified through systematic monitoring and evaluation of post-fire effects. Because significant change is expected in both the ecosystem characteristics (Neilson, 2007) and the public receptor (Theobold, 2005) impacts relating to wildland fire in the decades ahead, long-term post-fire effects monitoring will be needed to help model the benefits of fire use in sustaining ecosystems.

DoD installation managers share several fire use benefits, needs, and constraints with other federal, state, and local land managers, but they also have to work under some dissimilar circumstances. DoD managers employ fire for sustainable ecosystem management at DoD installations. DoD managers' use of fire is constrained principally by smoke impacts on people living in proximity to DoD installations and by their ability to quantify, model, and monitor long-term ecosystem effects. DoD installations (Figure 3) are located in a variety of ecosystems (Figure 4) with differing fire regimes and with differing proximity of communities potentially impacted by smoke and other prescribed fire effects (Figure 5).

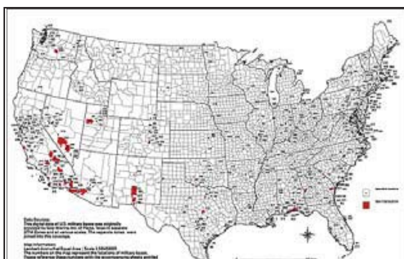

**Figure 3. Military Bases in the Contiguous United States**

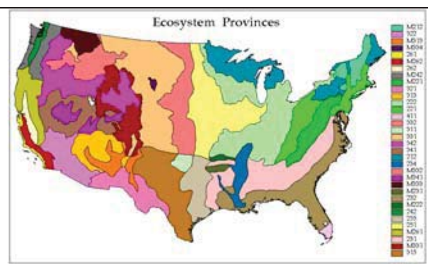


**Figure 4. Bailey Ecosystem Provinces (Bailey, 1995)**

**Figure 5. Characteristics and location of the Wildland Urban Interface (WUI) in the United States (Radeloff et al., 2003)**

Fire use guidelines (including smoke management) are maintained by the National Wildfire Coordinating Group (NWCG) Fire Use Working Team (FUWT). The Fire Effects Information Systems (FEIS) is a useful online repository for information of living organisms and their biology, ecology, and relationship to fire. FEIS is the home site for the "Rainbow Series," a six volume series summarizing various components of wildland fire effects on ecosystems (e.g., effects on flora, fauna, water, soils, air, and nonnative invasive species). Therefore, a body of fire use and effects information is available for specific application to DoD installations. The Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) "is a five-year, multi-partner project producing consistent and comprehensive maps and data describing vegetation, wildland fuel, and fire regimes across the United States." Future DoD fire use project data and information will benefit from consistency with LANDFIRE. LANDFIRE anticipates increasing use of Satellite Remote Sensing (SRS) technology for future data base updates and for ecosystem change monitoring.

Most existing fire use effects information is based on empirical information and thus does not incorporate larger scale changes in demographics or climate change driven ecosystem effects. To project the long-term effects and benefits of fire use on DoD installations, we need to begin to incorporate parameterizations of these types of large-scale change in DoD fire use planning. For example, a prescribed fire used today that realistically reduces the risk and or potential size of a wildfire 10 years in the future may gain the added benefit of lessened smoke impacts on the future increased civilian population in proximity to DoD installation. Likewise, when assessing the projected long-term ecological benefits of a prescribed fire, such change agents as invasive species and climate variability/change should be factored into the benefits and constraints balance.

Long-term post-fire effects of both prescribed fires and wildfires originating on, or propagating onto, DoD installations need to be quantified, modeled, and monitored to more accurately describe the ecological and societal benefits deriving from fire use and the smoke impacts inherent therein. For example, do the projected benefits of fire use actually accrue in the long-term and can those benefits be quantified by post-fire monitoring and assessment? Can long-term post-fire monitoring and assessment be accomplished in a cost-effective manner? Does prescribed fire use provide smoke management benefits when compared to probable wildfire occurrence? These questions are amplified when increasing larger-scale environmental change is viewed as affecting the envelope for DoD operations over the next 15 years (2010–2025) and beyond.

### 8.3.2 Significance

Quantification, modeling and monitoring of post-fire effects are critical components of a fire management program to verify that prescribed burn program objectives are being achieved, provide for accurate communication of the benefits of prescribed fire programs to regulators and concerned publics, and better predict post-fire ecosystem evolution in view of larger-scale environmental change.

Multiple pre-fire, fire, and post-fire variables contribute to post-fire effects in terms of erosion, invasive species, regeneration, wildlife habitat, hazard reduction, vegetation recovery, etc. Systematic evaluation of post-fire conditions is the only means available to accurately assess the long-term outcomes of fire management programs. Because post-fire evaluation will need to cover a growing catalogue of individual burn events over an increasing period of time, methodologies are needed that provide broad spatial coverage in a cost-effective manner and data inventory systems that provide long-term accumulation, analysis, and access.

Because long-term post-fire effects play out over decadal timeframes and are likely to be impacted by large scale change agents, in situ and near proximity measurement of post-fire effects will be fragmented and overly burdensome to maintain. Incorporating SRS and GIS technologies into the program for post-fire effects at DoD installations will enable proper temporal and spatial scaling, as well as data management, needed for quantification, modeling, and monitoring of post-fire effects at DoD installations. Use of these technologies also will facilitate multiple installation usage of obtained fire information.

### 8.3.3 Recommendations

The following recommended work would establish quantification, modeling and monitoring of post-fire effects at DoD installations to improve fire management effectiveness. Accomplishing these objectives would serve to enhance DoD fire management programs, facilitate communications with regulators and concerned publics, and prepare DoD to better manage ecosystem holdings under changing large-scale environmental conditions.

- Develop/adapt/modify a relational database management system to support immediate and long-term monitoring and reporting of fire effects at DoD installations
- Develop models and linkages necessary for DoD cooperation with FEIS, LANDFIRE, and other applicable fire effects systems
- Develop/apply satellite remote sensing methodologies to provide cost effective long-term monitoring of post-fire effects at DoD installations, including burn severity assessment, burned area and burned area recovery, post-fire vegetation dynamics, erosion; invasive species monitoring habitat recovery, etc.
- Develop techniques and models for quantifying how DoD fire management impacts carbon storage in DoD managed ecosystems

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## 8.4 Develop surface characterization procedures for determining dust emission potential

### 8.4.1 Background

Military training ranges tend to have a considerable potential for fine particle dust emissions generated by mechanical disturbance and by wind erosion of surface materials, especially in areas where the ground surface is regularly disturbed. This includes, unpaved roads, trails and staging areas, and munitions impact areas at weapons ranges. The dust emission potential of these areas is also affected by weather cycles and is intensified by drought conditions that may be associated with climate change. In the implementation of dust controls by preventive and mitigative measures, the ground surface condition needs to be regularly monitored for its dust emission potential defined in both time and space.

The potential of a ground surface area to emit fine particles during high wind events is a complex function of the degree of compaction of the surface, the texture of loose particles on the surface, the moisture content of the surface, the protection afforded by non-erodible elements on the surface (agglomerates larger than 1 cm in diameter), and as a result of mechanical disturbances. In the case of open area wind erosion, surface protection is also afforded by any live vegetation or debris that blocks the wind flow. It should be noted, however, that the availability of loose sand-sized particles at upwind locations can cause emissions to occur from an otherwise stable surface under high-wind conditions, because of the sandblasting effects of saltating sand particles that bounce across the soil surface.

Field inspection methods have been developed for determining the dust emission potential of different ground surfaces. The dry silt content (particles passing a 200-mesh screen upon dry sieving) of the surface material has traditionally been used as a surrogate for fine particle dust emission potential of travel surfaces. Questions, however, have been raised as to whether dustiness surrogates can be determined that can relate more directly to the fine particle content of the surface material available for entrainment by vehicle movement. As part of the measurement of silt content, moisture content also is determined.

Manual methods for determining crust strength include a dropped ball test and a friability test on carefully removed sections of crust. A hand-sieving test is available for measuring the threshold friction velocity of loose dust particles on the soil surface. The coverage of non-erodible elements can be used to adjust upward that threshold friction velocity. Finally the canopy coverage of vegetation can be used to estimate the surface protection formed by “wind shadows.”

