NBAF
NATIONAL BIO AND AGRO-DEFENSE FACILITY
Vaccines • Diagnostics • Countermeasures

Site-Specific Biosafety and Biosecurity Mitigation Risk Assessment

October 2010

Appendices to Final Report

Homeland Security
Science and Technology Directorate

Defending America Against Foreign Animal Diseases

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NBAF
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Stakeholder Engagement Plan

June 11, 2010

Homeland Security
Science and Technology Directorate

USDA

Defending America Against Foreign Animal Diseases

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1. Introduction and Background

The following document outlines a stakeholder engagement plan for the U.S. Department of Homeland Security's National Bio and Agro-Defense Facility (NBAF). NBAF will be a state-of-the-art integrated facility designed to protect the United States' agricultural economy, food supply, and public health from natural outbreaks or intentional introductions of foreign animal, emerging, and zoonotic (transmitted from animals to humans) diseases. DHS recognizes the need for comprehensive engagement plan to keep stakeholders informed as NBAF moves forward through design, construction, commissioning, and operation stages. DHS and the U.S. Department of Agriculture's Agricultural Research Service (ARS) and Animal and Plant Health Inspection Service (APHIS) (as the tenant research entities) are committed to transparency, open communication with stakeholders, and responding to stakeholder inquiries/concerns in a timely manner.

As with any high-containment laboratory, the study of high-consequence pathogens is not without risk. DHS is committed to mitigating these risks through comprehensive threat and risk analyses that will inform NBAF design, construction, and operation. Because public perception of these risks will be influenced by communications and outreach strategies, DHS will outline plans for risk communication as a part of the overall risk management strategy for NBAF. The purpose of the risk communication will be to educate and inform the public regarding risks and to inform the public in the highly unlikely event of an incident.

To facilitate open communication and transparency, DHS has prepared this stakeholder engagement plan as a dynamic document that will evolve with NBAF to guide efforts to provide consistent, timely and useful information. This plan draws upon stakeholder engagement best practices gathered from the Plum Island Animal Disease Center (PIADC) and other biocontainment laboratories, and builds on previous stakeholder engagement activities undertaken during the NBAF Site Selection EIS process. The plan also outlines a preliminary risk communication strategy that will be implemented when NBAF becomes fully operational in FY 2018. This stakeholder engagement plan will be reviewed at least annually and will be updated as needed.

2. Objectives

To ensure open communication and transparency with stakeholders, the primary objectives of this plan are to:

- Identify the appropriate stakeholders and specific activities, avenues, and venues to keep them engaged and informed.
- Establish public confidence in the NBAF project by facilitating continual dialogue among stakeholders, and DHS, and USDA (ARS and APHIS).

- Proactively establish channels of communication (e.g. a Stakeholder Engagement Committee, regular meetings, a website) for this dialogue in order to disseminate information and gather feedback throughout the design, construction, and operation of NBAF.
- Specifically engage the local Manhattan, KS community to earn public trust.
- Outline preliminary risk communication strategies for NBAF.

3. Lead Agency and Activity Coordination

As the owner of NBAF, DHS is responsible for the planning, construction, and operation. As such, DHS will work with federal partners and other involved organizations to coordinate stakeholder engagement activities. Specifically, the DHS Office of National Laboratories (ONL) within the Science and Technology (S&T) Directorate will take the lead on stakeholder activity coordination. The Director of ONL will work with senior DHS officials to answer questions regarding NBAF. ONL will be responsible for the primary information materials for NBAF, and will update and disseminate new information as it becomes available.

4. NBAF Stakeholders – Definition

For the purposes of the NBAF project, the term "stakeholder" is defined as any person or organization potentially affected by the planning, construction, and operation of NBAF, interested in the issues of biological and agricultural safety relative to current and emerging foreign animal diseases (FADs), or interested in business or research opportunities at NBAF. Currently, identified stakeholders include:

- The local community of Manhattan, KS, Kansas State University (K-State) and the Heartland BioAgro Consortium (HBAC)
- Private sector, non-profit, non-governmental organizations, and academia
- DHS, USDA and other Federal agencies
- State and local government
- Congress
- General public

5. Specific Stakeholder Engagement Activities and Action Plans

The following is a breakdown of the specific engagement activities and action plans that DHS intends to undertake with various NBAF stakeholders. The following activities incorporate many of the best practices of other high containment laboratories. The overall purpose of these activities is to increase

public confidence by establishing a continual and open dialogue between DHS and stakeholders to inform, engage, and answer questions.

5.1 - The Local Community of Manhattan, KS, K-State, and HBAC

The members of the local community of Manhattan, KS are important to the success of NBAF. A strong community engagement program is the best method to inform the public, gain feedback, and develop/maintain the facility's reputation for public accountability, safety and trustworthiness. Through events such as open houses, facility tours, and town halls, the public can learn about laboratory operations and the control measures used to protect the staff, the community, and the surrounding environment. These initiatives help establish the relationships that build public confidence and accountability between the laboratory and members of the local community.

Kansas State University (K-State) already has a BSL-3 facility, the Pat Roberts' Biosecurity Research Institute (BRI). Local and regional stakeholders were engaged before and during the construction of the BRI. They are being kept updated on the status of the BRI while research is being launched by K-State faculty and scientists. DHS and USDA will work with these stakeholders to stand up the research at NBAF. To engage the local Manhattan community and other stakeholders, DHS will establish a Stakeholder Engagement Committee (SEC) and a comprehensive community outreach program to engage the public and facilitate a dialogue. To execute these approaches DHS and USDA will:

- Establish an active community outreach program, prior to beginning construction, which includes the establishment of an NBAF Stakeholder Engagement Committee (SEC). The goal of the SEC is to promote better understanding of laboratory activities (including preparedness in case of an emergency) among the general public, serve as an information exchange between the community and the laboratory, and facilitate community outreach events.

- Establish a mechanism, either through the SEC or otherwise, where members of the local Manhattan community can interact with the laboratory director and staff to ask questions and understand the facility's ongoing work in science and operations, including preparedness in case of emergency.

- Continue to participate, give briefings, gather feedback, and answer questions on the status of the program in NBAF-related meetings where members of the Manhattan community are present.

- Pro-actively seek to engage the community at each milestone of the construction project (i.e., completion of the site-specific risk assessment, award of site-preparation, etc.) through neighborhood or town hall-style meetings.

- Prepare fact sheets and briefing materials to clearly present and explain the mission, design, research, risks, and mitigation strategies associated with NBAF.

- Participate in open houses and other public outreach activities on the campus of K-State.

- Prior to and continuing through operations, host educational programs, facility tours, community forums, community days, open houses, and town hall meetings to engage and inform the general public and to facilitate communication and dialogue.
- Regularly update the DHS NBAF website, www.dhs.gov/nbaf, to disseminate timely and accurate information.

5.2 - Private Sector, Non-profit, Non-governmental Organizations, and Academia

The private sector, non-profit and non-governmental organizations, and academia are important partners in NBAF and its success. These groups represent the producer groups, agricultural associations, environmental groups, researchers, and academicians. To engage these stakeholders, DHS and USDA will, (in addition to the activities listed above):

- Establish mechanisms for information exchange between DHS and these organizations, such as research forums, national conferences, and general meetings.
- Hold monthly meetings with the HBAC to establish a cooperative relationship, inform them regarding NBAF's progress.
- Strengthen and focus community outreach efforts by keeping an integrated calendar of events where these groups will be present.

5.3 - DHS, USDA and Other Federal Agencies

ONL is the DHS office responsible for NBAF construction and operations/maintenance, and will continue to engage and communicate with DHS senior staff and other Federal agencies to keep them informed on the progress of NBAF. In addition to DHS, USDA ARS and APHIS as the lead partner agencies conducting research at NBAF are vital components in the success of the overall public outreach effort. DHS will continue to work with USDA to inform them of the progress of NBAF and to partner together in public outreach. To engage other Federal agencies, DHS and USDA will, (in addition to the activities listed above):

- Continue to proactively provide timely information and regular updates to Federal agencies through briefings, materials, website updates, and meetings.
- Commit to meeting regularly with officials from PIADC and other relevant biolabs for on-going public outreach support and collaboration.

5.4 - State and Local Government

Similar to the methods employed to engage federal government partners, DHS will seek to engage state and local government through the timely and accurate dissemination of information through a variety of methods outlined below. To engage these stakeholders, DHS and USDA will utilize all activities listed above.

5.5 - Congress

In keeping with standard practice and operations, the DHS and USDA will regularly inform Congress on the planning, construction, and operations of NBAF, as needed. The purpose of engagement with Congress is to provide timely information, discuss issues, answer questions, ensure transparency and open communication, and mitigate the risks associated with NBAF. Specifically, DHS ONL will work through the Office of the Under Secretary for S&T, the Office of Strategy, Policy and Budget, the Office of Legislative Affairs, and the Office of Public Affairs to conduct briefings, answer questions, and receive feedback from members of congress and their staff. USDA ARS and APHIS will work through their legislative affairs channels to inform members of congress, their staffs, and any appropriate committees.

5.6 - General Public

DHS intends to keep the general public informed and engaged regarding the mission, research, risks and mitigation strategies associated with NBAF. DHS considers the general public to be an important stakeholder in NBAF as the mission of NBAF is to protect the nation's animal agriculture and public health. Thus, public outreach will inform the general public as to the benefits of having this facility and inform them of possible risks to animal or public health from FADs, emerging, and zoonotic diseases. To engage these stakeholders, DHS and USDA will utilize all activities listed above.

6. Risk Communication

DHS is committed to implementing a comprehensive risk communication plan as part of the risk communication strategy at NBAF. The NBAF risk communication strategies will address qualitative and quantitative risks, clearly explain to the public in lay terms the risks of the facility, and demonstrate how DHS and USDA intend to mitigate those risks. The development of the EIS and the Site-Specific Risk Assessment are the first steps in the risk communication process. Building upon the risk communication plans of PIADC and other relevant biocontainment facilities, NBAF will employ many of the same mechanisms that have proved successful in mitigating risks and informing the public of incidents at these biolabs.

For example, NBAF will have an incident reporting system to facilitate communication between the laboratory and the community, including stakeholders. The reporting system establishes a tiered communication system for evaluating the severity of an incident, the appropriate "Incident Reporting System Response" and the required reporting to the community. The more serious the incident and the potential risk, the broader and the more high-level the incident reporting. This tool ensures that the community is kept fully informed on day-to-day activities, and understands the severity of various incidents that may occur at the laboratory and the associated potential effects on their community. It also provides a consistent method of communication to the community from the laboratory.

7. List of Acronyms and Abbreviations

ARS	Agricultural Research Service (USDA)
APHIS	Animal and Plant Health Inspection Service (USDA)
BRI	Pat Roberts' Biosecurity Research Institute
DHS	U.S. Department of Homeland Security
FAD	Foreign Animal Diseases
HBAC	Heartland BioAgro Consortium
K-State	Kansas State University
NBAF	National Bio and Agro-Defense Facility (DHS)
ONL	Office of National Laboratories (DHS)
PIADC	Plum Island Animal Disease Center (DHS)
SEC	Stakeholder Engagement Committee
S&T	Science and Technology (DHS)
USDA	U.S. Department of Agriculture

Appendix B: a) SSRA Scenario Database Description
b) SSRA Scenario Database (Electronic)
(Provided as separate file, "SSRAScenarioDatabase.mdb")

Please Note: In order to run the database, the user must extract the zip file, "SSRA Scenario Database.zip." It will create a folder called "SSRA Scenario Database," which contains the database (SSRAScenarioDatabase.mdb), and a folder containing the reference files (ReferenceFiles). For the database to work correctly, the database and the folder containing the reference files must reside in the same parent folder.

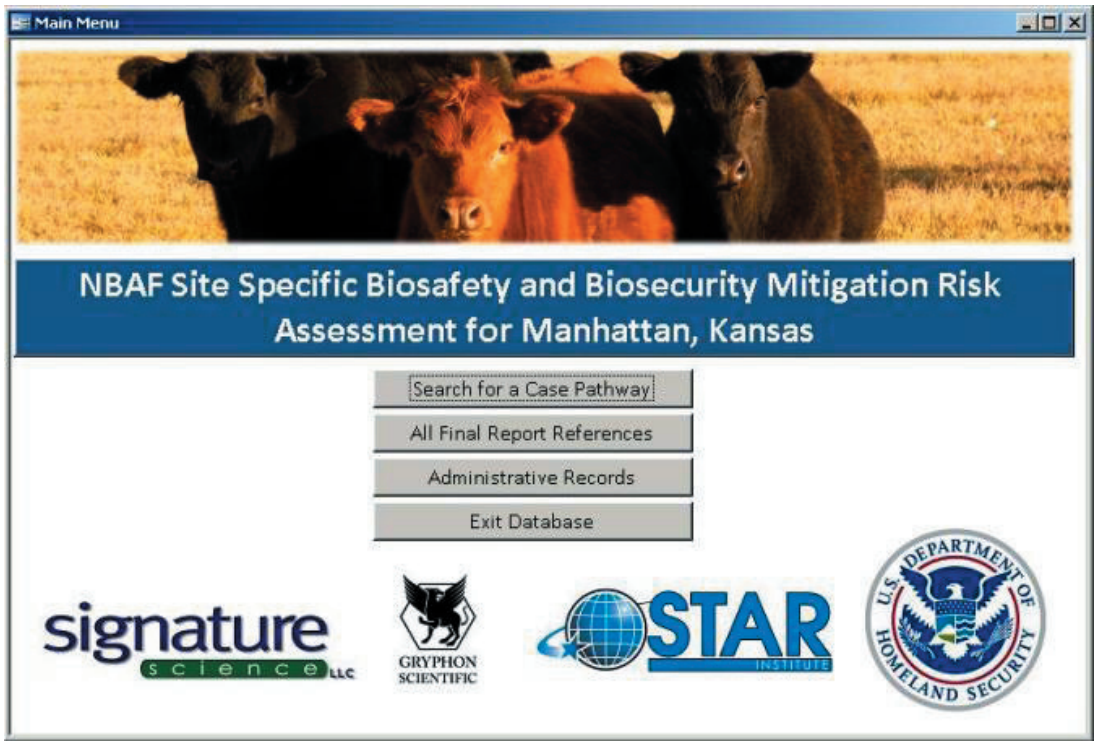


Figure 1: Main Menu of SSRA Database

The Scenario Database is a compilation of information on the SSRA source terms, initial conditions, and references used in each Scenario and Case Pathway. The Database also serves as a data repository for all future NBAF risk assessments and reference information. From this menu, users can access three main areas: case pathways, references, and records. The 'Search for a Case Pathway' button allows users to search the database for various detailed scenario predictions. The 'All Final Report References' button provides a master list of all references used in the SSRA final report. The 'Administrative Records' button provides users with access to all raw data files that fed into the air transport and dispersal modeling. Records include detailed information on local and state cattle populations, feed lots, sales barns, human population maps, Kansas State University floor plans, and other related information.