Soil texture maps also have been used to classify the wind erodibility of soils into broad groups. A Wind Erodibility Group (WEG) soil classification has been developed that relates soil texture to its propensity for fine particle re-suspension. It should be noted, however, that typical soil texture maps are directed to farming applications and represent the "A" horizon to a tillage depth in the range of one foot. As a result, usually a large discrepancy exists between the texture of loose material on a non-agricultural soil surface and the parent soil represented on a soil classification map. For example, in native desert areas of the west, stable soil surfaces are covered with a rather homogeneous coating of soil deposited from the airborne soil mix that settles after successive high wind events.

Although wind-generated emission rates can be inferred from dust concentrations measured above the eroding surface during high wind events, the association of net emissions with specific ground areas is difficult because of the high background dust levels. Portable wind tunnels provide for well-controlled wind erosion test environments, but they have limitations with regard to simulating fully developed saltation and the complexity of turbulent flow associated with high wind events. Perhaps the most important limitation of wind tunnel testing is the high cost of implementation, which makes it infeasible for characterization of large land areas associated with military training ranges.

At an intermediate level, dust emission characterization for road surfaces and open ground areas can be obtained using various surface particle re-suspension devices that have been developed to measure the reservoir of fine particles on an aggregate surface. These devices tend to be portable and less expensive to operate, but they typically provide only relative measures of surface emission potential. In addition, a lack of information exists on performance comparability between these devices and the more refined methods that measure actual emissions from traffic or wind erosion.

### 8.4.2 Significance

The air quality impacts of fine particle dust emissions generated by military training activities may have a detrimental effect that could impair the full use of military installations. This has become more critical in areas that are nonattainment with the NAAQS for PM ($PM_{10}$ and $PM_{2.5}$). It is expected that fine particle dust emissions from military installations may be subject to additional attention and restrictions to bring nonattainment areas into compliance with the $PM_{10}$ and $PM_{2.5}$ NAAQS.

An integrated set of surface inspection and test procedures is needed to determine the dust emission potentials of travel on otherwise disturbed surfaces and open areas. This information will be extremely useful to asses the contribution of dust emissions to the air quality in relation to the NAAQS. Such procedures should be feasible for application to large land areas and travel routes associated with military training ranges. These procedures might be structured in a tiered fashion starting with Level 1 manual screening methods for isolating problem areas that require further characterization. The Level 2 procedures would incorporate the smaller automated devices for generating and measuring particle re-suspension. The Level 3 procedures would include more costly methods, such as wind tunnels or plume profilers. A key part of this research need is the definition of the performance comparability and limitations of each method in relation to the most appropriate reference methods for measuring dust emission potentials.

Improving our ability to continuously monitor the potential for fugitive dust emissions will enable military establishments to better manage those processes and to more easily complete their environmental permit and related emissions reporting requirements. Such knowledge is likely to lead to easier and less costly PM emission reductions for SIPs and permitting purposes. Such improvements in management practices will ultimately translate into better operational range sustainability, environmental benefits, and cost savings by efficiently predicting and controlling the most significant sources of fugitive dust.

### 8.4.3 Recommendations

The goal of this proposed area of investigation is to conduct fundamental and applied research that leads to a better understanding of how best to characterize soil and substrate properties for the purpose of developing more accurate, comprehensive, continuous, and useful predictors of airborne dust emission potential. Work should focus on one or more of the following specific objectives in order to fill important gaps in the current knowledge base:

- Compiling new or improved relationships between soil composition and other parameters and the pre-disposition for the particles becoming airborne as the result of mechanical and wind disturbances. The research should use independent technologies and methodologies for cross-comparing and validating the resulting equations and relationships, taking into account the variability in soil texture and moisture conditions.
- Determining the range, specificity, and applicability of new, remote-sensing technologies, in comparison with surface inspection and test methods, for quantifying the primary soil characteristics as found in the first bullet.
- Preparing an integrated data collection and validation approach to correlate results of airborne dust quantities with other emission-estimating techniques. This shall include procedural and accuracy requirements for individual military installations to use in obtaining the site-specific data required as found in the first bullet.
- Investigating alternative land characterization methods for acquiring the needed soils data (e.g., satellite information) and for developing appropriate algorithms for maintaining a knowledge base suitable for military access and use in determining site-specific $PM_{2.5}$ and $PM_{10}$ fugitive dust emissions.

## 8.5 Improve understanding of the generation and transport of fugitive dust as a function of the interaction between soils, terrain, and mission activity

### 8.5.1 Background

Estimating fugitive dust emissions on military installations is often hampered by inadequate information related to soil characteristics found at the emission points and the operation of equipment causing PM emissions. Fugitive dust is created by vehicle and aircraft maneuvers, artillery/missile backblast, range maintenance and construction activities, and wind erosion. Fairly good information exists for total miles traveled by U.S. Army and Marine vehicles. Selected information also is known on the extent of paved and unpaved roads found on military installations. For example, it is estimated that unpaved road surfaces account for 93 percent and 85 percent of the road networks at Forts Leonard Wood and Jackson, respectively. The activity information, however, is collected mainly for maintenance purposes and critical activity information is missing that is needed to accurately estimate emissions. This missing information includes the ratio of paved/unpaved travel, daytime versus nighttime travel, and the frequency of time the vehicles operate at different speeds on these surfaces. Ground-based vehicles are only part of the picture. A similar situation exists for rotary wing aircraft in which the hours of operation are known but not how often the aircraft are flying low enough to cause fugitive dust emissions or how many takeoffs and landings are from paved and unpaved surfaces.

Soil, vegetation, and terrain information is vital for estimating fugitive dust emissions and determining the near field (up to 200 meters) reduction of fugitive dust during plume transport. Soil characteristics that are important include soil moisture, size distribution of soil particles, chemical composition, and extent of soil surface disturbance. Information that can help identify near field sinks of fugitive dust includes the presence of significant terrain features and the type, height, and density of vegetation. In general, the information described above is often unknown for military fugitive dust generation points. Soil moisture content is a particularly difficult problem to overcome because of the large temporal and spatial variation of this parameter.

### 8.5.2 Significance

The lack of specific equipment activity, soil, and vegetative information prevents military installations from accurately estimating fugitive dust emissions and near field deposition reductions. Without reasonable values of required information, neither the military nor regulators can determine the relative contribution of military fugitive dust sources to local and regional PM emission inventories. The inability to determine representative fugitive PM emission estimates can result in overly conservative emission estimates that could lead to future compliance driven limitations on military training and testing activities. Compliance problems will increase as existing PM NAAQS are enforced and become more stringent, as visibility regulations become established, and as population densities increase around military installation borders. As fugitive dust issues continue to emerge, the need for military specific information to properly apply fugitive dust emission, transport, and mitigation models will become more critical.

### 8.5.3 Recommendations

Address issues related to understanding the interaction of the quantity and duration of military activities with landscape characteristics that increase or diminish the generation and transport of fugitive dust. In all cases, the information must be characterized according to its relative importance and the uncertainties associated with its collection and use. The requirements include the following recommended efforts:

- Investigate on-site operation of military activities during training and testing and identify those operational characteristics/use dynamics that generate fugitive dust. Variables to be considered include those operational parameters that have an especially high potential to generate PM. Investigative studies of typical training and testing scenarios should determine normal ranges for each important variable. For example rotary wing aircraft could be instrumented to record their elevation above the ground, their speed, and the number of takeoff and landings on unpaved surfaces.
- Understand the landscape characteristics, soils, vegetation, and terrain that play an important role in fugitive dust generated directly from military training and testing activities. This would include the soil characteristics and the mechanics of soil particle movement and deposition within varied terrain that can affect the potential to generate PM. This would also include their importance in near field reduction of dust transport. This latter consideration

can be related to vehicle use and dynamics, but more importantly to soils, vegetation types, and local conditions relating to climate and terrain that increase the transport of PM.

- Identify the interactions of anthropogenic and natural conditions that influence wind generation of fugitive dust. Most current wind erosion models and tools, e.g., the Wind Erosion Prediction System (WEPS), were not developed with consideration of the parameters of military unique use of land and the complex terrains that exist on installations.
- Provide methodologies for military installations to follow in obtaining the prioritized parameters defined through the above three bullets. The data gathering activities should develop new data collection methodologies that would serve as blueprints for all installations.
- Create a database of training and testing activity and landscape characteristics data relevant to predicting fugitive dust emissions and near field reduction of fugitive PM plume transport. Data should include quality ratings and metadata referencing the sources of the included information. Initially the database would house information that is known and also provide a framework for information that still needs to be collected. When complete, the database would provide typical or default values for military installations that are not able to collect their own information.

## 8.6 Develop an emissions model broadly applicable to wheeled and tracked vehicle fugitive dust emissions

### 8.6.1 Background

Fugitive dust is created by vehicle and aircraft maneuvers, artillery/missile backblast, range maintenance and construction activities, and wind erosion on disturbed surfaces (Belnap et al., 2007; Gillies et al., 2005; Gillies et al., 2007; Kuhns et al., 2005; McFarland et al., 2006; Moosmüller et al., 2005). The amount of dust suspended depends on the properties of the soil (especially the reservoir of small particles and moisture content), the method and intensity of suspension (mechanical or turbulence), and prevailing meteorological conditions (Cowherd, 2001; Watson et al., 2000). Early work, and the basis for most emission factors used in EPA's emission inventory, obtained measurements of Total Suspended Particulate (TSP)—50% of particles <~50 μm aerodynamic diameter—at various heights in the downwind plumes. These have been adapted to $PM_{10}$ and $PM_{2.5}$ using assumed particle size multipliers. These emissions were empirically related to soil silt content (determined by dry sieving, geometric diameter <75 μm) and various mechanical and meteorological variables (e.g., vehicle speed, surface friction velocity, vehicle weight).

Recently, more complete surface characterization, remote sensing, in situ particle sizing, and micrometeorological measurements have been combined with improved theories of forces acting on suspendable particles. This knowledge is scattered, however, and has not been used in a comprehensive study to bridge the gap between relevant properties of soils and activities and the models that estimate off-site source contributions, despite several workshops that intended to set research priorities (Countess et al., 2001; Cowherd, 1992; Watson and Chow, 2000).

Although it is commonly assumed that most dust settles out near the source, current modeling efforts predict large contributions at downwind receptors (Cakmur et al., 2004; Schwede and Paumier, 1997; Tegen et al., 2002). Chemical signatures of Asian and African dust storms have been detected at locations thousands of kilometers from the points of origin (VanCuren, 2003), confirming the potential for long-range effects. Soil properties relevant to suspension are poorly characterized, as are the interactions between the loose soil surface and mechanical and aerodynamic suspension processes and the deposition or impaction on obstacles of particles soon after suspension. Measurements of marker species in suspended dust that might provide a detectable "fingerprint" at downwind receptors (Labban et al., 2006) are also lacking. These knowledge gaps result in highly uncertain emission rates and an inability to quantify $PM_{2.5}$ and $PM_{10}$ source contributions at sensitive receptors. The effectiveness of dust mitigation measures, such as suppressant application, re-vegetation, and shelter belts, is also unknown because few systematic and quantitative studies have been completed.

### 8.6.2 Significance

Fugitive dust generating activities often result in highly visible plumes, portions of which may be transported to areas of human exposure (Pope, III and Dockery, 2006) and visibility-protected national parks and wilderness areas (Watson, 2002). Some of these dusts also may contain HAPs that also are regulated. Better theoretical and empirical approaches to relating emissions to surface properties and to the models that estimate their impacts are needed. These approaches must be developed in an integrated and cost-effective manner that can span a wide range of situations. It is also important to legitimize these approaches and methods for use by a broader audience to address $PM_{10}$ and $PM_{2.5}$ SIPs, reasonable progress required by the CAVR, and Title V HAPs permitting.

### 8.6.3 Recommendations

This project would provide a linkage between easily measured soil surface properties that could be obtained at a large number of facilities at a relatively low cost and source and receptor models that estimate the off-site contribution of suspended dust to $PM_{2.5}$ and $PM_{10}$ concentrations. It would combine measurement and theory to create an emissions model applicable to wheeled and tracked military vehicles that could be applied at a large number of facilities other than those at which the tests are conducted. The experiment should include sufficient independent to allow evaluation of the emissions model. This project should be coordinated with other research that would develop and apply methods to determine relevant surface properties and activities at military bases and the source and receptor models that would use the emissions characteristics to determine off-site impacts of dust raised from wheeled and tracked vehicles operating on unpaved surfaces. It would take advantage of different dust mitigation efforts to quantitatively estimate their effectiveness.

Variables relevant to dust suspension would be tabulated, and the range of these variables to be encountered at different DoD facilities would be examined to design real-world emission characterization experiments. Proven methods, including both in situ and remote sensing, would be identified and integrated into a reliable and deployable package that can be efficiently moved from location to location to obtain dust suspension measurements for activities surfaces that are judged to cause the greatest potential for offsite impacts. Data acquisition, processing, and validation software would be integrated with the measurement hardware to provide rapid and reliable integration of measurements from different continuous instruments and laboratory analyses. Relevant properties to be measured include—but are not limited to—particle size distributions at different heights and downwind locations, plume heights for different suspension causes, micrometeorological parameters that engender suspension, transport, and deposition, and chemical fingerprints in relevant size fractions. Acquired data should be used to develop and validate theoretical models that relate surface properties, activities, and meteorology to emission quantities and composition for relevant size fractions. The experiments should cover a sufficient range of variables to quantify confidence intervals when emission models are applied to less costly parameters measured at a large number of locations. The validated and documented database produced should be sufficient for use in testing source and receptor models that estimate off-site impacts of the dust emissions.

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## 8.7 Develop and validate near-field models for fugitive dust emissions

### 8.7.1 Background

Environmental analysts rely on both monitoring and modeling to achieve air quality goals. Clearly, models that accurately simulate the physical processes that emit and transport PM provide the best tools for planning and projecting future conditions. Nevertheless, development of reliable models for open fugitive dust sources, such as those found at military installations, has been especially challenging.

At present, a major discrepancy exists between near-source measurements of fluxes of fugitive dust and other flux measurements made further downwind. The flux is defined as the mass of material flowing through a vertical cross-wind plane per unit time at any downwind distance. In the absence of removal by deposition or chemical reactions, the flux should be conserved. Some recent source apportionment studies show that the contribution of fugitive dust is substantially lower at large distances than one would predict based on emission inventories (Watson and Chow, 2000; Countess, 2003). Although these comparisons concern regional air quality with transport on the order of 10 km or greater, a similar mismatch is observed to occur on a smaller scale as well.

The nature of open fugitive dust sources requires that emission characterization be performed in the immediate vicinity of the source; however, only a fraction of the measured mass measured is available for transport away from the immediate source vicinity. Gravitational settling (possibly enhanced by agglomeration) and deposition may remove a substantial fraction of the mass from being transported very far downwind. Although the “transportable fraction” depends on many factors (such as surrounding ground cover, atmospheric stability, and injection height), an *ad hoc* “factor of four” value has been proposed as a gross average. This adjustment factor was conceived as a simple interim approach until thorough investigations could be undertaken (Countess, 2003; Pace, 2005).

Because of the need to sample over the effective plume area, measurements are typically made where the plume has a small cross-section. This “near-source measurement plane” for horizontal mass flux is on the on the order of 5 to 20 meters away from the source As the plume, however, continues to move downwind it interacts with the surroundings (such as ground cover, other vegetation, and surface obstacles). Various physical phenomena can occur, such as diffusion/mixing, gravitational settling, agglomeration to form larger particles, and electrostatic forces between particles and the surroundings (as well as among other particles). One can reasonably expect that at least some effects are highly correlated. For example, agglomeration would enhance any gravitational settling, whereas electrostatics could accentuate particle deposition onto surrounding vegetative surfaces.

### 8.7.2 Significance

By the time that the plume travels on the order of a few hundred meters from the source, the different physical processes will have produced at least two effects. First, the mass flux has decreased because of various removal processes. Second, the particle size distribution will have changed;[1] however, how different physical processes combine to produce those effects in any general physical setting is currently unknown.

The overstatement of how much PM mass travels away from the source has clear implications for DoD mission readiness. State and other regulatory agencies could impose severe restrictions on how and where training can be conducted. In other words, decisions are based on flawed information that overstates the near-field air quality impact of range activities. Training activities may be unnecessarily restricted until improved models become available to simulate suspension, transport, and removal processes.