Figure 2: Case Pathway Search Menu

The Case Pathway Search Menu is an interface that allows the user to select criteria based on pathogen and/ or transport mechanism. At present, the Database contains only two pathogens, FMDv and RVFv. However, the design of the Scenario Database allows the addition of pathogens, scenarios, and references as needed in the future.

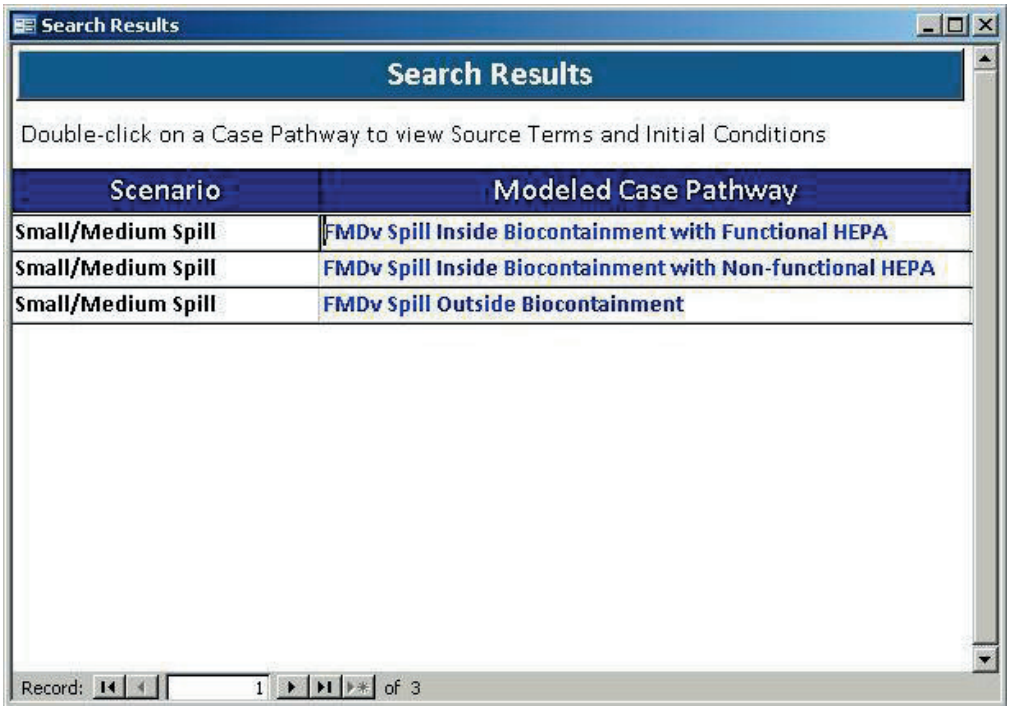


Figure 3: Case Pathway Search Results Menu

The Case Pathway Search Results Menu displays a Scenario with its associated Case Pathways. From this window, users can select individual Modeled Case Pathways, each leading to detailed data Modeled Cases.

Source Terms/Initial Conditions

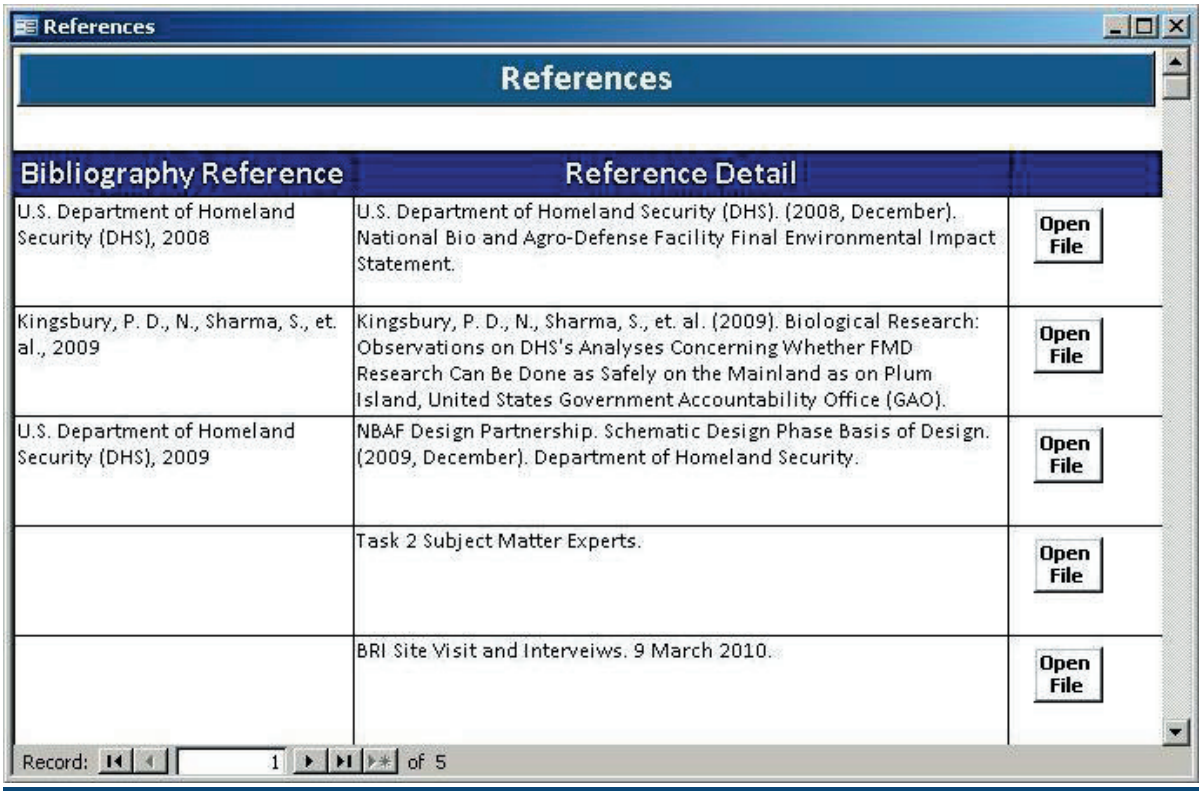
Modeled Case: FMDv Spill Inside Biocontainment with Functional HEPA

Source Term / Initial Condition	Data	Unit	Comments/Assumptions	
Pathogen Name	FMDv	NA		View References
Material at Risk (MAR)	1.00E+12	iu	Concentration x volume (100 mL). MAR= Material at risk.	View References
Concentration (N)	1.00E+10	iu/mL		View References
Quantity of viable pathogens released from biocontainment	1.00E+03	iu	Q=MAR*DR*ARF*LPF = 1.0E+12*1*1.0E-4*1.0E-5	View References
Particle (virion) size	25	nm		View References
Damage Ratio(DR)	1.00E+00	NA	Damage Ratio (DR)= 1, all pathogen at risk.	View References
Airborne Release Fraction (ARF)	1.00E-04	NA	Total pathogen is only reduced by ARF. EIS conservative estimate.	View References
Leak Path Factor (LPF)	1 or 1.0E-05	NA	No filtration or losses. Unmitigated (1, HEPA failure) and Mitigated (1.0E-05 - HEPA failure only); EIS default. Both must	View References
Location Label	Centroid	NA		View References
Northing	319607.181	NA		View References
Easting	1714593.452	NA		View References
Lat	39°12'07.968"	NA		View References
Long	-96°34'49.634"	NA		View References
Elevation	85	feet		View References
Area(s) in Facility	BSL-3E (spill) / AHU-3E (Stack release)	NA		View References
Room Example	Special Procedure – FMD Production and Inactivation	NA		View References
Location Point Comments	Outside of BSC	NA		View References
Mean Mass Diameter (MMD)	14.79	µm	Notes related to validation of MMD and sigma-g can be found in PSD Calculations_BJS_4 15 2010.xlsx	View References
Geometric Standard Deviation (Sigma-g)	2.0	µm	Notes related to validation of MMD and sigma-g can be found in PSD Calculations_BJS_4 15 2010.xlsx	View References
Particle Size Distribution Bin Boundaries	STAR to calculate and forward to SSLLC	µm		View References
Temperature Inside Facility	72	deg F	Inside labs	View References

Record: 1 of 44

Figure 4: Source Terms/Initial Conditions Menu

The Source Terms/Initial Conditions result displays the specific data modeled for the Case Pathway selected. For each source term or initial condition, users may view the related references used in the modeling by selecting the View References button.



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Kingsbury, P. D., N., Sharma, S., et. al., 2009	Kingsbury, P. D., N., Sharma, S., et. al. (2009). Biological Research: Observations on DHS's Analyses Concerning Whether FMD Research Can Be Done as Safely on the Mainland as on Plum Island, United States Government Accountability Office (GAO).	Open File
U.S. Department of Homeland Security (DHS), 2009	NBAF Design Partnership. Schematic Design Phase Basis of Design. (2009, December). Department of Homeland Security.	Open File
	Task 2 Subject Matter Experts.	Open File
	BRI Site Visit and Interveiws. 9 March 2010.	Open File

Record: 1 of 5

Figure 5: References Menu

The References Menu displays bibliography references and files used in the selected modeling source terms and initial conditions. Scenario Database users may access the files simply by selecting the appropriate button.

References

All Final Report References

Bibliography Reference	Reference Detail	
Bennett, A. and Parkes, S, 2006	Bennett, A. and Parkes, S. "Microbial aerosol generation during laboratory accidents and subsequent risk assessment." Journal of Applied Microbiology. 100 (2006) 658-663.	Open File
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Kenny, M.T. and Sabel, F.L. ,1968	Kenny, M.T. and Sabel, F.L. (1968) Particle size distribution of Serratia marcescens aerosols created during common laboratory procedures and simulated laboratory accidents. Appl Microbiol 16, 1146–1150.	Open File
Kingsbury, P. D., N., Sharma, S., et. al., 2009	Kingsbury, P. D., N., Sharma, S., et. al. (2009). Biological Research: Observations on DHS's Analyses Concerning Whether FMD Research Can Be Done as Safely on the Mainland as on Plum Island, United States Government Accountability Office (GAO).	Open File
U.S. Department of Homeland Security (DHS), 2009	NBAF Design Partnership. Schematic Design Phase Basis of Design. (2009, December). Department of Homeland Security.	Open File
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Wild, T. F., Burroughs, J. N. and Brown, F, 1969	Wild, T. F., Burroughs, J. N. and Brown, F. "Surface Structure of Foot-and-Mouth Disease Virus."J. gen. Virol. (1969), 4, 313-320.	Open File

Record: 1 of 7

Figure 6: All Final Report References Menu

The All Final Report References Menu provides a detailed list of all references and files used in the creation of the SSRA Final Report. As with the References Menu, users utilize the Open File button to view the selected files.

Appendix C: A Subject Matter Panel Review of the Qualitative Assessment of Hazards and Risks Associated with Research on Eight (8) Specific Pathogens at the Planned National Bio- and Agro-Defense Facility (NBAF) in Manhattan, KS

NBAF
NATIONAL BIO AND AGRO-DEFENSE FACILITY
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Qualitative Risk/Hazard Assessment Final Report

June 2010

A Subject Matter Expert Panel Review of the Qualitative Assessment of Hazards and Risks Associated with Research on Eight (8) Specific Pathogens at the Planned National Bio- and Agro-Defense Facility (NBAF) in Manhattan, Kansas.

Homeland Security

Defending America Against Foreign Animal Diseases

Executive Summary

The Department of Homeland Security (DHS) is in the process of developing the facility design, defining operational procedure requirements, and planning mitigation strategies for the new National Bio- and Agro-defense Facility (NBAF) that will be built in Manhattan, Kansas. DHS has listed eight pathogens that may be used in research programs at the new facility once construction and commissioning are complete, and all programmatic prerequisites (permitting, licensure, SOPs, certifications, registrations, program-specific risk assessments, staffing, training, etc.) are satisfied. Additional pathogens of interest may also be studied in the future, as indicated in the body of the report. An Environmental Impact Statement (EIS) (DHS, 2008) provided a non-site specific assessment of potential hazards and risks associated with accidents at the NBAF that could result in a loss of biocontainment and resulting infection(s) of humans and susceptible animal species. A Threat Risk Assessment (TRA) (DHS, 2010) considered potential hazards associated with an intentional compromise of biocontainment (by theft or sabotage) that could also result in a loss of biocontainment. Fortunately, the NBAF is being designed by a world-class design team, the NBAF Design Partnership (NDP), which is incorporating the most current proven biosafety and biocontainment technologies, leveraging experiences and "lessons learned" from containment facilities around the world as evidenced later in this report. Thus, when constructed as designed and operated with appropriate protocols, the NBAF will be one of the safest and most secure biocontainment facilities (arguably, the safest and most secure) in the world. However, it is impossible to eliminate all risks—either accidents or intentional events.