### 8.7.3 Recommendations

Some field work has characterized particulate flux at different downwind distances (Etyemezian et al., 2003; Cowherd et al., 2006). Nevertheless, much more research is needed to develop and validate models that simulate emission (suspension), transport (advection, dispersion), and removal (deposition) processes that affect open fugitive dust. Inherent in the development is examination of the interplay of those and other physical phenomena (agglomeration, electrostatic forces, etc.) on the scale of a few hundred meters. Successful development of these models would greatly assist in planning to achieve environmental compliance. Additional benefits might include reduced safety hazards, increased efficiency in training, and lower vehicle maintenance costs.

[1] One would reasonably suspect that the material leaving the control volume is finer than that entering because deposition removes more massive (larger) particles. One can envision, however, situations (such as agglomerating particles traveling with a fast wind over a smooth surface) in which the size distribution might become coarser.

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## 8.8 Evaluate dispersion models for offsite impact, including evaluation with receptor-oriented source apportionment models

### 8.8.1 Background

Air quality regulators and land managers are under increased pressure to assess the environmental and regulatory impacts of non-point source emissions from DoD installations on air quality and public health. At DoD installations the primary non-point sources of interest are prescribed burns, PM generated from vehicle movement, and fugitive emissions from OB/OD. Both gases and particles are of concern. In all cases the source emissions are uncertain, including the mass that is released, its chemical composition and particle size distribution, its distribution in space and time, and its thermodynamic characteristics (e.g., heat released in prescribed fires and OB/OD). The spatial variations in local meteorology, including vertical profiles to heights where the plume extends, are seldom well known.

Many DoD installations currently use a variety of dispersion models for estimating the plume rise, transport and dispersion, and chemical conversions and deposition over distances where offsite health impacts may occur. The distances of interest range from the site boundaries out to 100 km or more from the source, where effects on PM2.5 and gas (e.g., $O_3$, NOx, and VOC) concentrations may be significant. For the larger distances, hybrid models are often used, where a near-field plume model is linked with a regional grid model.

An informal survey revealed that different DoD installations use different dispersion models. These include EPA-developed short distance models such as AERMOD (Cimorelli et al., 2005; and Perry et al., 2005), EPA and USFS-developed Lagrangian puff models for moderate distances such as CALPUFF (EPA, 1993 and 1995) and its DoD supported version of DUSTRAN (Allwine et al. 2007), the NOAA HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model as modified for dust (Draxler, 2004), the DoD-developed Lagrangian puff model HPAC (DTRA, 2004 and Sykes et al., 2007), DOE and NOAA-developed emergency response models National Atmospheric Release Advisory Capability

(NARAC; Nasstrom et al., 2005) and Areal Locations of Hazardous Atmospheres (ALOHA; NOAA, 1992), regional Eulerian 3-D grid chemistry models such as Community Model for Air Quality (CMAQ; Byun and Schere, 2006), and hybrid models that link near-field plume models to Eulerian grid models (Gillani and Pliem, 1996; Isakov et al., 2007; Karamchandni et al., 2000; and Stein et al., 2007). Some comprehensive hybrid modeling systems have been developed specifically for modeling dispersion from prescribed burns (e.g., ClearSky by Jain et al., 2007). Additionally, some DoD installations are still using legacy dispersion models such as the Ocean Breeze-Dry Gulch (OBDG) model, which is a correlation developed by the USAF over 50 years ago for application to Vandenburgh and Cape Canaveral. A needed task is to carry out a scientific review of these models and other candidate models, to evaluate them using available field data, and to make revisions that correct biases. For example, Chang et al. (2003) evaluated CALPUFF, HPAC/SCIPUFF, and Vapor-Liquid-Solid Tracking model (VLSTRACK) using observations from two mesoscale field experiments. That reference outlines and applies a statistical evaluation methodology that is becoming a standard in the United States and can be used for the new proposed study.

Because of the fact that PM, VOCs, NOx, and other chemicals emitted as non-point sources from DoD installations are not unique but are present in the atmosphere as a result of emissions from a wide variety of sources, it is necessary to also use receptor-oriented source apportionment models to help evaluate the dispersion models, as well as to improve the source emissions models. Gifford (1959) laid the foundation for this field of study by showing how a dispersion model could be “run upwind” from a receptor location and the resulting contours interpreted as the probability of the source being at any underlying position. Research on this methodology has led to the growth of a large community of researchers in EPA and DoD studying receptor modeling. Watson and Chow (2000 and 2007) surveyed the literature and made recommendations regarding source apportionment of suspended particles, which is of interest to DoD installations. Several groups are investigating use of in situ and remote sensors on facility boundaries to detect the presence and concentrations of various chemicals and particles. These types of remote sensing devices have been sited around some large refineries and chemical processing plants for several years.

### 8.8.2 Significance

The proposed research would accomplish a scientific review of existing and candidate air dispersion models. Accomplishment of such research will advance the science and technology for simulating transport and dispersion in general, which will be of use to all U.S. agencies developing transport and dispersion models; provide scientific reviews and performance evaluations of the candidate dispersion models, including assessments of the benefits of using receptor-oriented source apportionment models, which are also of use to all agencies; and provide regulators and decision-makers with improved general tools for assessing and determining acceptance criteria for models.

### 8.8.3 Recommendations

Research is needed to develop the science and technology necessary to compare and enhance different dispersion models for offsite impact due to non-point-source emissions from DoD installations. The comparison and enhancement would begin with the several dispersion models that are currently used and/or are appropriate for DoD facilities, and it would include scientific review plus evaluation (sometimes called independent validation and verification [IV&V]) with offsite observations. A component of the comprehensive evaluation must include use of receptor-oriented source apportionment models combined with the off-site observations. If biases or deficiencies are found, and the reasons can be identified, the dispersion models should be enhanced so that they better agree with observations. Five areas of research are needed:

- **Scientific Review of Dispersion Models and Identification of Gaps**. As discussed in the background section, a wide variety of dispersion models are in use or are available for use to estimate the transport and dispersion of non-point source emissions, such as prescribed burns, dust raised by military exercises, and OB/OD. A scientific review needs to be conducted, at the level of a peer-review for a journal, of each model's technical documents. Model capabilities should be compared and contrasted for a wide range of scenarios and summary recommendations made, including identification of remaining gaps in scientific contents and in field experiments (data). The comparisons should include other dispersion models that are not used by DoD and EPA, but are widely used elsewhere, and/or dispersion models recently proposed in the literature. Interest exists in using the enhancements in these other models to improve the models used at DoD facilities.
- **Performance Evaluation of Dispersion Models and Recommendations**. A subset of the better transport and dispersion models coming out of the scientific peer review should be subjected to performance evaluation using a spectrum of field experiment observations, covering an appropriate range of scenarios (such as prescribed burns at various locations, during various times of the day, with different vegetation and burn rates) as much as possible. The evaluation should include the relative performance of different models, with determination of whether a significant difference exists between the performance measures of pairs of models. Hybrid (linked) models should be included in these comparisons.
- **Evaluation of Models from a Receptor-Oriented Source Apportionment Point of View and Suggestions for Operational Use**. The available field data near DoD installations on composition of gas and particle concentrations should be used with the set of better-performing source models identified from the above work, together with receptor-oriented source apportionment methods, to evaluate the capability of the receptor models to aid in identifying specific emissions from DoD bases. The accuracy of the results can then be assessed and used to develop a set of suggestions for operational use by decision-makers.
- **Uncertainty/Sensitivity Analyses**. A better-performing subset of the dispersion models reviewed and evaluated above should be used to carry out sensitivity analyses in which the sensitivity of the model outputs to small changes in various key inputs are studied. Additionally, the uncertainties of the model inputs (e.g., emissions and meteorology) and individual modules (e.g., plume rise from multiple area sources in a prescribed burn, or chemical mechanism for NOx) should be investigated. Major outcomes should be identification of those inputs and modules that contribute most to the uncertainty in the model outputs and recommendations as to areas of research in which future improvements should be made.
- **Identification of Major Scientific Gaps, Including the Need for Additional Field Experiments or Monitoring to Fill the Gaps**. Following the completion of the above research, a small set of major scientific gaps should be identified and recommendations made for additional research and development, field experiments, and routine monitoring. In cases where mature state-of-the-art technology is identified in other agencies or countries, an effort should be made to incorporate the new technology into existing dispersion models.