DHS has commissioned a Site-Specific Risk Assessment (SSRA) that is intended to address local/regional characteristics and use high fidelity modeling techniques with the latest (15%) NBAF design plans in an updated assessment of risk. Two elements of risk that will be unique to NBAF are 1) the research and handling (in the highly-contained laboratory environment) of Foot and Mouth Disease virus (FMDv) on contiguous mainland United States (Manhattan, Kansas) and 2) the capability for research work with zoonotic agents in large animal models in a BSL-4 containment environment at the proposed NBAF.

Foot and Mouth Disease virus (FMDv) and Rift Valley Fever virus (RVFv) were selected for further quantitative (including modeling) SSRA. Inclusion of FMDv in the SSRA was mandated by congress in the Homeland Security Appropriation Act of 2010 (P. L. 111-83 §560). FMDv was selected for further quantitative study as it is persistent as a dry virus, highly contagious, air transmissible, and has sufficiently characterized etiology to be modeled effectively. Furthermore, The Food Conservation and Energy Act of 2008 (P.L. 110-246) specifically amended a prohibition on FMDv research on the mainland in 121 USC 113(a) to allow FMD research at a designated facility on the U.S. mainland – thus assessment of the agricultural economic impact from a potential outbreak of FMDv on the mainland is critical to understanding the risk and developing appropriate mitigation strategies. The other seven pathogens identified by DHS as research candidates for NBAF are Rift Valley Fever virus (RVFv), African Swine Fever virus (ASFv), Classical Swine Fever virus (CSFv), Hendra virus (Hev), Japanese Encephalitis virus (JEv),

Nipah virus (Niv), and *Mycoplasma mycoides* (the causative agent of Contagious Bovine Pleuropneumonia, or CBPP). It is notable that BSL-4 containment is required for Hev and Niv, while the other pathogens can be handled at BSL-3 (BMBL-5, 2007). In an effort to expand the scope to include a different representative risk, DHS included RVFv for the SSRA. RVFv was selected from among the seven remaining pathogens because it is a zoonotic, vector-borne virus that is spread by several species of mosquito. The other zoonotic pathogens to choose from either did not have a well defined etiology like the paramyxoviruses, Nipah and Hendra (and thus lacked sufficient data for quantitative modeling); or had a more limited host range like Japanese Encephalitis virus that is spread by certain bird species. The remaining two pathogens are not zoonotic and, therefore, would not provide an opportunity to model risks to human community health.

Six of the proposed NBAF pathogens were not specifically considered in the current quantitative assessments of the SSRA; therefore, a separate qualitative assessment of the hazards and relative risks of the complete set of eight pathogens was performed. This report presents the summary of this qualitative assessment. The assessment was performed between late-April and mid-May of 2010 and culminated with a subject matter expert panel discussion on May 11th, 2010. Part of the NBAF's mission will be to respond to emerging disease threats. If a new, highly infectious and transmissible animal pathogen were to emerge, NBAF would be the facility likely to be designated to research the threat. It must be noted that the Panel's assessment herein is limited to the eight pathogens, and that further analysis will be required if the NBAF undertakes research or studies with organisms with a higher potential to infect humans.

The Panel concluded that, in general, the current design strategy for NBAF containment systems and features and preliminary operations and mitigation plans are consistent with the anticipated NBAF research needs and activities that could involve all eight proposed pathogens. This conclusion indicates that the Panel did not find design elements or operation/mitigation strategies that would preclude the use of the eight pathogens at the NBAF but does not mean that the NBAF will be ready to begin related research programs upon completion of laboratory commissioning. Some supplemental/temporary equipment and accommodations may be required for the specific animal models and research programs required to support the anticipated needs related to the eight pathogens. In addition, program-specific prerequisites, experimental design, protocol verification (including containment systems efficacy and testing), and other supporting pre-program activities are expected to be completed before research on any pathogen begins. The Panel also concurs with the current SSRA plan to include discussion on risk mitigation, design, and operational strategies for the NBAF BSL-4 facilities.

Additionally, the Panel concluded that the magnitude of potential consequences and risks of a loss of containment/outbreak for the NBAF are adequately-represented by the quantitative assessment being performed for FMDv and RVFv. Although it is reasonable and valuable to assess the risk of all eight of the proposed NBAF pathogens, in particular pathogens that must be handled at BSL-4 (Niv and Hev), a full quantitative assessment of risk (to include fate, transport and deposition modeling) of Nipah and Hendra will be far more meaningful and accurate as more data regarding their transmissibility,

pathogenesis, susceptibility, etc. are determined by the scientific community. Based on the etiological, biosafety, biosecurity, and host range properties of the other, well-characterized Risk Group 3 and 4 pathogens (WHO) reviewed during this assessment, the Panel concludes that there is no evidence that the NBAF design, operation, and mitigation strategies are not compatible with the complete list of eight pathogens and that the quantitative modeling efforts being performed for FMDv and RVFv are reasonably representative (for the intended SSRA purposes of design feedback, operational planning, and mitigation strategies development) at the current point in the NBAF design process.

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Objective

Provide a qualitative site-specific assessment of the hazards and risks (this Qualitative Risk Assessment or QRA) associated with the full suite of eight pathogens to inform the Site-Specific Risk Assessment (SSRA) and supplement recommendations and conclusions for design, operations, and mitigation feedback.

Work Process

Signature Science began management and coordination of the QRA Subject Matter Expert (SME) Panel Meeting on April 22, 2010. Potential SMEs were identified in the areas of foreign animal disease research, animal handling, BSL-3 and BSL-4 biocontainment laboratory facility design and systems, epidemiology, biosafety, biosecurity, mitigation and response, agricultural economics and public health. (Appendix A contains a list of QRA SME Panel members.) The Panel Meeting was set for May 11, 2010 at Signature Science's Austin, Texas campus. The meeting was continued on May 12 to accommodate more individuals' schedules. SMEs were contacted and enlisted for the effort based on their availability to participate and their ability to supplement a literature review with contributions in the following areas:

- Pathogen-specific (of the eight) anecdotal information or experiences;
- Relevant BSL-3Ag, BSL-3, or BSL-4 insight on design considerations, operating practices, and/or mitigation strategies;
- Unpublished (but referenced) research or data of interest; and
- Pathway expertise (liquid effluent, solid waste disposal, carcass disposal, and ventilation system (air handling)) relevant to the SSRA objectives.

In parallel with the meeting coordination effort, a literature review commenced with the objective of developing a summary of characteristic data on each of the eight pathogens to be referenced in support of Panel discussions. The matrix included data on pathogen etiology, host range, epidemiology, immune response, and laboratory requirements. (The Pathogens Summary Matrix is attached in Appendix B.) Expectations and instructions for the SMEs were documented and, along with a draft of the pathogen summary information, were sent to the SMEs on April 28. (The QRA SME Instructions document is attached in Appendix B.) Input to the pathogen summary information and the QRA process was requested from the SMEs and received throughout the following week. Signature Science continued the literature review and meeting coordination efforts, with a final Data Packet sent to the SMEs on May 5, 2010. The SME Panel met in Austin on May 11 and again, with subset group, on May 12. SMEs unable to travel to Austin participated via teleconference.

Discussion sessions included a review of the current NBAF design status, waste treatment pathways, solid waste handling plans, air filtration systems, ventilation system controls, and person/animal/material handling flows. SMEs reviewed and adjusted the proposed set of pathogen-influenced design, operations, and mitigation considerations. SMEs also established the working range of design, operations, and mitigation-influencing pathogens and accompanying research program characteristics. SMEs quantified the range of pathogen characteristics and discussed design implications. SMEs compared and assessed the NBAF design based on the established pathogen characteristics, and developed and presented recommendations and conclusions. (Notes from the QRA SME Panel Meeting are attached in Appendix C.)

The QRA SME Draft Final Report, incorporating the Panel's recommendations and conclusions, was provided to the QRA SME Panel and additional reviewers on May 14. (A list of QRA Final Report Reviewers is attached in Appendix D.) SME and reviewer comments and input were incorporated into this Final Report.

Pathogen/Research Program Characteristics

During the QRA SME Panel Meeting, a subset of pathogen and accompanying research program characteristic categories were identified as critical to determining whether NBAF was designed for and could mitigate hazards presented by conducting research with these pathogens at the facility. The categories identified and considered in this QRA included: anticipated research needs of the NBAF, associated anticipated animal models, pathogen-specific operational protocols, pathogen-specific occupational health and biosafety considerations, availability of vaccines and therapies, pathogen-specific biosecurity considerations, pathogen-specific outbreak mitigation response strategy considerations, pathogen-specific inactivation requirements and methods, North American vector range (indigenous), North American host range (indigenous), endemnicity potential, morbidity and mortality (animal), morbidity and mortality (human), diagnostic capability in local and regional areas including NAHLN and LRN, potential economic impact of an outbreak due to a "regulation induced trade ban" and potential economic impact of an outbreak due to an "effective trade ban." As part of the QRA process, it was important to understand whether work with any of the pathogens required facilities and strategies above and beyond those under consideration within the context of the SSRA.

Key considerations for each category are described below, along with a summary analysis of implications and suggested modifications to accommodate any pathogens with special requirements.

Anticipated Research Needs

The general research areas anticipated at the NBAF (as identified by the QRA Panel and listed in Table 1 below) that span all eight of the proposed research pathogens described above include vaccine

development and efficacy studies (limited to master seed stock preparation, not vaccine production), development of biological countermeasures in the areas of agent surveillance, detection, post-exposure cleanup and restoration, identification of genetic and biological determinants of disease susceptibility, pathogenesis and persistence, and pathogen route of entry and infectious dose determination.

Table 1. Anticipated Research Needs

	General	Pathogen Specific
ASFv	Vaccine development and efficacy Countermeasures Pathogenesis Route of entry and infectious dose, including aerosol generation Improved diagnostics and development of rapid penside tests	Strain characterization Host immune response Mode of transmission in arthropod vectors Maintenance of virus in arthropod vectors
CSFv		Strain characterization Host immune response Diagnostics development Effective DIVA vaccine
FMD		Mechanisms of replication and persistence Sterile immunity Duration of immunity Host immune response Pre-viremic events in hosts Early immune enhancement DIVA vaccines Carrier state in animals Carrier state in humans Rapid diagnostics Drug therapy discovery (Gay, 2007)
JEv		Mode of transmission - arthropod vectors Replication in domestic mosquitoes Transovarial mosquito infection North American susceptible hosts
RVFv		Mode of transmission - arthropod vectors Replication in domestic mosquitoes Transovarial mosquito infection
Hev	Vaccine development and efficacy Countermeasures Pathogenesis Route of entry and infectious dose Improved diagnostics and development of rapid penside tests	Mode of transmission Natural reservoir Susceptibility of North American bats Drug therapy discovery
Niv		Mode of transmission Drug therapy discovery
CBPP		American Bison host studies Drug therapy discovery Differential diagnostics Development of sensitive/specific antemortem test

Several pathogen-specific research focus areas were identified, such as those for Foot and Mouth Disease Virus (FMDv) for example, that included increased emphasis on vaccination development efforts that would (if successful) allow vaccinated herds to maintain a disease-free status through the introduction of DIVA vaccines, or prevent vaccinated animals from being carriers of FMDv through the development of vaccines that impart sterile immunity. Clearly, diagnostic tool and assay development are important countermeasures to control highly contagious, high-economic impact threats such as FMDv and to differentiate foreign animal diseases (FADs), such as CBPP, from closely related non-pathogen organisms.

Other pathogen-specific research areas involve work to identity modes of transmission, North American domestic host susceptibility and identification of natural reservoirs. Research of vector-borne FADs such as ASFv, JEv, and RVFv will likely involve the study of infected arthropods (specifically ticks and mosquitoes) and large animal hosts such as cattle, horse and sheep. Studies may also include surveying the domestic counterparts to known vectors and reservoirs of these FADs to understand the potential to infect, amplify and spread the disease domestically. This may include studying the replication potential of JEv and RVFv in domestic mosquito species, or Hendra and Nipah in North American bats.

The current NBAF design will accommodate basic research; diagnostic development, testing and validation; advanced countermeasure development (including GMP vaccine development laboratories); and training for the high-consequence livestock diseases included in the preceding table. The existing facility at PIADC has been safely conducting research in similar areas of vaccines and biological countermeasures to FMD and other high consequence foreign animal diseases and diagnostic and detection tools for high-priority foreign animal and high-consequence zoonotic diseases for over 50 years. The NBAF design basis has leveraged existing, successful, and well-characterized facility elements, such as those at the PIADC, and current state-of-the art containment techniques and improvements to maximize the safe handling of the research pathogens.

The Panel agreed that the current NBAF design, in general, was adequate to address the research areas identified for each of the eight proposed research pathogens, with the following exception: the potential animal models and arthropod vectors necessary to fulfill these research needs may require BSL-3E and BSL-4 containment for small mammals, birds and mosquitoes at the NBAF. The NBAF BSL-3E space, as of the April 30, 2010 design iteration, does include an insectary (comprised of two holding/rearing rooms and one entry vestibule), which could support transovarial studies on mosquitoes infected with pathogens that require BSL-3 containment within small insectary environmental chambers. Although not included in the current design plan, according to the NBAF Design Partners (NDP), due to the containment nature of the BSL-4 space (i.e., sealed enclosure, pressure controlled air environment, HEPA filtration, etc.) it is possible for an insectary to be arranged within BSL-4 laboratories and BSL-3Ag facilities (as appropriate based upon agent risk assessment). This could be accomplished using commercially available (e.g., Darwin or Espec) insect rearing environmental chambers, which come in a wide array of sizes and operating systems to control the interior environment and accommodate a variety of arthropods. Work with infected arthropods, even within the designated chambers, poses a

risk to staff and for potential release. Therefore, the Panel recommends that procedures and housing chambers designed for this work be fully verified prior to implementation. If NBAF research includes arthropod vector exposure to infected hosts for transmission studies, then appropriate housing to contain both the potentially infected arthropod and the animal host (presumed to be large mammal such as a cow, horse or sheep) will need to be designed, developed, and verified prior to implementation as this system is not currently part of the NBAF design (small mammal considerations discussed in the following animal model segment).