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## 8.9 Develop monitoring methods to determine source and fenceline amounts of fugitive dust emissions for source and ambient compliance monitoring

### 8.9.1 Background

DoD conducts military training and testing activities on approximately 30 x $10^6$ acres of land. These lands can be far removed from other human inhabitants or can occur in close proximity to populated areas. Such DoD activities result in air emissions, many of which are under regulatory control. The focus of this priority write-up was formulated based on the "Workshop on Research Needs for Assessment and Management of Non-Point Source Air Emissions from DoD Activities" with the intent to provide technical capabilities to support management practices at local and regional scales.

In particular, emission of dust to the atmosphere at DoD facilities and its transmission off of DoD facilities has become a more pronounced issue as housing developments are being built closer to DoD facilities. There is also concern about the impact of dust emissions on visibility in Class 1 Areas. Extensive work has occurred to characterize PM with diameters < 2.5 µm ($PM_{2.5}$) and < 10 µm ($PM_{10}$) in the ambient environment and emitted from sources. Unfortunately, methodologies used to characterize fugitive dust are not directly transferrable to methods that can be used to monitor $PM_{2.5}$ and $PM_{10}$ in the ambient environment or for emissions from sources. The ability to monitor fugitive dust emissions at sources and in the ambient environment is not sufficiently developed to meet DoD needs scientifically (i.e., generation, transport and receptor relationships for dust) or with respect to current or future regulations.

### 8.9.2 Significance

Non-point source dust emissions occur as a result of DoD activities, but these activities are not well understood as to how they generate the dust emissions and how to possibly regulate them. Understanding these emissions is important as a result of possible NAAQS pertaining to mass concentrations of PM (http://www.epa.gov/air/criteria.html), the Regional Haze Rule http://www.epa.gov/visibility/program.html) pertaining to visibility degradation, and possible nuisance claims by people located near the boundaries of DoD facilities. Methodologies need to be developed that take into consideration meteorological and field conditions, rapid in-situ PM sampling strategies (e.g., isokinetic sampling and sampling parallel to gas flow streamlines for point measurements) and new detection strategies (e.g., remote mass, composition, or optical sensing technologies). This information then needs to be integrated with facility activity records to relate source activities with the resulting dust emissions.

### 8.9.3 Recommendations

The following topical areas are recommended to provide additional data and technological developments for facility managers to achieve source compliance and ambient fence line monitoring for fugitive dust emissions at DoD facilities.

- Develop and implement low-cost monitoring techniques of dust that quantify mass concentration, chemical speciation, and/or optical properties for sources and along facility fence lines. PM mass concentration measurements will provide information related to NAAQS PM requirements, chemical speciation will provide tracer information to identify sources of emissions, and optical properties of PM will provide measurements related to regulatory requirements pertaining to the Regional Haze Rule. The monitoring devices should provide in-situ detection of PM with near real-time response to distinguish between mass concentrations for PM with diameters < 2.5 µm ($PM_{2.5}$) and PM with diameters < 10 µm ($PM_{10}$) for NAAQS considerations. Optical measurements used for visibility monitoring do not have to be PM size selective, but must be flexible to operate under a wide range of ambient monitoring conditions. Remote-path dependent and point-based monitoring techniques should be considered as possible monitoring techniques.
- Develop methods to rapidly integrate dust mass and/or visibility monitoring measurements with simultaneous meteorological observations and field conditions when the plumes are detected. Meteorological observations will describe parameters such as wind speed, wind direction, and relative humidity (http://www.weather.gov/data/current_obs/) while field condition data will describe parameters such as vegetation type, soil type, and moisture content. Simultaneous plume, meteorology, and field characterization will allow identification of the critical parameters associated with the identification and transport of dust plumes at DoD facilities for sources and at facility fence lines to be able to better monitor and then control dust emissions.
- Develop software to readily inventory current and predict future training and testing activities that have potential to generate dust and be transported over fence lines at DoD facilities. Such information can then be used to identify current and future PM sources at the facility that can impact the facility's ability to meet EPA air quality regulations.
- Integrate results from the source and fence line monitoring measurements, meteorological observations, field condition data, and activity records for military training and testing

activities to provide a readily useable tool to describe the current and future dust mass emissions and visibility effects of DoD activities. Such a tool will assist facility managers to identify which current and future activities generate dust emissions and cause visibility degradation, and which meteorological and field conditions are responsible for those conditions when the emissions occur. Facility managers can then fulfill their training and testing missions while also meeting their regulatory requirements.

## 8.10 Evaluate fugitive emissions from storage, handling, and transfer of fuels and the effects of these emissions on air quality

### 8.10.1 Background

Fuel storage, handling, and usage are significant sources of air pollution at DoD facilities. As such, the environmental impact of fuel changes should be closely evaluated as part of the decision making process. The DoD "single fuel" policy is an example of a fuel change that may have broad environmental impacts, including impacts on air pollution. As a result of implementing the DoD "single fuel" policy it is expected that diesel fuel, Jet Propellant–4 (JP-4) and JP-5 will be replaced by JP-8. In addition to other environmental impacts, this policy may result in variations of fugitive VOC emissions from the storage, handling, and transfer of JP-8. This is because the volatility and composition of JP-8 is different than the volatility and composition of the fuels that it will replace. Another fuel change that could have broad impacts across the environmental spectrum is the introduction of alternative fuels.

Alternative fuels are expected to be more commonly used at DoD installations as a result of energy and environmental initiatives (both voluntary and mandatory) geared to reduce the U.S. dependency on foreign oil and the environmental consequences of using fossil fuels. The effects on air quality from potential increases in fugitive emissions of JP-8 and alternative fuels at DoD installations are largely unknown.

The location of emission increases can result in different regulatory and environmental consequences. For example, many DoD facilities are located in areas that do not comply with the NAAQS. In these areas, increased fugitive VOC emissions are not allowed without concurrent reductions of VOC from other sources. Unless the emissions impacts resulting from a fuel change are quantified and plans are made to offset any increases, DoD installations in some cases may not be able to conform to the State Implementation Plans or could face penalties for noncompliance with state and federal environmental regulations.

The consequences of emission changes may become more serious in the future. The NAAQS for $O_3$ and PM ($PM_{10}$ and $PM_{2.5}$) are becoming more stringent. To bring all NAAQS nonattainment areas into compliance, it is expected that EPA and the SIPs will each impose additional requirements on sources of VOC, which are precursors of both $O_3$ and $PM_{2.5}$. Accordingly, fugitive emissions from the storage, handling, and transfer of fuels will be subject to additional controls.

### 8.10.2 Significance

Without a clear and scientific understanding of the fugitive emissions from the storage, handling, and transfer of JP-8 and alternative fuels at DoD installations, regulatory agencies could impose unnecessary burdens and controls to fuel-related activities at these installations. Understanding the quantity and chemical constituents of fugitive emissions from the storage, handling, and transfer of JP-8 and alternative fuels at DoD installations is essential to provide the environmental risk analyses that are necessary to generate practical decisions and prevent the imposition of unnecessary penalties and controls to fuel-related activities at DoD installations

### 8.10.3 Recommendations

Proposed areas of research include the following:

- Characterizing significant sources of fugitive emissions from storage, handling, and transfer of JP-8 and alternative fuels at DoD installations. This would include evaluating facilities (e.g., storage tanks, fuel lines, pump stations), fuel transfer and handling equipment (e.g., pipelines, tank trucks, portable fuel filters), fuel-handling procedures (e.g., aircraft, ships, and vehicles fueling), and scenarios (e.g., piers, airfields, construction sites, troops maneuver areas) to prioritize sources of fugitive emissions based on their potential to impact air quality
- Performing a life cycle analysis to compare the environmental benefits and disadvantages of the single fuel policy. Issues considered should be air pollutant emissions, water and wastewater impacts, and solid and hazardous waste impacts
- Identifying gaps in available information that need to be filled to assess the impact of fugitive emissions from JP-8 and alternative fuels
- Identifying the chemical/physical/toxic properties of fugitive emissions from JP-8 and alternative fuels and evaluate existing emission factors and dispersion modeling techniques that can be used effectively to assess the impact
- Developing a methodology for identifying and quantifying fugitive emissions from storage, handling, and transfer of JP-8 and alternative fuels at DoD installations
- Developing a methodology to assess the effects on the air quality of these fugitive emissions (e.g., monitoring and/or use of modeling)
- Identifying potential mitigation strategies to reduce environmental impacts, including air emissions
- Assessing the effectiveness of potential mitigation strategies

## 8.11 Develop optical remote sensing methodologies to quantify volatile organic compound emissions at DoD installations

### 8.11.1 Background

Department of Defense policy requires that all training ranges and operational bases be managed and operated in such a way as to support their long-term national defense mission while protecting human health and the environment. In addition, energy efficiency regarding the use of petroleum, oil, and lubricants (POL) is becoming more critical to the military because of cost and the mission need to reduce quantities of POL involved with transport and storage. POL shall be defined here to include non-petroleum sources such as bio-diesel and bio-jet fuels.

Evidence is accumulating in the private sector that process upsets and leaks of all kinds are contributing to the emissions of VOC in quantities heretofore unknown and unexpected. These emissions also are important in regional ozone and global warming problems. Large quantities of hazardous VOC emissions also are becoming evident, primarily through the use of new technologies in the field of optical remote sensing of emissions.

Standard and current military protocol is to track the presence and use of hazardous chemical materials at installation levels through use of the Pharmacy System. Thus, to the fullest extent possible, VOC emission measurements should be correlated with the Pharmacy System nomenclature and data.

### 8.11.2 Significance

Military facilities will be under increasing pressure by environmental regulators and political groups to further improve their environmental performance and reduce their carbon emission footprint. New NAAQS for ozone and particulates will also require the military to maintain more accurate emission inventories and advanced compliance assurance monitoring. New, more accurate VOC measurement methodologies are needed to achieve these goals.

Improving our ability to continuously monitor and measure VOC emissions, especially those fugitive emissions from open sources and commonly undetected leakages from POL infrastructures such as piping and pumping stations, will enable military establishments to better manage those processes and to more easily complete their environmental permit and related emissions reporting requirements. Based on the private sector experience, such knowledge is likely to lead to easier and more inexpensive emission reductions through better and more focused housekeeping and maintenance activities. These new methodologies also would be essential for developing data to substantiate reductions required for Emission Offset programs. In some circumstances, agencies may allow a well-designed and documented continuous fence-line VOC monitoring system to be substituted for resource-intensive point-by-point periodic monitoring (e.g., the Leak Detection and Repair Rule) Such improvements in management practices can ultimately translate into better range operational sustainability, environmental benefits, and cost saving by efficiently detecting and correcting otherwise neglected leakages of POL.

### 8.11.3 Recommendations

Fundamental and applied research is needed that leads to a better understanding of the basic mechanisms for measuring, both qualitatively and quantitatively, airborne emissions of VOC at a variety of military installations. Work should focus on addressing one or more of the following important gaps in the current knowledge base:

- Determining the range, specificity, and applicability of optical remote sensing (ORS) and other emission-measurement technologies for quantifying previously unaccounted VOC emissions from small, individual processes and macro-scale (e.g., total) area-wide VOC emissions at the spatial scope of significant area sources within military installations. Total VOC shall be quantified as well as those individual gaseous components important to regulatory agencies in residual risk and similar permitting and modeling programs for air toxics. Individual compounds selected for quantification shall be based on those defined by EPA as priority hazardous pollutants and those hazardous VOC materials for which the use and presence in military installations is tracked by the Pharmacy System.
- Developing scientific methodologies for compiling site-specific test plans, conducting comprehensive baseline test programs, and applying resulting data to a number of individual military installations having a wide range of processes in which VOC emissions might be expected to occur. These approaches should include identification of important activity

parameters and concentration boundaries and sufficient data from which to compile complete and accurate hourly, daily, and annual emission inventories.

- Preparing an integrated data validation approach that utilizes separate and independent technologies and correlate results with other, standard emissions-estimating techniques. For each military installation in the proposed study, comparisons also should be made with the current VOC emissions inventory, Toxic Release Inventory, RCRA or Title V permits, SIP requirements, and Emissions Management System. The primary data collected should be both total and speciated VOC concentrations within the three-dimensional space encompassing the spatial scope of significant area sources within military installations.
- Developing Quality Assurance methodologies and algorithms that are sufficient to meet data quality objectives as established by the regulatory data requirements and expectations for each military installation.
- Developing new methodologies sufficient for continuously determining *x,y,z* wind vectors for open, area-wide emission sources within military installations. The new methodologies would include seamlessly applying such vectors to the corresponding *x,y,z* pollutant mass concentrations to achieve total mass pollutant flux across a given "fence-line" or vertical plane.

SERDP/ESTCP has previously supported multiple projects on ORS of emissions resulting in the development of ORS protocols and subsequent acceptance by EPA as OTM-10, a general framework for field use of ORS in determining emissions. As a result, OTM-10 should be used as a starting point for the methodologies developed in 1-5 above. Further, it is intended that research results eventually should be documented as sub-set refinements and adaptations of the OTM-10 where appropriate and provided to EPA for inclusion into their national emissions characterization library of measurement protocols.

To address data gaps identified in the bullets above, sufficient operational data, process information, sample, and related parameters should be collected concurrently with all field studies to independently correlate the measured VOC emissions with those normally estimated and calculated using standard emission inventory procedures.

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# 9 Additional Workshop Outcomes

In addition to developing a list of the highest priority research and development needs (discussed in Section 8), other priorities were identified by the workshop attendees as important needs. Because these priorities either fall outside the scope of the workshop or may constitute policy or management initiatives that cannot be addressed by SERDP or ESTCP, they are identified here rather than in the aforementioned list of priorities. Although SERDP and ESTCP may not be able to react to each need that was identified at this workshop, the workshop priorities and other findings and recommendations are being made available to other organizations with the ability to act in ways appropriate to those organizations.

## 9.1 General Findings and Recommendations

This workshop was convened with a well-defined scope; however, identification and documentation of appropriate ideas related to general air quality science, technology, and management were encouraged. Although the following general findings and recommendations were outside the scope of this workshop or may lend themselves to policy or administrative approaches outside of SERDP and ESTCP's purview, they are listed here because they may improve the overall approach to improving air quality:

- Improve interagency cooperation and coordination:
    - Develop means to make databases more readily available
    - Integrate databases from monitoring (e.g., web fire for emission factors, speciate database)
    - Evaluate best modeling systems for gas and PM emissions and transport for widespread uniform use (restrict to perhaps two or three recommended models)
- Implement a mechanism to discuss commonality of facility needs and generalization of tools and training available for widespread use
- Work to promote a regional emphasis on prescribed burns and wildfires to promote awareness of regional differences in emissions, etc.
- Include some measure of uncertainty as part of standard protocol for all measurement programs/models
- Determine what opportunities may exist for aligning what SERDP and ESTCP are doing in air quality research and demonstration with other ongoing agency programs in air quality (e.g., EPA ORD-near roadway work)
- Leverage air quality models applicable to both SERDP/ESTCP's SI and WP focus areas
- Establish a national center(s) of excellence with a focus on fugitive emissions to support collaborative approaches and advancements.

## 9.2 Future Air Quality Research Needs—Sustainable Infrastructure

The air quality emphasis area under SI attempts to develop and demonstrate technologies to monitor air emissions, determine their composition, predict their dispersion, and assess and reduce their environmental impacts. Such technologies include managing the generation and impacts of dust from military operations on training and testing areas. The SI area of investment does not include combustion or industrial sources.

Because SERDP/ESTCP at present are uncertain as to their eventual role in contributing to greenhouse gas (GHG) science and technology, SERDP/ESTCP decided not to make GHG issues a focus of the workshop. The working group, however, identified two GHG-related research needs that SERDP could potentially fund under its SI (and potentially WP) focus area. The two research needs are:

- Identifying the benefits/tradeoffs of prescribed fires vis-à-vis carbon sequestration and GHG.
- Identifying GHG emissions from DoD sources, to include estimating the amount of GHGs and those GHG emission factors specific to DoD.

## 9.3 Future Air Quality Research Needs—Weapons Systems and Platforms

The WP focus area develops and demonstrates technologies and materials that reduce waste and emissions associated with the manufacturing, maintenance, and use of DoD weapons systems and platforms to help reduce future environmental liabilities and their associated costs and impacts. In terms of air emissions, the WP focus area develops and demonstrates the science and technologies to assess and reduce or eliminate the production or release of hazardous air emissions from diesel and turbine engines, weapons, and munitions, as well as technologies that reduce or eliminate shipboard air emissions.