Anticipated Animal Models

The NBAF will require a level of flexibility in room design and layout to accommodate the range and size of animal species required to meet the planned research and training missions. While the current research program is limited to eight pathogens, future disease priorities may require the adoption of other animal models as novel emerging pathogens are identified. For example, the Australian Animal Health Laboratory now must house certain bat species, which require specialized handling and care facilities not in the original research mission, in response to the emerging Hendra/Nipah virus situation in the Pacific region. A certain level of design and research program flexibility must be maintained to be prepared for unknown future research needs; however, this planning must account for the overall NBAF mission and the availability of other U.S. research facilities to meet growing needs. Within the United States, there are other facilities that can perform small animal or non-human primate models of human and animal disease. NBAF's mission will be predominantly focused on large animals that are natural hosts and are of significant agricultural or economic concern.

The proposed eight pathogens have overlapping requirements for animal models that fall within the NBAF mission and current NBAF design considerations including cows, pigs, sheep, goats, and possibly horses. (See Table 2 for anticipated animal models.) The majority of the eight pathogens to be researched at the NBAF have acceptable animal models using either cows or pigs. The NBAF design was focused on the use of large animal models and, as such, is well-suited for research with these mammals, including the American Bison, if needed, for CBPP research.

Table 2. Anticipated Animal Models

ASFv	Pigs, soft ticks
CSFv	Pigs
FMD	Cows, pigs, sheep, goats, wild ungulates
JEv	Pigs, birds, mice, primates, mosquitoes
RVFv	Cows, rats, bison, sheep, goats, mosquitoes
Hev	Golden hamster, bats, horses
Niv	Cats, golden hamster, ferret, bats, pigs
CBPP	Cows, bison

The NBAF should reserve small animal (mice, rats, hamsters, bats, ferrets, etc.,) housing and research space within the containment laboratories for additional study of the eight research pathogens and/or

reagent generation. Special accommodations, such as microisolators, should also be considered for those other animal species to be demonstrated during the Foreign Animal Disease training programs, such as chickens to demonstrate exotic Newcastle disease and avian influenza (see "Other Pathogen Considerations" section for details regarding the Foreign Animal Disease Diagnostician (FADD) training program). Although not part of the current design detail, the modular and flexible nature of the basic NBAF design can accommodate the study and rearing of small mammals (including bats) in BSL-4 containment with only slight modification. Currently, all NBAF animal rooms are capable of housing various commercially available penning systems, either portable or fixed, to accommodate a variety of species, research models and sizes (such as mice, rats, hamsters, ferrets, and piglets). The current NBAF containment lab environmental systems can be adjusted to control air pressure and temperature for the various species (large or small). Bat rearing and research studies (if desired) can be accommodated within BSL-4 containment through the use of netting suspended from the ceiling or side walls; however, portable or demountable divider partitions would need to be designed and constructed to allow researchers to enter the holding room and observe the bats without entry to the actual nesting areas.

Pathogen-Specific Operational Protocols

Currently, the NBAF animal flooring systems are designed as built-up high performance resin finish systems with appropriate slip resistance for both animal and staff safety. The high performance finish systems include a waterproof membrane system over a double concrete slab system to protect basement construction. All animal pens that accommodate large animals will be equipped with an embedded rubber floor system for animal comfort. These design elements are appropriate for large animal work; however, the current NBAF design assumes that no natural or artificial bedding material will be used at the NBAF. If neonatals or small animals are to be studied or used for the generation of reagents, natural bedding materials may be appropriate to maximize small animal care and waste control and should be considered. As the use of natural bedding materials may have an impact on liquid and solid waste disposal design and operations, these elements should be thoroughly evaluated to ensure drains and traps can handle residual soft bedding wash-down into the liquid waste-steam, etc., at the NBAF.

Table 3. Pathogen-Specific Operational Protocols

ASFv	Standard BSL-3 Ag Practices
CSFv	Standard BSL-3 Ag Practices
FMD	Standard BSL-3 Ag Practices
JEv	Standard BSL-3 Ag Practices
RVFv	Standard BSL-3 Ag Practices
Hev	BSL-4 w/ Large animals
Niv	BSL-4 w/ Large animals
CBPP	Standard BSL-3 Ag Practices

As seen in Table 3, above, six of the eight foreign animal diseases evaluated in this qualitative risk assessment can be handled under BSL-3 Ag operating conditions (ASFv, CSFv, FMDv, JEv, RVFv, and CBPP). The Plum Island Animal Disease Center (PIADC), Institute for Animal Health and Canadian Science Center for Human and Animal Health successfully work with four of these agents (ASFv, CSFv, FMDv, and CBPP) in large animals (cattle, sheep, pigs) under the safety practices and engineering controls offered at the BSL-3 Ag level.

The current NBAF design also includes Animal BSL-4 laboratories equipped to handle large animals such as cattle, horses, sheep and swine. Operations within an Animal BSL-4 laboratory that include experimentation and handling of large potentially infected animals that may kick, bite, spit, spray urine or solid wastes, etc., come with a unique set of safety considerations. Of the current pathogens proposed for study at the NBAF, Nipah and Hendra are the only agents that require BSL-4 and ABSL-4 practices and facilities. The operational protocols for handling large animals are clearly understood and used successfully within BSL-3 Ag facilities; however, transfer of these practices to operations within Animal BSL-4 laboratories may require special consideration and additional training of staff to ensure operator safety. Areas discussed by the Panel included: methods/equipment used in animal penning and caging, animal transfer and movement, necropsy procedures, and specialty PPE and decontamination considerations.

The Panel concluded that the NBAF design should address the following requirements regarding large animal penning, caging, transfer and movement within BSL-4 containment laboratories:

- Penning systems that are designed for flexibility (multiple species) and durability due to exposure to disinfectants and abuse by animals;
- A penning system that assists to herd or direct animals to restraint systems;
- Animal restraint systems (“squeeze” and “head gates”) that permit the researcher controlled access to the animals without danger;
- A carcass removal system from the room; this includes properly locating mechanical assist points inside the room and access to doors to the contained corridor leading to necropsy;
- An animal feeding process that permits the animal care attendant to remotely drop feed into bins/troughs that protect him/her from the animal;
- Breathing air systems that permit the researcher and animal care attendant full access to the animals without risking an air supply line breach or difficulties switching from one air port to another; different options exist including an internal penning system allowing 360º access with a center rotating boom, zip line to manage the air coil or perimeter drops that avoid the line crossing through the animals zone/path; and
- Air pressure resistant (APR) doors that are robust to allow an animal hitting it without deformation.

Through discussion with the NDP, the Panel determined that the current NBAF design adequately addresses the animal penning, caging and transfer concerns identified. The applicable NBAF design elements that address these concerns include:

NBAF Penning and Caging Design Elements:

- NBAF penning and gating systems will be designed to protect the staff from charging or kicking animals with appropriate impact design, as well as shin and leg protection systems;
- Individual restraint systems will be installed in each pen to allow research staff to have a full range of access to the animal. Restraint systems will include self-locking head gates, tie rings, and pen panels that rotate on a fixed position to allow additional restraint. All embedded restraint systems will be recessed and sharp edges on all exposed surfaces will be covered to prevent staff injury or snagging of clothing or PPE. Recessed systems will also consider ergonomics to allow appropriate finger and hand clearance;
- All penning and gating latching and hinging systems will consider ergonomics and safety in their designs. Designs must provide positive latching and an automatic ratchet system to prevent impact and kick back of the gating swings. All penning systems will be polished smooth of burrs and welds to prevent injury to animals and staff; and
- All penning and gating systems are proposed to be stainless steel and be sealed to prevent contamination.

NBAF Animal Movement Operations:

- Once animals are within the containment facilities, the intent is to move animals individually or in manageable groups, whether in the clean or dirty corridors:
- Incoming animals will be staged at the arrival dock and the animals sorted and moved to pre-scheduled rooms via the clean corridor in groups sized to the animal room capacity;
- The clean and dirty corridor system will be designed with a series of control gates allowing movement of animals in groups compatible with room size and capacity. Controls gates will be positioned at intervals down the length of the corridor to permit slow and systematic movement. Animals will be guided into each pen via a series of room control gates and penning systems;
- The large animal rooms will be equipped with a herd management chute system to allow twice daily procedures including blood drawing and weighing;
- Animal restraint squeeze chutes will be provided at all animal operations requiring procedural activities to ensure staff safety;
- Additional animal restraint systems will be included to accommodate species that are not suited to traditional large animal squeeze chute systems. These include a white tail deer drop chute;

- All animal rooms are capable of housing various penning systems portable or fixed to accommodate a variety of specie or research models and sizes; and

- The NBAF design team consulted with world-renowned animal behaviorist, Temple Grandin, to include design elements that minimize distress during animal transfers and procedures (such as using curved corners during herding activities, incorporating light at the end of a shoot system, etc.).

Comprehensive pathogenesis research includes necropsy of infected animals. The Panel agreed that infected animal necropsy poses the highest risk of aerosol generation and worker injury/exposure, in particular necropsy of large animals potentially infected with Nipah and Hendra, which must be done in BSL-4 facilities. The NBAF design team has already included, or is currently considering inclusion of, the following elements to improve operator safety during large animal necropsy:

- Carcasses may be moved from holding rooms by a system of embedded rings for electric winch attachment. Overhead rail systems were investigated but viewed as problematic especially considering decontamination and compartmentalization of containment zones and the loss of continuity of the hoist rail system. Carcasses may also be moved by modified electric forklifts fitted with stainless steel containment pans. All other animals will be walked to the necropsy facility;

- Necropsy suite will be fitted with a squeeze chute system to assist in the euthanasia process and final weigh-out prior to necropsy. All animal movement in the necropsy will be done by a hoist rail and lift system with access to the carcass coolers and carcass disposal system;

- Necropsy suite size may be scaled down to minimize surface area for room decontamination (not currently part of the NBAF design, but can be considered);

- Include a cleanable or disposable curtain system that surrounds the necropsy table and serves to prevent excessive spraying of blood or bodily fluids (being considered); and

- Splash and sprays may be mitigated by limiting or restricting use of aerosol-generating necropsy equipment such as band saws in the necropsy area.

Regarding decontamination and specialty PPE considerations the Panel had the following recommendations:

- Proper donning/doffing, decontamination, and inspection of footwear is important due to presence and potential packing of infected fecal material. The Panel recommends that standard operating procedures require the “buddy system” so that staff can inspect one other for fecal material prior to showering out. Related to this, the chemical decontamination showers should be designed to allow for at least two people to accommodate mutual inspection; and

- Positive air encapsulating suits that permit worker protection, good flexibility, good visual range, filtered air, and clear ergonomic communication system between workers are critical to operator safety, especially when working with large animals.

Specific NBAF PPE considerations for BSL-3 and BSL-4 laboratories will be determined during the full scale mock-up phase of the NBAF design process.

Pathogen-Specific Occupational Health and Biosafety Considerations

Standard medical support services, such as those identified in the Biosafety in Microbiological and Biomedical Laboratories (BMBL) 5th edition, are expected to be sufficient for those personnel working with the zoonotic FADs proposed for the NBAF (JEv, RVFv, Hev, and Niv). These medical support services are expected to include at a minimum: access to available immunizations, periodic medical evaluations and medical support for occupational illnesses and injuries.

Table 4. Pathogen-Specific Occupational Health and Biosafety Considerations

ASFv	Humans not susceptible. Animal handling precautions.
CSFv	Humans not susceptible. Animal handling precautions.
FMD	Humans not susceptible. Animal handling precautions.
JEv	Medical monitoring and local support. Animal handling precautions.
RVFv	Medical monitoring and local support. Animal handling precautions.
Hev	Medical monitoring and local support. Animal handling precautions.
Niv	Medical monitoring and local support. Animal handling precautions.
CBPP	Humans not susceptible. Animal handling precautions.

Special consideration should be given to those medical support services provided for personnel working with Hev and Niv, which must be handled at BSL-4. BSL-4 occupational health standard operating procedures for work with these pathogens should address unexplained worker absence and include protocols for the monitoring (including serum sample collection), medical evaluation, work-up, and follow-up of workers with unexplained non-specific illness (BMBL, U.S. Department of Health and Human Services, Fifth Edition 2007).

Due to the exotic nature of the FADs proposed for study at the NBAF, establishment of local medical personnel and facilities that are accessible to the NBAF workforce and knowledgeable in the prevention, diagnosis, treatment, and isolation of the proposed zoonotic diseases should be part of the comprehensive NBAF Occupational Health and medical monitoring program. All animal handling personnel working within the BSL-4 laboratories must have specific and thorough training in handling hazardous infectious agents and infected animals, including training in animal husbandry procedures, hazards present, and precautions to prevent exposures. In addition, laboratory personnel should have a thorough understanding of the signs and symptoms of disease caused by the zoonotic agents (Hev, Niv, RVFv).

Human Vaccines and Therapies

Vaccines and/or therapeutics are available to personnel identified as having an occupational risk of exposure to two (JEv, RVFv) of the four zoonotic pathogens considered in this QRA. (See Table 5 for more detail.) Because BSL-4 agents were not explicitly considered for the SSRA, it is particularly important to assess whether the current NBAF design and anticipated standard practices safely

accommodate research and support staff performing research activities for those pathogens for which no vaccine is available. As with any pathogen that must be handled in BSL-4 containment, it is critical that the facility Biosafety Officer review and validate the proposed test plans, and research methodologies and staff readiness prior to initiating work. It has been demonstrated at facilities similar in design and function to the proposed NBAF workspace that workers have safely accomplished critical research with Hev and Niv. Furthermore, without research facilities such as the NBAF, it would not be possible to advance the ability to detect, treat, and mitigate future risks from these diseases.