The working group identified three needs that fall outside the scope of the SI focus area; however, these needs do fall under the scope of the WP focus area and are here provided so that for the WP focus area can consider them in future statement of need (SON) development. The WP-related needs identified during the workshop are as follows:

- Determine the environmental effects of fuel changes to include better understanding of emissions from alternative fuels and the environmental effects of a single DoD fuel policy
- Develop an emissions characterization methodology for OB/OD (Note: this effort is the subject of an FY09 SON)
- Design OB/OD impact points/areas, to include a more optimal design of OB/OD pits to minimize emissions
- Identify potential reuse of explosives components of munitions and long-term alternatives to OB/OD
- Identify additives to put in OB/OD pits to act as sponge to absorb gaseous pollutants.

## 9.4 Management and Assessment Recommendations

Finally, the working group recommended the following management practices and assessments (surveys or inventories):

- Consider applying pharmacy inventory practices to DoD use of solvents
- Evaluate work practices to determine if changes could be made to reduce solvent loss
- Improve source characterization of gaseous emissions, to include:
  - Develop an inventory of DoD bases/suspected fugitive gases to better target the development of technologies/methods, in particular for VOC fugitive emissions
  - Develop tiered approach of monitoring for specific species at certain installations
  - Research and document potential sources:
    - Refueling/transfer operations: VOC, SVOC, HC

    - Storing/transferring operations: diesel, solvents, gasoline, JP-5, JP-8, etc., BTEX, VOC, SVOC, HC, ketones, aldehydes
    - Fires (prescribed and wildfires), OB/OD, and other combustion scenarios: VOC, SVOC, HC, Acrolein, HCHO, CO, CO2, HCN, HCl, $NO_x$, $SO_x$
    - Industrial rework/maintenance (electroplating, welding, painting): Cr (VI) (as particle), ketone, BXT, HCN, HCl
    - Landfills, wastewater (IWTP), refuse disposal: VOC, CH4, HC, NH3
    - Mobile sources: CO, CO2, HCN, HCl, $NO_x$, $SO_x$
- Develop a state-of-the-science document describing monitoring and modeling available to meet DoD's requirements in addition to satisfying regulatory agency needs (stress needs of the facility managers).
- Document DoD research pertaining to fire activities.

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# Appendix A Participant List

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# Appendix B Agenda

| Research Needs for Assessment and Management of Non-Point Air Emissions from DoD Activities | | | |
|---|---|---|---|
| **Tuesday February 19, 2008** | | | |
| 1300 - 1315 | Workshop Opening & Welcome | Mr. Brad Smith and Dr. John Hall | SERDP/ESTCP |
| | | Mr. Richard Wayland | EPA Office of Air Quality Planning and Standards |
| 1315 - 1345 | SERDP/ESTCP Overview | Mr. Brad Smith | SERDP/ESTCP |
| 1345 - 1430 | General Overview of Regulatory Issues | Mr. Bob Schell, Dr. Connie Oldham, Dr. Ravi Srivastava, Mr. John Bosch | EPA Office of Air Quality Planning and Standards |
| 1430 - 1500 | Military Air Quality Issues | Mr. Felix Mestey | Navy/DoD Clean Air Act Services Steering Committee |
| 1500 - 1520 | Break | | |
| 1520 - 1540 | Regional Haze and Visibility | Dr. John Watson | Desert Research Institute |
| 1540 - 1600 | Status of Available Technologies for Characterization and Monitoring | Mr. Dennis Mikel | EPA Office of Air Quality Planning and Standards |
| 1600 - 1620 | Remote Sensing Applications: Fugitive Emission Monitoring and Modeling | Dr. Robert Spellicy | Industrial Monitor and Control Corp. |
| 1620 - 1640 | State of the Modeling: Fugitive Emissions and Ozone | Dr. Steven Hanna | Harvard University School of Public Health |

| | | | |
|---|---|---|---|
| 1640 - 1700 | Mitigation Techniques | Dr. Dick Gebhart | U.S. Army Corps of Engineers, Engineering Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL) |
| 1700 - 1715 | Breakout Session Charges/Assignments | Dr. John Hall | SERDP/ESTCP |
| 1715 | Adjourn for the day | | |
| 1730 | Reception - light hors d'oeuvres (and cash bar) | | |

<table>
<tr><th colspan="4">Research Needs for Assessment and Management of Non-Point Air Emissions from DoD Activities</th></tr>
<tr><th colspan="4">Wednesday February 20, 2008</th></tr>
<tr><td>0800 - 0830</td><td colspan="3">Coffee</td></tr>
<tr><td rowspan="4">0830 - 1030</td><td rowspan="4">Breakout Session 1: Particulate Emissions from Non-Point Sources</td><td>Breakout Group</td><td>Session Chairs</td></tr>
<tr><td>A - Characterization (Room C111B)</td><td>Dr. Ram Hashmonay (ARCADIS)<br>Dr. Bryce Bird (State of Utah-Division of Air Quality)</td></tr>
<tr><td>B - Monitoring & Modeling (Room C111C)</td><td>Dr. Mark Rood (University of Illinois)<br>Mr. Tyler Fox (EPA Office of Air Quality Planning and Standards)</td></tr>
<tr><td>C - Mitigation (Room C112)</td><td>Dr. Dick Gebhart (ERDC-CERL)<br>Ms. Julie McDill (Mid-Atlantic Regional Air Management Association)</td></tr>
<tr><td>1030 - 1050</td><td colspan="3">Break</td></tr>
<tr><td>1050 - 1220</td><td colspan="3">Breakout Session 1: Particulate Emissions from Non-Point Sources (continued)</td></tr>
<tr><td>1220 - 1335</td><td colspan="3">Lunch (provided)</td></tr>
<tr><td>1335 - 1435</td><td colspan="3">Breakout Session Reports: Particulate Emissions from Non-Point Sources (Room C111A)</td></tr>
</table>

| | | | |
|---|---|---|---|
| 1435 - 1455 | Break | | |
| 1455 - 1655 | Breakout Session 2: Gaseous Emissions from Non-Point Sources | **Breakout Group** | **Session Chairs** |
| | | *A - Characterization (Room C111B)* | Dr. Ram Hashmonay (ARCADIS)<br>Dr. Bryce Bird (State of Utah-Division of Air Quality) |
| | | *B - Monitoring & Modeling (Room C111C)* | Dr. Mark Rood (University of Illinois)<br>Mr. Tyler Fox (EPA Office of Air Quality Planning and Standards) |
| | | *C - Mitigation (Room C112)* | Dr. Dick Gebhart (ERDC-CERL)<br>Ms. Julie McDill (Mid-Atlantic Regional Air Management Association) |
| 1655 | Adjourn for the Day | | |

<table>
<tr><th colspan="4">Research Needs for Assessment and Management of Non-Point Air Emissions from DoD Activities</th></tr>
<tr><th colspan="4">Thursday February 21, 2008</th></tr>
<tr><td>0745 - 0815</td><td colspan="3">Coffee</td></tr>
<tr><td rowspan="4">0815 - 0945</td><td rowspan="4">Breakout Session 2: Gaseous Emissions from Non-Point Sources (continued)</td><td>Breakout Group</td><td>Session Chairs</td></tr>
<tr><td>A - Characterization (Room C111B)</td><td>Dr. Ram Hashmonay (ARCADIS)<br>Dr. Bryce Bird (State of Utah-Division of Air Quality)</td></tr>
<tr><td>B - Monitoring & Modeling (Room C111C)</td><td>Dr. Mark Rood (University of Illinois)<br>Mr. Tyler Fox (EPA Office of Air Quality Planning and Standards)</td></tr>
<tr><td>C - Mitigation (Room C112)</td><td>Dr. Dick Gebhart (ERDC-CERL)<br>Ms. Julie McDill (Mid-Atlantic Regional Air Management Association)</td></tr>
<tr><td>0945 - 1005</td><td colspan="3">Break</td></tr>
<tr><td>1005 - 1105</td><td colspan="3">Breakout Session Reports: Gaseous Emissions from Non-Point Sources (Room C111A)</td></tr>
</table>