Table 5. Human Vaccines and Therapies

ASFv	Not Applicable – Non-zoonotic.
CSFv	Not Applicable – Non-zoonotic.
FMD	Not Applicable – Non-zoonotic.
JEv	JE-VAX® (Biken) & Ixiaro® inactivated vaccines are available. In addition, the Green Cross vaccine is licensed for use in several South East Asia countries.
RVFv	Supportive care typically administered. An inactivated vaccine (TSI-GSD-200) and a live-attenuated vaccine (MP-12) are available to veterinary and laboratory personnel under IND status.
Hev	No vaccine, but treatment with antivirals and supportive care has been applied.
Niv	No vaccine available.
CBPP	Not Applicable – Non-zoonotic.

Pathogen-Specific Biosecurity Considerations

The National Select Agents Registry (NSAR) Program oversees the activities of possession of biological agents and toxins that have the potential to pose a severe threat to public, animal or plant health, or to animal or plant products. APHIS and CDC implement the provisions through a series of regulations. These regulations include lists of select agents for USDA (9 CFR 121.3) and overlap agents—those pathogens that are listed for both USDA and HHS (9 CFR 121.4). As shown in Table 6, all eight of the pathogens included in this qualitative assessment require Select Agent registration—five USDA select agents (ASFv, CSFv, FMDv, JEv, and CBPP) and three overlap select agents (Hev, Niv, and RVFv).

Table 6. Pathogen-Specific Biosecurity Considerations

ASFv	USDA Select Agent
CSFv	USDA Select Agent
FMD	USDA Select Agent
JEv	USDA Select Agent
RVFv	HHS Select Agent USDA Select Agent
Hev	HHS Select Agent USDA Select Agent
Niv	HHS Select Agent USDA Select Agent
CBPP	USDA Select Agent

The nature of the research work at NBAF will require DHS compliance with the NSAR Program. Through the program, APHIS and CDC provide security information guidance documentation (and a security plan template) that assist the laboratory entity in compliance with appropriate federal regulations. The general security requirements include (but are not limited to) a written security plan for the following security program elements (9 CFR 121.11):

Site-Specific Risk Assessment (note: while the terminology is the same, this requirement is not satisfied by the SSRA referenced in other parts of this Panel report)

- Physical security, inventory control, and information control systems;
- Access control;
- Access approval;
- Means of securing Select Agents and toxins;
- Intra-entity transfers;
- Drills and exercises; and
- Records retention.

Information in the NBAF plan must be developed to address specific NBAF-related threats, in addition to general biocontainment concerns. Because of recent foreign reports of FMDv infection and public concern about the substantial economic consequences from FMDv outbreaks, this pathogen has the potential for elevating the perceived threat level (DHS, Threat Risk Assessment, 2010). Thus, FMDv may be considered as a security risk bounding pathogen from the USDA Select Agent list. RVFv is an overlap pathogen representing risks to both susceptible animal species and humans. Thus, FMDv and RVFv are considered to represent the biosecurity risk space. The potential consequences of containment losses due to intentional actions related to these two pathogens are addressed in the SSRA and TRA. Therefore, the complete range of eight NBAF pathogens is adequately represented, for modeling purposes—not specific planning purposes—by FMDv and RVFv.

Pathogen-Specific Outbreak Mitigation Response Strategy Considerations

Each pathogen will require a tailored outbreak response strategy, but there are key core steps to any Foreign Animal Disease (FAD) response including:

- Identify the agent;
- Slaughter animals on affected premises;
- Potentially cull or vaccinate uninfected animals in zone around outbreak;
- Dispose of carcasses and exposed materials;

- Disinfect exposed premises;
- Designate infected zone, with control of susceptible animal movements;
- Initiate an epidemiological investigation, with tracing of possible sources and possible spread of infection; and
- Surveillance of infected zone and surrounding area as needed to regain trade status.

Table 7 outlines mitigation response strategy considerations for each pathogen. Three pathogens will require additional response steps, as they are insect-borne. ASFv, in its sylvatic cycle, is transmitted by soft ticks; it is also spread from pig to pig via direct contact. JEv and RVFv are transmitted by mosquitoes and, to some extent, biting flies. A well-defined vector control program will be needed for the control of certain types of ticks and mosquitoes. These plans should include the disruption of both human and animal feeding cycles by the use of behavior modification (avoidance and repellants) and insecticides. Tailored plans may be required depending upon the feeding habits and activity of the potential insect host. For instance, some mosquito species are active during daylight while others are active early evening.

Table 7. Pathogen-Specific Outbreak Mitigation Response Strategy Considerations

ASFv	Cull infected and susceptible animals in control zone; Control/monitor feral pig populations
CSFv	Cull infected animals; vaccinate as needed; Control/monitor feral pig populations
FMD	Cull vs. vaccinate decision monitor potential wild animal reservoirs (wild pigs and deer)
JEv	Vector control measures; monitor bird populations
RVFv	Culling of infected animals; Vector control measures
Hev	Cull infected animals; Monitor local horse and bat populations
Niv	Culling procedures for pig industry; monitor bats and other susceptible animal species
CBPP	Culling procedures for cows; monitor bison population; vaccine is available

For disease outbreaks that have a major trade impact and for which vaccines currently exist as a potential control measure, such as FMDv, detailed plans and guidance documents on the cull vs. vaccinate decision must be clearly elucidated and all stakeholders must understand the implications of the decision. USDA APHIS has developed such plans; however, local and State planners may require assistance to adapt or refine these materials for use locally.

Disease surveillance programs may be required for susceptible feral animal populations to track potential introduction into those reservoirs.

Pathogen-Specific Inactivation Requirements and Methods

There are numerous chemicals that can be used for disinfection and inactivation of the eight pathogens. Table 8, below, itemizes current methods by pathogen. At least two types of readily-available and commonly used chemicals including alkalis and halogens (including some specific oxidizing agents) can, and most likely will, be used at NBAF. The alkalis (sodium hydroxide and others) are effective against ASFv, CSFv, FMDv, and, the pathogen that causes CBPP. The halogens (sodium hypochlorite and potentially some iodophors) may be selected for use on JEv, RVFv, Hev, and Niv. An oxidizing agent (such as Virkon®-S) is also likely to be used at NBAF. Virkon®-S has demonstrated efficacy against several of the eight pathogens in its current use as general disinfectant at the PIADC. In order to mitigate possible use of the 'wrong' disinfectant, the NBAF should, in its operational planning, strive to develop universal methods of disinfection, with the use of one or two agents that will work with all pathogens. Some of these chemicals present engineering and operational challenges for NBAF designers and researchers. Compatibility issues and the corrosive characteristics of decontamination chemicals/solutions influence the selection of materials of construction and other engineering/design practices. Operational challenges will be managed by the development and validation of facility-specific protocols and procedures.

Table 8. Pathogen-Specific Inactivation Requirements and Methods

	Chemical	Temperature (High)	pH
ASFv	Sodium hydroxide Hypochlorites Formalin Iodophors (OIE, 2009)	60º C (20 minutes) 56º C (70 minutes) (OIE, 2009)	<3.9 >11.5 (OIE, 2009)
CSFv	Sodium hydroxide (2%) Formalin (1%) Sodium carbonate (OIE, 2009)	90 º C (1 minute) 70 º C (5 minutes) 65.5 º C (30 minutes) (FAD, 7th Ed., 2008)	<3 >11 (OIE, 2009)
FMD	Sodium hydroxide (2%) Sodium carbonate (4%) Citric acid (0.2%) Acetic acid (2%) Sodium hypochlorite (3%) Resistant to: Iodophors Quaternary ammonia Phenol (OIE, 2009)	121º C (< 5 minutes) (Walker, 1984)	<6 >9 (OIE, 2009)
JEv	Sodium hypochlorite (1%) Iodine Iodophors Ethanol Formaldehyde (OIE, 2009)	56º C (30 minutes) 40º C (thermal inactivation point) (OIE, 2009)	<3 >9 (OIE, 2009)

Table 8. Pathogen-Specific Inactivation Requirements and Methods

	Chemical	Temperature (High)	pH
RVFv	Sodium hypochlorite Calcium hypochlorite Formalin (OIE, 2009)	56º C (120 minutes) (OIE, 2009)	<6.8 (OIE, 2009)
Hev	Lipid solvents (alcohol, ether) Sodium hypochlorite (OIE, 2009)	60º C (60 minutes) (OIE, 2009)	<4.0 >11.0 (OIE, 2009)
Niv	Sodium hypochlorite (OIE, 2009)	60º C (60 minutes) (OIE, 2009)	<4.0 >11.0 (OIE, 2009)
CBPP	"Routinely used disinfectants" Mercuric chloride (0.01% for 1 minute) Phenol (1% for 3 minutes) Formaldehyde solution (0.5% for 30 seconds) (OIE, 2009)	56º C (60 minutes) 60º C (2 minutes) (OIE, 2009)	N/A

Autoclaves and effluent treatment systems rely on the use of moist heat to inactivate pathogens. The maximum deactivation temperature of the eight pathogens (based on a 60-minute exposure time) is driven by FMDv—FMDv is known for its heat tolerance. Standard autoclave conditions (121ºC, 15 psi above atmospheric pressure) are adequate for the deactivation of all eight pathogens—including FMDv, in most cases. Common batch processing of liquid effluent decontamination systems can be adjusted to accommodate the heat inactivation requirements of nearly all mesophilic pathogens—subject to verification and validation in waste matrix and its components.

All seven viral pathogens have a similar range of pH toleration. Generally, the pH range of pathogen inactivation for all eight pathogens is < 3.0 and > 11.5. Hev and Niv (the two pathogens from the set of eight that must be handled at BSL-4) have a relatively high tolerance for acidic or basic environments—inactivation of these viruses occurs below an approximate pH level of 3 and above 11. CSFv inactivation levels are estimated to be less than 3.0 and greater than 11.

North American Vector Range (indigenous)

Within five years of its introduction to North America, West Nile virus spread from New York to California because of its ability to infect both native bird and mosquito species. The rapid spread of West Nile virus was facilitated by migration of susceptible bird species. There is concern that a similar situation could occur if an insect-borne pathogen is somehow released from the NBAF. Table 9, below, lists the indigenous North American vector range, where applicable, for the eight pathogens.

Table 9. North American Vector Range (indigenous)	
ASFv	*Ornithodoros* ticks are common in the United States, but ASFv infection in some tick species results in higher tick mortality.
CSFv	No insect vector
FMD	No insect vector
JEv	Several North American species of *Culex* mosquitoes have been shown to experimentally transmit JEv.
RVFv	Potentially transmitted by multiple types of mosquitoes that are widespread in the US.
Hev	No insect vector
Niv	No insect vector
CBPP	No insect vector

It has been shown experimentally that North American mosquito species may transmit JEv (Reeves, 1946) and RVFv (Turrel, 2008) to some degree. It is unclear, however, if these species can efficiently transmit these viruses in nature. *Culex* mosquitoes have a broad geographical distribution in the United States and can potentially transmit both JEv and RVFv. In addition, North America has a broad range of soft tick species that have been shown, at least experimentally, to transmit ASFv (Groocock, 1980). Soft ticks of the genus *Ornithodoros* that are similar to those that spread ASFv in Europe (Endris, 1992) and Africa are located within North America. In Africa, these ticks typically live in underground burrows associated with wild pigs. More research will be required to better define the risk of transmission and spread of these viruses by North American insect species.

North American Host Range (indigenous)

NBAF's mission is focused on pathogens that are agriculturally important; therefore, the susceptible animal populations in North America are numerous and widely distributed (see Table 10). There are multiple domestic and wild susceptible animal species in North America that are at risk of infection to many of the eight pathogens in the NBAF research mission.

Table 10. North American Host Range (indigenous)	
ASFv	Domestic pig farms throughout the US and wild pigs from Texas up through parts of the US Midwest.
CSFv	Domestic pig farms throughout the US and wild pigs from Texas up through parts of the US Midwest.
FMD	Susceptible domestic and wild animal populations widespread across North America
JEv	Pigs, birds, horses, and other equids (donkeys) but it is unclear what wild birds or vectors may spread the disease in North America.
RVFv	Susceptible domestic and wild animal populations widespread across North America
Hev	North American bat susceptibility ill-defined; bat-to-horse transmission may be less likely in North America because lack of presumed susceptible bat host.
Niv	North American bat susceptibility ill-defined; bat-to-pig transmission may be less likely than in Asia because of animal control measures; however, pig to pig transmission is still likely.
CBPP	Cow population is wide spread; bison more limited distribution within North America

FMDv and RVFv have the largest range of susceptible animal species that are native to North America. Other pathogens, such as Niv, Hev, ASFv, CSFv, and JEv have a more limited range of susceptible host species in North America that may assist control measures.

Fruit bats are considered a major, natural reservoir for Hev and Niv viruses in Asia, but the *Pteropus* genus is limited in North America. It is unclear if other bat species in North America are susceptible to Hev or Niv virus infection and would serve as a suitable animal reservoir.

Potential Endemnicity

All eight of the pathogens currently on the NBAF research agenda are considered Foreign Animal Diseases in the United States. However, this does not mean that these diseases were never present within the United States at one time in the past. CSFv, FMDv, CBPP were eradicated in the United States in 1976, 1929, and 1892, respectively. There has never been an outbreak of ASFv, JEv, Hev, or Niv in the United States. With so little known about the ability of North American bat species to act as hosts for Hev or Niv it is very difficult to determine how likely a release will result in an endemic status in the United States in this animal population. The Panel's analysis of potential endemnicity of the eight pathogens is summarized in Table 11, below.