<table>
<tr><td>1105 - 1220</td><td colspan="3">Lunch - EPA cafeteria</td></tr>
<tr><td rowspan="4">1220 - 1420</td><td rowspan="4">Breakout Session 3: Sources and Activities</td><td>Breakout Group</td><td>Session Chairs</td></tr>
<tr><td>1 - Fire Emissions<br>(Room C111B)</td><td>Dr. William Sommers (George Mason University)<br>Dr. Allen Riebau (U.S. Forest Service - retired)</td></tr>
<tr><td>2 - Training Range Emissions<br>(Room C111C)</td><td>Dr. John Watson (Desert Research Institute)<br>Mr. Robert Lacey (ERDC-CERL)</td></tr>
<tr><td>3 - Fuels, Lubricants, and Solvents<br>(Room C112)</td><td>Mr. John Bosch (EPA Office of Air Quality Planning and Standards)<br>Ms. Elizabeth Hill (Research Triangle International)</td></tr>
<tr><td>1420 - 1440</td><td colspan="3">Break</td></tr>
<tr><td>1440 - 1610</td><td colspan="3">Breakout Session 3: Sources and Activities (continued)</td></tr>
<tr><td>1610 - 1630</td><td colspan="3">Break</td></tr>
<tr><td>1630 - 1715</td><td colspan="3">Breakout Session Reports: Sources and Activities (Room C111A)</td></tr>
<tr><td rowspan="2">1715 - 1730</td><td rowspan="2">Summarization of Workshop and Next Steps</td><td>Dr. John Hall</td><td>SERDP/ESTCP</td></tr>
<tr><td>Mr. John Bosch</td><td>EPA Office of Air Quality Planning and Standards</td></tr>
<tr><td>1730</td><td colspan="3">Adjourn</td></tr>
</table>

| Research Needs for Assessment and Management of Non-Point Air Emissions from DoD Activities | | |
|---|---|---|
| **Friday February 22, 2008** | | |
| **POST WORKSHOP MEETING**<br>**By invitation only** | | |
| 0830 - 1200 | Steering Group Meeting<br>(invite only)<br>(Room C1114) | **Attendees** |
| | | *Organizers* |
| | | *Session Chairs* |
| | | *Facilitators* |
| | | *White Paper Authors* |
| | | *Steering Committee Members (optional)* |
| | | *Scribes* |
| 1200 | Lunch (provided) and Adjourn | |

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# Appendix C Workshop Charge

## Workshop on Research Needs for Assessment and Management of Non-Point Air Emissions from DoD Activities

February 19–21, 2008
Research Triangle Park, NC

***Workshop Charge Statement***

**Background:** The Department of Defense (DoD) conducts military training and testing activities on approximately 30 million acres of land. These lands can be far removed from other human inhabitants or can occur in close proximity to populated areas. Through the conduct of its mission activities, DoD is a source of air emissions, many of which are under regulatory control. The focus of this workshop will be on DoD non-point source (i.e., fugitive and area sources) air emissions, including:

- Dust emissions due to military training, testing, and related activities
- Prescribed burning and wildfire emissions
- Evaporative emissions from the use and storage of fuels, lubricants, and solvents.

The focus of the workshop is on identifying science and technology needs for characterization, monitoring, modeling, and impact assessment and mitigation of non-point source emissions. Emissions from stationary stacks and exhaust emissions from internal combustion engines will not be addressed at this workshop. Furthermore, the workshop will not directly address research needs associated with human health effects.

Given the closure of military installations as a result of the 2005 Base Realignment and Closure (BRAC) initiative and other force redeployments, more military personnel will be testing and training on a smaller inventory of installations. In addition, development pressure continues adjacent to many of the installations and places more and more people in proximity to the impacts of DoD activities. These two factors in combination place tremendous pressure on DoD's continued ability to test and train without interruption, and to effectively manage its natural resources, because of potential air-quality-related compliance issues or community complaints.

**Objective**: SERDP and ESTCP must determine how their limited research and demonstration funds can best be invested to improve DoD's ability to address its air-quality-related environmental requirements while sustaining the military training and testing mission. To strategically guide future investments and facilitate long-term cooperation and coordination among workshop participants, this workshop will:

(1) Assess DoD air quality management needs, with a focus on non-point source air emissions
(2) Assess the current state of practice relative to these needs
(3) Assess the current state of the science and technology related to these needs and practices

(4) Identify the gaps in knowledge, technology, and management that if addressed could improve DoD and EPA's ability to address its air quality issues
(5) Set priorities for future SERDP and ESTCP investments to address these gaps.

**Approach:** The workshop, to be held at the U.S. EPA Laboratory in Research Triangle Park, North Carolina, from 19 February through 21 February 2007, will be an invitation-only forum of about 70 participants. Invitees to the workshop will include senior researchers and managers from DoD, other federal and state agencies, academia, industry, and the non-governmental organization (NGO) community. Elements of the workshop will include commissioned paper presentations and three to four breakout sessions on relevant topics.

**Product**: The workshop activities, deliberations, and findings will be summarized in a published report that will serve as a strategic plan for SERDP and ESTCP to guide future investments in non-point source air quality science and technologies.

**Sponsors**: This event is sponsored by SERDP and ESTCP. The U.S. EPA Office of Air and Radiation, Office of Air Quality Planning and Standards (OAR/OAQPS) will host the workshop. SERDP and ESTCP are DoD programs designed to support research, development, demonstration, and transition of environmental methodologies and technologies required by DoD to perform and sustain its mission. Air quality is an important focus area for these two programs. SERDP and ESTCP seek to improve DoD's response to air quality issues through strategic investments that address DoD environmental requirements. The primary mission of the U.S.EPA/OAR/OAQPS, located at the U.S. EPA Research Triangle Park Laboratory, is to preserve and improve air quality in the United States. The strategic vision of OAQPS is to lead and manage national air quality programs to protect public health and the environment from air pollution.

# Appendix D White Papers

***The U.S. Clean Air Visibility Rule and Military Non-Point Source Emissions***

John G. Watson, Desert Research Institute

***Emission Measurement and Ambient Air Monitoring In Assessment of Non-Point Sources***

John Bosch, EPA Office of Air Quality Planning and Standards
Kerry Kelly, University of Utah
JoAnn Lighty, Ph.D., University of Utah
Dennis Mikel, EPA Office of Air Quality Planning and Standards
Barrett Parker, EPA Office of Air Quality Planning and Standards
Robin Segall, EPA Office of Air Quality Planning and Standards

***Mitigation Techniques for Fugitive Dust Emissions from DoD Training Activities***

Niels Svendsen ERDC-CERL
Dick Gebhart, ERDC-CERL
Chatten Cowherd, MRI
Greg Muleski, MRI

***White Paper on Air Quality Modeling***

Steven Hanna, Hanna Consultants
M. Talat Odman, Georgia Institute of Technology

***Optical Remote Sensing for Assessment of Non-Point Sources***

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Eben D. Thoma, Office of Research and Development, National Risk Management Research Laboratory, Air Pollution Prevention and Control Division, U.S. EPA
Ram A. Hashmonay, ARCADIS Inc.
Wei Min Hao, U.S. Forest Service, Missoula Fire Sciences Lab
Mark J. Rood, Department of Civil and Environmental Engineering, University of Illinois Urbana-Champaign

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# Appendix E Supplemental Materials

The Department of Transportation provided additional materials after the workshop. The following documents can be found at the SERDP web site, http://www.serdp.org/xxxx.

- ***Strategic Plan for Particulate Matter Research: 2005 to 2010***
- ***Strategic Workplan for Air Toxics Research, 2005***
- ***AQRS PM Research Plan***

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**12. DISTRIBUTION/AVAILABILITY STATEMENT**
Approved for public release; distribution is unlimited

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**
As it carries out its mission activities, the DoD generates a variety of air emissions, many of which are under regulatory control. In February 2008, SERDP and ESTCP sponsored the Workshop on Research Needs for Assessment and Management of Non-Point Air Emissions from Department of Defense Activities, hosted by the EPA at its facility in Research Triangle Park, NC. The objectives of the workshop were to (1) assess DoD air quality management needs, focusing on non-point source air emissions, (2) assess the current state of practice relative to these needs, (3) assess the current state of the science and technology related to these needs and practices, (4) identify the gaps in knowledge, technology, and management that, if addressed, could improve DoD's and EPA's ability to address emissions from non-point sources, and (5) set priorities for future SERDP and ESTCP investments to address these gaps. During the course of the workshop, discussions resulted in the prioritization of investment opportunities to address such gaps and management challenges.

**15. SUBJECT TERMS**
air quality, non-point source, fugitive dust, particulate matter, fuels, solvents, DoD

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