Table 11. Potential Endemnicity

ASFv	Low to moderate, as low virulent strains could enter the animal population undetected for weeks; requires close contact between soft tick and susceptible animal populations. Outbreaks in Europe mid-20th century were eradicated. Some North American ticks infected with ASFv have increased mortality. No outbreak ever reported in the US. Feral pigs could harbor the virus undetected.
CSFv	Low to moderate, as low virulent strains could enter the animal population undetected for weeks; requires close contact between susceptible animals. Vaccine is available to limit disease, but trade impacts. Eradicated in the US in 1976 (USDA-APHIS, 2005). Feral pigs could harbor the virus undetected.
FMD	Moderate; eradication typically by culling and/or vaccination programs, but major trade impacts. Eradicated in the US in 1929 (USDA-APHIS, 2007). Strict importation limits from endemic countries are in place.
JEv	Moderate; requires close contact between mosquito vectors, water sources, and susceptible animal populations. Vaccine is readily available for humans. No outbreak ever reported in the US.
RVFv	Moderate; broad animal host and vector range. No outbreak ever reported in the US.
Hev	Unknown; little is known about factors impacting endemnicity in North America. No outbreak ever reported in the US.
Niv	Unknown; little is known about factors impacting endemnicity in North America. No outbreak ever reported in the US.
CBPP	Low; eradicated in US in 1892 (FAO Animal Health Manual, 2002) but modern control measures could limit spread. A vaccine does exist to limit infection. Strict importation limits from endemic countries are in place.

Infection of North American soft ticks has been demonstrated experimentally, but it resulted in higher tick death, suggesting that non-adapted ticks may not be ideal hosts and that establishing an endemic infection may be more difficult (Kleiboeker, 1998; Endris 1992; Niebylski, 1987; Groocock, 1980). CBPP is difficult to detect before death, so the disease could spread extensively before being identified. In that case, a large-scale slaughter operation may be required to eradicate the disease.

Pigs are the only reservoir for CSFv, so direct contact between susceptible animals is required to maintain the disease in a population. Modern agricultural control programs may prevent the reestablishment of CSFv in the United States (CFSPH, 2007).

Of greatest concern for establishing a more permanent presence in the United States are FMDv and RVFv due to the high number of susceptible domestic and wild animal populations. In general, modern biosecurity and animal control measures limit the establishment of permanent disease status for most of these eight pathogens; however, given the complex interactions between susceptible animal species, geographical distributions, and the potential role of insect vectors, more detailed studies will be required for each pathogen to determine the likelihood of establishing an endemic infection in the United States if a release occurs.

Morbidity/Mortality (Animal)

All of the pathogens on the current NBAF research schedule cause significant morbidity or mortality in animals of agricultural concern, such as cows, pigs, or sheep (see Table 12). With all of the pathogens there is a range of morbidity and mortality depending upon the host animal, pathogen strain, general health, animal age, living conditions, and supportive care.

Table 12. Morbidity/Mortality (Animal)

ASFv	Morbidity approaches 100% (CFSPH, 2008). Mortality – Acute: often approaches 100% in domestic swine. Subacute: 30-70%. Chronic: low mortality (OIE, Oct. 2009).
CSFv	Varies with viral strain. Acute: high mortality (100%) Subacute: lower morbidity and mortality rates. Chronic: few animals affected – always fatal. Some cases are asymptomatic (CFSPH, 2008).
FMD	Morbidity is close to 100% in domestic animals. Mortality is 1-5% in adults; 20% in calves (FAD, 7th Ed., 2008); 70% in young pigs and lambs.
JEv	Morbidity in horses reported from field cases range from less than 1% to 1.4%. Mortality in non-immune infected piglets can approach 100%. Rate is near zero in adult swine. Mortality rates in horses can vary from 5-15% but can reach 30-40% in more severe epizootics (OIE, Oct. 2009).
RVFv	Morbidity is highly variable and dependent on susceptibility of hosts and presence of insect vectors. It can be very high and affect entire herds (FAD, 7th Ed., 2008). Mortality during epidemics is 10% (cattle); 20% (calves); 70-100% (lambs, kids); 10-70% (adult sheep, goat) (FAD, 7th Ed., 2008).
Hev	Infections seem uncommon in horses. The case fatality rate in horses, as of Sept 2009, is 75% (CFSPH, Sept. 2009).
Niv	Morbidity in confined animals approaches 100% and mortality tends to be low in swine older than 6 months. Mortality in piglets can be high (40%). High morbidity and low mortality (<5%) in young swine. Limited clinical information exists for other species, such as dogs and cats. Fruit bats show no serious signs of infection (OIE, Oct. 2009).
CBPP	CBPP is not thought to be a highly contagious disease. With increased confinement, morbidity rises. In a herd situation where animals have close contact, the infection rate is 50-80%. Most animals that present with severe acute infection will die. The mortality rate has ranged from 10-70% in various outbreaks. Mortality in the subacute and chronic forms may depend on other intercurrent factors such as plane of nutrition, level of parasitism, and general body condition (FAD, 7th Ed., 2008).

While natural mortality is low in FMD-infected animals, the morbidity of the disease is very significant. Sickened animals have considerable weight loss. The low infectious dose, pathogen stability, broad host range, and the high morbidity make FMD a major agricultural concern. While the other pathogens cause severe disease or death, the relative impact on the agricultural sector is more limited because of narrowed host range.

Morbidity/Mortality (Human)

Only the zoonotic pathogens JEv, RVFv, Niv, and Hev have the ability to infect humans (see Table 13). ASFv, CSFv, FMD, and CBPP do not, generally, cause human disease. JEv and RVFv cause human disease over a wide global area but few cases result in actual clinical disease (1% or less). Both JEv and RVFv are insect-borne, so the disease could potentially be spread over a larger geographical area by insects. If introduced into North America, this low level of infection in humans may go undetected for a period of time as the general symptoms may not immediately indicate a novel infection. Hev and Niv have a more limited global distribution and the diseases are more rare in comparison to JEv or RVFv, but the mortality rates can be significantly higher (>40%). For human disease implications, RVFv is of great concern because of the broad animal and insect host range and the ability to potentially spread to a wider geographical area before the disease is detected.

Table 13. Morbidity/Mortality (Human)

ASFv	Not applicable – Non-zoonotic.
CSFv	Not applicable – Non-zoonotic.
FMD	Not applicable – Non-zoonotic.
JEv	Most human infections with JEv are asymptomatic; <1% of people infected with JEv develop clinical disease. Case–fatality ratio is approximately 20%–30%. Among survivors, 30%–50% may still have significant neurologic or psychiatric sequelae, even years after their acute illness (CDC, 2010).
RVFv	Most people with RVF recover spontaneously within a week. Ocular disease is seen in approximately 0.5% to 2% of cases, and meningoencephalitis and hemorrhagic fever in less than 1%. The case fatality rate for hemorrhagic fever is approximately 50%. Deaths rarely occur in people with eye disease or meningoencephalitis, but 1% to 10% of patients with ocular disease have some permanent visual impairment. The overall case fatality rate for all patients with RVF is less than 1%. (WHO, May 2010)
Hev	Hev infection has been reported in 7 people, all of whom had close contact with infected horses during their illness or necropsy; 4 of those died. Only a percentage of those exposed to infected horses have become ill. There has been no evidence of seroconversion in people who are often in close contact with flying foxes. (WHO, July 2009 and CFSPH, Sept. 2009)
Niv	Humans are susceptible to infection, resulting in serious clinical disease. Mortality rate in humans is high; 40-75% recorded in different outbreaks. (WHO, July 2009)
CBPP	Not applicable – Non-zoonotic.

Diagnostic Capability in Local and Regional area and the NAHLN (National Animal Health and Laboratory Network) and LRN (Laboratory Response Network)

Both the NAHLN and the LRN were established to provide regional surveillance and diagnostic capabilities for animal and human pathogens of significant concern. Currently, the LRN does not have a distributed capability to address the zoonotic pathogens (JEv, RVFv, Hev, and Niv) at its reference laboratories located in regional proximity to the proposed NBAF site. However, diagnostic capabilities and advanced handling capabilities (BSL-3 and BSL-4 facilities) are available at the National Labs equipped to manage diagnostic specimens indicated for JEv, RVFv, Hev, and Niv analyses. This Panel recommends evaluating methods for enhancing local diagnostic capability for the pathogens being researched at the NBAF, to support regional surveillance and reachback capability.

Similar to the LRN, the NAHLN provides a distributed, regional capability of surveillance and diagnostic capability for exotic animal diseases. In addition, veterinary biologics are also sustained at the regional sites. Of the eight pathogens considered for this QRA, it is understood that only two (CSFv and FMDv) of the pathogens are currently involved in NAHLN surveillance (CSFv) and/or diagnostic (CSFv & FMDv) programs (see Table 14). In addition to the NAHLN, APHIS laboratories in Ames, IA and on Plum Island lead national level exotic and foreign animal disease research and sustain the requisite facilities and animal models necessary to understand and prepare for these threats. The NBAF represents a critical and much needed addition to the nation's capabilities and preparedness in a region that is uniquely susceptible and impacted by foreign animal disease.

Table 14. Diagnostic Capability In Local and Regional area and the NAHLN (National Animal Health and Laboratory Network) and LRN (Laboratory Response Network)

ASFv	Capability not currently indicated; however, NAHLN is finishing the validation of a PCR assay. (Martin, 2010)
CSFv	Yes. Kansas State Veterinary Diagnostic Laboratory and other NAHLN laboratories. http://www.aphis.usda.gov/animal_health/nahln/labs.shtml
FMD	Yes. Kansas State Veterinary Diagnostic Laboratory and other NAHLN laboratories. http://www.aphis.usda.gov/animal_health/nahln/labs.shtml
JEv	Capability not specifically indicated at NAHLN. No LRN capability.
RVFv	Capability not specifically indicated at NAHLN. No LRN capability.
Hev	Capability not specifically indicated at NAHLN. No LRN capability.
Niv	Capability not specifically indicated at NAHLN. No LRN capability.
CBPP	Capability not currently indicated; however, NAHLN is finishing the validation of assays. (Martin, 2010)

Trade Regulations and Potential Restrictions

The OIE requires immediate notification from member countries of listed or emerging diseases (OIE, 2010 and OIE, 2009). Member countries can self declare freedom of a country, zone or compartment from an OIE listed disease. However, OIE does not recognize self declaration for bovine spongiform

encephalopathy, foot and mouth disease, rinderpest and contagious bovine pleuropneumonia. If a notification is provided for a particular disease, immediate international and domestic trade restrictions are likely for the affected species listed in Table 15. In addition to trade bans specified by national and international regulations, an important consideration is the duration and magnitude of an effective trade ban which may be realized by the uncontrolled release of any of these pathogens. Effective trade bans and restrictions reflect the changes in commerce and trade (e.g., consumer behavior, political decisions, interest group behavior, market reactions) that can augment the impacts of regulation induced trade bans and/or cause significant economic disruption in the absence of any officially mandated ban (see for example Paarlberg, et al 2003, Otte, et al 2004).

Table 15. Trade Regulations and Potential Restrictions

ASFv	OIE listed and notifiable disease; Agricultural sectors with high probability of immediate international trade restrictions after notification include swine.
CSFv	OIE listed and notifiable disease; Agricultural sectors with high probability of immediate international trade restrictions after notification include swine.
FMD	OIE listed and notifiable disease; Agricultural sectors with high probability of immediate international trade restrictions after notification include cattle, swine, sheep, goats, farmed cervids.
JEv	OIE listed and notifiable disease; Agricultural sectors with high probability of immediate international trade restrictions after notification include swine.
RVFv	OIE listed and notifiable disease; Agricultural sectors with high probability of immediate international trade restrictions after notification include cattle, bison, sheep, and goats.
Hev	Not an OIE listed disease (AU DAFF, 2008). Agricultural sectors with high probability of immediate international trade restrictions after notification include equine.
Niv	OIE listed and notifiable disease; Agricultural sectors with high probability of immediate international trade restrictions after notification include swine.
CBPP	OIE listed and notifiable disease; Agricultural sectors with high probability of immediate international trade restrictions after notification include cattle and bison.

Recent disease outbreaks in livestock provide examples of swift reactions by trading partner and the important economic consequences of these events. Domestically these include the impacts of H1N1 on the U.S. swine sector and BSE on the U.S. beef sector. Internationally, examples include FMD in the U.K.; BSE in Canada; Hev in the equine sector of Australia; Niv in Bangladesh, India, and Malaysia. Additional information can be found at web sites for USDA-APHIS (www.aphis.usda.gov), UK-DEFRA (www.defra.gov.uk/animalhealth), and FAO (www.fao.org).

Summary of Key Conclusions and Recommendations

The Panel concluded that, in general, the current design and strategy for NBAF containment systems and features and preliminary operations and mitigation plans are consistent with the anticipated research needs and anticipated NBAF activities that could involve all eight pathogens. Site and design specific risk mitigation strategies for potential events (earthquake, tornado, flood, dust storm, etc.) that could adversely impact operations of the facility and therefore containment should continue during the design process.

Specific supplemental and/or temporary equipment and accommodations may be required to support the anticipated animal models and research program needs related to the eight pathogens. In addition, program-specific prerequisites, experimental design, protocol (including containment systems efficacy and testing) verification, and other supporting pre-program activities are expected to be completed before research on any pathogen begins.

The Panel concluded that the magnitude of potential consequences and risks of a loss of containment/outbreak for the NBAF are well-represented by the quantitative assessment being performed for FMDv and RVFv. It is reasonable and valuable to assess the risk of all eight of the proposed NBAF pathogens, in particular pathogens such as Niv and Hev which must be handled at BSL-4. However, a full quantitative assessment of risk (to include fate, transport and deposition modeling) for all eight pathogens was not found by the Panel to be necessary or entirely feasible (e.g. for Nipah and Hendra) until the NBAF design is more mature and additional published data and validated models are available. In particular, a full quantitative assessment of risk for Nipah and Hendra will be far more meaningful and accurate as more data regarding their transmissibility, pathogenesis, susceptibility, etc. are determined by the scientific community.

Part of the mission of NBAF is to respond to emerging threats. If a new, highly infectious and transmissible organism were to arise, NBAF would be the likely facility designated to investigate (beyond the diagnostic role where the samples are logged and discarded). It must be noted that the Panel's assessment is limited to the eight pathogens which have been represented, and that further analysis will be required if the NBAF undertakes research or studies with organisms with a higher infectious potential for humans.

Other Pathogen Considerations

In addition to the eight pathogens listed as major NBAF priorities, other pathogens may be used or stored at the facility. The Foreign Animal Disease Diagnostician (FADD) School held at PIADC does not demonstrate for training purposes the high-consequence zoonotic diseases on the research list: RVF, JEv, Niv, or Hev. The training program demonstrates several pathogens that are not included in the NBAF research plan:

- African horse sickness (non-contagious, insect-borne reovirus)
- Sheep pox (contagious, poxvirus)
- Heartwater (non-contagious, insect-borne *Ehrlichia ruminantium*)
- Rabbit hemorrhagic disease (contagious, calicivirus)
- Velogenic Newcastle disease (contagious, paramyxovirus)
- Avian influenza (contagious, H5N2 strain that does not cause disease in humans)
- Peste des Petits Ruminants (contagious, paramyxovirus)

It is expected that these FADD School training demonstrations will continue once this function migrates to the NBAF. Additional diseases that may be demonstrated at PIADC include:

- Rinderpest (contagious, paramyxovirus)
- Goat Pox (contagious, poxvirus)
- Lumpy Skin disease (insect-borne, poxvirus, may be emerging)
- Swine Vesicular disease (contagious; picornavirus; identical clinical signs, in pigs only, as FMD)

Rinderpest is believed to be eradicated globally, so training demonstrations with this pathogen ceased in November 2009; however, it is conceivable that it might be shown in the future due to agroterrorism concerns. None of the above pathogens cause significant human disease. In order to perform the training mission, NBAF will have to store and propagate stocks of the above pathogens. Students will monitor the disease course, collect diagnostic samples, and perform necropsies to better understand the disease course and pathology. As a result of these activities, significant amounts of the pathogens will be in the facility solid and liquid waste streams.

In addition to its training mission, the NBAF will also receive diagnostic samples from both domestic and international sources. Some of these samples may contain unknown pathogens. Typically diagnostic

specimens are destroyed soon after agent identification. The amount of pathogen in each sample is generally small and considered a lower risk if handled properly.

The NBAF may also continue the repository mission of PIADC. If so, small amounts of a wide variety of agricultural agents may be stored in secured freezers at the facility. This repository, or pathogen library, is extremely valuable for future research or disease outbreak investigations.

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Appendix A: QRA Subject Matter Expert Panel Members

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Appendix B: Pathogens Summary Matrix and SME Panel Instructions

QRA Pathogen Summary Matrix 5/10/2010

Agents to Review	Etiology										
Elements	Family	Type	Zoonotic	Insect-borne	Size (diameter)	UV (stability)	Temperature (stability)	Humidity (stability)	Heat Inactivation	Disinfectant Inactivation	pH Inactivation
Viruses											
African Swine Fever (ASFv)	Asfarviridae *Asfivirus*	DNA	No	ticks (Ornithoro-doros) [OIE, 2009]	200nm (80nm core) [FAD, 2008]	Purified ASFv inactivated by irradiation 40 min at a distance of 30 cm of a germicidal lamp (Sylvania 15 W) [Alcami, 1989]	Highly resistant to low temps.[OIE, 2009]	Remains viable for long periods in blood, feces and tissues. [OIE, 2009]	56°C/70 min 60°C/20 min [OIE, 2009]	sodium hydroxide hypochlorites iodine compounds [OIE, 2009]	<3.9 >11.5
Classical Swine Fever (CSFv)	Flaviviridae *Pestivirus*	RNA	No	No	40-60 nm	Rapidly inactivated. [Edwards, 2000]	Relatively stable at lower temps [FAD, 2008]	May survive prolonged periods in favorable environment where cool, moist and protein rich, as found in stored meat.	90°C/1 min 70°C/5 min 65.5°C/30 min [FAD, 2008]	ether, chloroform ß-propiolactone chlorine-based [OIE, 2009]	<3.0 >11.0
Foot and Mouth Disease Virus (FMD)	Picornaviridae *Aphthovirus*	RNA	No	No	25-28nm [FAD, 2008]	Less stable with increased UV [CSFPH, 2007]	Less stable with increased temp [CSFPH, 2007]	Less stable in lower humidity	70°C/30 min	low pH solutions alkaline solutions	<6.0 >9.0
Japanese Encephalitis Virus (JEv)	Flaviviridae *Flavivirus*	RNA	Yes	mosquito	40-65nm	Sensitive to UV [OIE, 2009]	TIP=40°C [OIE, 2009]	No data found. Does not persist outside a living host. [Spickler and Roth, 2007]	56°C/30 min	acid/alkaline common detergents	pH 1-3
Rift Valley Fever Virus (RVFv)	Bunyaviridae *Phlebovirus*	RNA	Yes	mosquito	90-110nm [FAD, 2008]	Destroyed by strong direct sunlight/UV radiation. [AUSVETPLAN, 1996]	Survives in freeze dried form and aerosols at 23°C [OIE, 2009]	Survives at 50-85% humidity [OIE, 2009]	56°C/120 min	ether, chloroform sodium hypochlorite	<6.8
Hendra Virus (Hev)	Paramyxoviridae *Henipavirus*	RNA	Yes	No	38-600nm (polymorphic)	No data found (NCD: stable up to 45 min)	No data found	No data found.	60°C/60 min [OIE, 2009] (Paramyxovirus)	hypochlorite, iodophors biguanidines	<4.0 >11.0
Nipah Virus (Niv)	Paramyxoviridae *Henipavirus*	RNA	Yes	No	40-600nm (polymorphic)	No data found (NCD: stable up to 45 min)	No data found	May be transmitted on fomites. Unpublished experiments suggest it can survive for days in fruit juice or fruit bat urine. [Spickler and Roth, 2007]	60°C/60 min [OIE, 2009] (Paramyxovirus)	lipid solvents [OIE, 2009] sodium hypochlorite	<4.0 >10.0
Bacteria											
Contagious Bovine Pleuropneumonia (CBPP)	*Mycoplasma* *mycoides* *mycoides (MmmSC)*	DNA	No	No	100-200nm (polymorphic)	Readily killed by UV light but protected in glass bottles. [Hudson, 1968]	Survives well only in vivo. [FAD, 2008]	Survives a few days in tropical conditions; up to 2 wks in temperate climate. [OIE, 2009]	56°C/60 min [OIE, 2009] 60°C/2 min	mercuric chloride phenol formaldehyde solution	Inactiv-ated by acid and alkaline [OIE, 2009]

QRA Pathogen Summary Matrix

5/10/2010

Agents to Review	Host Range			Epidemiology			
Elements	Domestic Animals	Wild Animals	Humans	Transmission / Routes	Survival	Carrier State	Incubation Period
Viruses							
African Swine Fever (ASFv)	Swine *(Sus scrofa)*	Wild and feral swine	No	Blood and secretions. Direct/indirect contact, tick bite	Remains viable for long periods in blood, feces and tissues; especially infected, uncooked or undercooked pork products. Can multiply in vectors (Ornithodoros sp.) [OIE, 2009]	African wild swine, and in domestic pigs in enzootic areas [OIE, 2009]	5-15 days; <5 days by tick bite
Classical Swine Fever (CSFv)	Swine *(Sus scrofa)*	Wild and feral swine	No	Oral and oronasal routes, via direct or indirect contact. Pig to pig; fomites [FAD, 2008]	Moderately fragile and does not persist in environment. Sensitive to drying and UV light. Survives well in pens during cold conditions (up to 4 weeks in winter). Survives 3 days at 50°C and 7-15 days at 37°C. Survives in meat during salt curing and smoking for 17 to >180 days depending on the process used. Virus persists 3-4 days in decomposing organs and 15 days in decomposing blood and bone marrow. [OIE, 2009]	No carrier state. Infected pigs only resevoir of virus. [CSFPH, 2009]	2-14 days, typically 3-4 [OIE, 2009]
Foot and Mouth Disease Virus (FMD)	Cloven-hoofed, primarily cattle	Cloven-hoofed	No	Direct contact between infected and susceptible animals. Direct contact between fomites and susceptible animals. Inhalation of infectious aerosols. [OIE, 2009]	Survives in lymph nodes and bone marrow at neutral pH, but destroyed in muscle at pH<6.0 i.e. after rigor mortis. Survives in frozen bone marrow or lymph nodes. Residual virus survives in milk and milk products during regular pasteurization, but is inactivated by ultra high-temp pasteurization. Survives drying but may persist for days to weeks in organic matter under moist and cool temps. Can persist in contaminated fodder and the environment for up to 1 month, depending on the temp and pH conditions. [OIE, 2009]	Recovered or vaccinated and exposed animals in which FMDv persists in the oropharynx for more than 28 days. Carrier state in cattle usually does not persist for more than 6 months. [OIE, 2009]	3-5 days; 24-26 hrs after outbreak [FAD, 2008]
Japanese Encephalitis Virus (JEv)	Horses, swine (amplifying)	Ardeid birds (egret, heron)	Yes	Bite from infected mosquito. No human-to-human transmission. [FAD, 2008]	Virus very labile and does not survive well in the environment; sensitive to UV light and gamma irradiation. [FAD, 2008]	Ardeid birds (egret, heron); swine [CSFPH, 2007]	4-14 days (horses)
Rift Valley Fever Virus (RVFv)	Wide range	Wide range	Yes	Bite from infected mosquito. Direct contact with infected animals and meat. To date, no human-to-human transmission and no transmission of RVF to health care workers when standard infection control precautions in place. [WHO, 2010] Mechanical transmission by various vectors possible. Aerosol transmission during endemics. Humans can theoretically infect mosquitos. [OIE, 2009 and CSFPH, 2007]	Survives in freeze dried form and aerosols at 23°C and 50-85% humidity. Virus maintained in the eggs of certain arthropod vectors during inter-epidemic periods. Can survive contact with 0.5% phenol at 4°C for 6 months. [OIE, 2009]	There is no carrier state in animals. [Geering, 2002]	12-72 hrs; 3-6 days (humans)
Hendra Virus (Hev)	Horses	pteropid bats (flying foxes')	Yes	Nasopharynx inoculation. Virus shed by flying fox placental fluids, urine [FAD, 2008]	Survives more than 4 days in flying fox urine at 22°C. Can remain viable for a few hours to a few days in fruit juice. Does not survive well at higher temps and is inactivated in less than a day in either urine or fruit juice at 37°C. [OIE, 2009]	pteropid bats [Calisher, 2006]	5-10 days (horses); 4-18 days (humans)
Nipah Virus (Niv)	Pig (amplifying), dog, cat, horse, goat	pteropid bats (flying foxes')	Yes	Respiratory secretions and saliva, urine. Aerosolized from pigs to pigs and humans; route of infection from bats to pigs unknown. Half of reported cases in Bangladesh 2001-2008 were due to human-to-human transmission. Highly contagious in swine. [WHO, 2010, CSFPH, 2007]	Nipah virus may be transmitted on fomites. How long this virus can survive in the environment is unknown; however, unpublished experiments suggest that it can survive for days in fruit juice or fruit bat urine. [CSFPH, 2007]	pteropid bats [Calisher, 2006]	7-14 days (pigs)
Bacteria							
Contagious Bovine Pleuropneumonia (CBPP)	Cattle	No	No	Transmitted from animal to animal in aerosols. This organism also occurs in saliva, urine, fetal membranes and uterine discharges. Carrier animals, including subclinically infected cattle, can retain viable organisms in encap-sulated lung lesions (sequestra) for up to two years. These animals may shed organisms, particularly when stressed. Close contact; aerosol up to 200 meters under favorable conditions. [CSFPH, 2008]	Survives well in frozen tissues. [OIE, 2009] Although there are a few anecdotal reports of transmission on fomites, mycoplasmas do not survive for long periods in the environment and indirect transmission is thought to be unimportant. [CSFPH, 2008]	subclinically infected cattle [CSFPH, 2008]	3 weeks - 4 months

QRA Pathogen Summary Matrix

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Agents to Review	Epidemiology				
Elements	Morbidity	Mortality	Treatment	Burden/Impact on Health Care system	Outbreak Control Measures
Viruses					
African Swine Fever (ASFv)	Very high	5% (late stages of epidemic) - 100% (early)	No treatment for infected animals.	None	Rapid culling; C&D; movement control; investigation; surveillance [OIE, 2009]
Classical Swine Fever (CSFv)	Highly variable [FAD, 2008]	10-20 days	No treatment for infected animals. [OIE, 2009]	None	Rapid culling; C&D; movement control; investigation; surveillance [OIE, 2009]
Foot and Mouth Disease Virus (FMD)	Close to 100% in domestic animals [FAD, 2008]	1-5% adults; 20% calves	No treatment for infected animals. Vaccine not used due to trade considerations. [APHIS, 2007]	None	Quarantines and movement restrictions, euthanasia of affected and in-contact animals, and cleansing and disinfection of affected premises, equipment and vehicles. Rodents and other vectors may be killed to prevent them from mechanically disseminating the virus. [CSFPH, 2007]
Japanese Encephalitis Virus (JEv)	Variable	5-30%	There is no treatment for humans other than supportive therapy. [CSFPH, 2007]	Major problem in endemic areas. Fatality rates can reach 25%, and 50% of cases result in permanent neurologic damage, psychiatric disturbances, ataxia and catatonia [OIE, 2009]	JEv vaccines can prevent disease in horses and pigs. Vaccines are protective for all genotypes. Vaccinating pigs can also decrease the amplification of the virus, and help protect horses and humans. However, JEv is also amplified in birds, and some infections will still occur. Stabling animals in screened barns can be partially protective, particularly during outbreaks. Mosquito control. [CSFPH, 2007]
Rift Valley Fever Virus (RVFv)	Highly variable	10% (cattle); 20% (calves); 70-100% (lambs, kids); 10-70% (adult sheep, goat)	No specific treatment, other than supportive care, is available; however, ribavirin has been promising in animal studies. Interferon, immune modulators and convalescent-phase plasma may also prove to be helpful. Most cases of Rift Valley fever are relatively mild, brief illnesses and may not require treatment. [CSFPH, 2007]	Major problem in endemic areas. Influenza-like syndrome; recovery in 4-7 days; complications include retinopathy, blindness, meningo-encephalitis, hemorrhagic syndrome with jaundice, petechiae and death.	Once an outbreak has occurred animal vaccination should NOT be implemented because there is a high risk of intensifying the outbreak. Restricting or banning the movement of livestock may be effective in slowing the expansion of the virus from infected to uninfected areas. As outbreaks of RVF in animals precede human cases, the establishment of an active animal health surveillance system to detect new cases is essential in providing early warning for veterinary and human public health authorities. [WHO, 2010]
Hendra Virus (Hev)	Low [FAD, 2008]	High [FAD, 2008]	Hev infections in humans are very rare, and proven drug therapies have not been developed; however, treatment with antiviral drugs, combined with supportive care, has been tried in recent cases. Other than supportive therapy, there is no treatment for Hendra virus infections in animals. In some cases, surviving horses have been euthanized due to uncertainties about virus persistence. [CSFPH, 2009]	Major problem to those with close contact with infected horses.	Horses that develop signs consistent with Hev infection should be isolated, and stringent infection control measures should be taken. People should limit interaction with the horse, using PPE to protect the skin, mucous membranes and eyes. Use caution to avoid generating aerosols or splashing material, both when examining the horse and during disinfection. Other horses, as well as domesticated animals (particularly cats) should be kept away from the suspect case. Exposed horses should be examined daily for signs of disease. Quarantines and rigorous hygiene have been effective in containing past outbreaks. The low rate of horse-to-horse transmission also aids control. [CSFPH, 2009]
Nipah Virus (Niv)	100% (pigs)	40% (piglets); 5% (pigs); 40-75% (humans)	Treatment is supportive, and may include mechanical ventilation. Ribavirin has been promising in some outbreaks but remains to be investigated fully. [CSFPH, 2007]	Serious clinical disease; no antiviral treatment	The Malaysian outbreaks were controlled in both domesticated animals and humans by culling more than one million pigs. In addition, pig farming was permanently banned in some high-risk areas. [CSFPH, 2007]
Bacteria					
Contagious Bovine Pleuropneumonia (CBPP)	50-80% in close-contact herd	10-70%	MmmSC susceptible to several antibiotics, but treatment may only slow the progression of the disease. In some cases, it can also promote the formation of sequestra. Antibiotics are ineffective in chronically affected animals. For these reasons, antibiotic treatment is discouraged, even in endemic regions. [CSFPH, 2008]	None	Outbreaks are eradicated with quarantines, movement controls, slaughter of infected and in-contact animals, and cleaning and disinfection. Many routinely used disinfectants are effective. The efficacy of eradication efforts can be monitored with serologic tests. [CSFPH, 2008]

QRA Pathogen Summary Matrix

5/10/2010

Agents to Review	Epidemiology	Immune Response		Laboratory	
Elements	Current Enzootoses	Natural Infection	Immunization	Staff/PPE Requirements	Biosafety Level
Viruses					
African Swine Fever (ASFv)	Enzootic in most countries of Sub-Saharan Africa including Madagascar. In Europe, successfully eradicated from the Iberian Peninsula but continues to be found in Sardinia. Recently appeared in Caucacus and Russia. [OIE, 2009]	Pigs infected with virulent strains often die prior to development of a detectable humoral immune response. [FAD, 2008]	No vaccine [OIE, 2009]	Standard	BSL-3Ag
Classical Swine Fever (CSFv)	Occurs in much of Asia, Central and South America, and parts of Europe and Africa.	CSFv is known for its ability to evade and compromise the host's immune system. [FAD, 2008]	A number of live attenuated vaccines used for CSF control around the world. C Strain is most widely used; suitable for use as emergency vaccine. [FAD, 2008]	Standard	BSL-3Ag
Foot and Mouth Disease Virus (FMD)	Endemic in parts of Asia, Africa, the Middle East and South America (sporadic outbreaks in free areas). [OIE, 2009]	Infected animals develop a humoral antibody that is transient in duration and specific for the infective sub-type virus. Protective antibodies are developed against FMDv structural proteins present in the virus capsid between 7 and 14 days post infection.	Currently, there is no universal FMD vaccine. Vaccine banks contain a wide variety of strains, particularly those judged to be the greatest threat of introduction, for use in an outbreak. [CSFPH, 2007] USDA has reservations about implementing a vaccination program if FMD is ever detected in the US, including the risk of spreading the disease and compromising our country's international trade status. [APHIS, 2007]	Standard	BSL-3Ag
Japanese Encephalitis Virus (JEv)	JEv is widespread in eastern, south-eastern and southern Asian countries and has spread to western India and to the western Pacific region including the eastern Indonesian archipelago, New Guinea and Northern Australia. [OIE, 2009]	Immunity subsequent to natural infection. [FAD, 2008]	Vaccination of horse and swine is advised. Several vaccines are available for humans. These vaccines are protective for all genotypes. In some countries, vaccination is routine in children. In non-endemic areas, laboratory workers at risk of infection should be vaccinated. [CSFPH, 2007 and CDC, 2010]	Enhanced	BSL-3Ag
Rift Valley Fever Virus (RVFv)	Endemic in tropical regions of eastern and southern Africa. Epizootic outbreaks in Africa among peri-endemic countries have been associated with above average rainfall and climatic conditions favorable for competent vectors. Post-2002 RVF activity in Senegal, Mauritania, Gambia, Madagascar, Swaziland and South Africa. [OIE, 2009]	Antibody response on day 4-5 post infection. [FAD, 2008]	Live attenuated Smithburn strain of RVF virus currently in use; induces lifelong immunity in livestock. [FAD, 2008] Human vaccine has been developed but has limited availability; addl vaccines are under investigation. [CSFPH, 2007]	Enhanced	BSL-3Ag
Hendra Virus (Hev)	Endemic to Australia [CSFPH, 2009]	Antibodies post-infection are detectable but because of the reportable and zoonotic nature of the disease, no info is available on whether these antibodies are protective against challenge. [FAD, 2008]	No vaccine		BSL-4
Nipah Virus (Niv)	Niv has been reported from Malaysia, Bangladesh and India. Areas of Southeast Asia where fruit bats (Pteropus) are present should be considered endemic. [OIE, 2009]	Humoral immune response in animals and humans [FAD, 2008]	No vaccine		BSL-4
Bacteria					
Contagious Bovine Pleuropneumonia (CBPP)	CBPP is widespread in sub-Saharan Africa, including countries in the West, South, East, and Central regions of Africa. [OIE, 2009]	Recovered animals not susceptible to reinfection [FAD, 2008]	Vaccine MmmSC (TI) used in enzootic areas [FAD, 2008]	Standard	BSL-3Ag

Qualitative Risk Assessment (QRA) SME Instructions

Background

DHS anticipates that research performed at the NBAF may include several pathogens. Specifically, eight pathogens have been named in the NBAF EIS:

1) African Swine Fever virus (ASFv), 2) Classical Swine Fever virus (CSFv), 3) Foot-and-Mouth Disease virus (FMDv), 4) Japanese Encephalitis virus (JEv), 5) Rift Valley Fever virus (RVFv), 6) Contagious Bovine Pleuropneumonia (CBPP), 7) Hendra virus (Hev), and 8) Nipah virus (Niv).

For the purposes of the EIS (December 2008) and its inherent hazard analysis and risk assessment, DHS selected FMDv, RVFv and Niv for modeling and assessment (EIS E-12). Subsequent Government Accounting Office (GAO) review (GAO, July 2009) suggests and Congressional Law (P.L. 111-83 § 560) requires that DHS prepares an additional Site-Specific (Manhattan, Kansas) Risk Assessment (SSRA) for FMDv with a different plume modeling approach. This SSRA is to be completed before NBAF construction funds will be released. DHS elected to add RVFv to the SSRA to include the additional fidelity and design feedback associated with the modeling and consideration of a zoonotic pathogen. Congress also conditioned the release of NBAF construction funding on a National Academy of Sciences (NAS) review of the SSRA. NAS recommended (NAS, March 2010) that all eight pathogens mentioned in the EIS be considered in the SSRA.

DHS is motivated to provide the safest large-animal biocontainment facility possible while minimizing construction delays (with significant delay costs) and satisfying Congressional requirements. NAS is motivated to seek the most comprehensive and complete SSRA that addresses potential hazards and risks. The solution identified by DHS is to:

- Provide the full-fidelity modeling and assessment of risk for the FMDv and RVFv pathogens, and
- Provide a qualitative site-specific assessment of the risks (this Qualitative Risk Assessment or QRA) associated with the full suite of eight pathogens to inform the SSRA and supplement recommendations and conclusions for design and operations feedback.

QRA SME Panel Schedule

QRA Instructions sent to SMEs (April 28) Draft Pathogen Summaries sent to SMEs (April 30) Optional Input due from SMEs (May 3) Electronic Data Packets sent to SMEs (May 5) QRA SME Panel Meeting (May 11-12, in Austin TX, or by dial-in) QRA Draft Report Working Group in Austin (May 13) QRA Draft Report (May 14) QRA Final Report (May 21)

QRA SME Panel Meeting

Location

The Meeting will be held at Signature Science's Austin, TX campus:

Signature Science, LLC
8329 N. MoPac Expressway
Austin, TX 78759
(512) 533-2000 (main)

Agenda

While the agenda has not been finalized, it is expected that discussions will begin at 0830 CDT and continue until 1630 CDT. A one-hour lunch break will occur from 1200-1300. A catered lunch will be provided in Austin on both days.

Dial-in Instructions

SMEs unable to travel to Austin on May 11-12 are welcome to participate via teleconference. Dial-in instructions are as follows: Dial (512) 583-2470 or (877) 474-4724, ext. 2470. The 4-digit bridge number is 4245.

Austin Logistics

Several hotels located near Signature Science offer government rates. We recommend the following that offer direct billing to Signature Science:

Staybridge Suites Austin Arboretum
10201 Stonelake Blvd.
(512) 349-0888

Hyatt Summerfield Suites
10001 N. Capital of TX Hwy.
(512) 342-8080

Please contact us if we can be of assistance in booking your travel.

SME Tasking

The instructions and expectations below describe the desired level of preparation for the QRA SME Panel Meeting. Please feel free to comment or ask questions regarding the instructions, schedule, and expectations.

1) SMEs will review the current NBAF design status, waste treatment pathways, air handling controls, and person/animal/material handling flows. This information will be provided with the electronic Data Packet on May 5.

2) SMEs will review and adjust the proposed set of "Pathogen-Influenced Design, operations, and mitigation considerations," or PIDs. The PIDS are those design, operations, and mitigation considerations that are a function of the research pathogen characteristics. Further information on liquid effluent, solid waste, fomite/carrier/vector, and air pathways will be provided to the SMEs with the electronic Data Packet.

3) SMEs will establish the working range of "Design, operations, and mitigation-Influencing Pathogen characteristics," or DIPs (based on pathogen summaries; may include an assessment of the extend DIPs for unknown pathogens) The DIPs are the characteristics of the pathogens that influence the design. DIPs will include, but are not limited to:

pH survival ranges Temperature survival range UV sensitivity
Vaccination Therapy Dose/response

4) SMEs will quantify the range of pathogen characteristics and discuss design implications. SMEs will compare and assess the NBAF PIDs based on the established DIPs, and develop and present recommendations and conclusions.

5) QRA SME Panel Final Report

The QRA SME Panel will develop and edit a report for delivery to the SSRA project by May 21. A working group of the QRA SME Panel will meet in Austin on May 13, following the Panel Meeting, to draft the QRA Final Report. The SSRA project team will review, edit, and provide final formatting for the QRA Final Report and incorporate into the SSRA final report. A proposed QRA SME Panel Final Report organization, subject to further review and change, is presented below:

I. QRA Executive Summary
II. QRA Objectives
III. Recommendations and Conclusions
APPENDICES: Data Packages Consensus QRA
Worksheets on PIDs and DIPs QRA SME Panel
Notes QRA SME Panel Bios References

6) Pathogen Summaries

Available scientific literature and referenced works will be reviewed and referenced to populate a summary for each pathogen. Draft Summaries will be sent electronically on April 30. Final Summaries will be delivered to the SMEs in the electronic Data Packet on May 5. The likely descriptors that will be included in the summaries are:

- Pathogen Definition
- Etiology
- Host Range
- Epidemiology
- Immune Response
- Staff/PPE Requirements
- BSL Requirements
- Research Needs

- Animal Models
- Laboratory Control Measures
- Diagnostic Methods
- Surveillance Techniques
- Outbreak Responses
- Trade Consequences
- Human Health Consequences (if applicable)

Each SME is asked to provide field and/or laboratory input related to pathogen characteristics for distribution to entire SME Panel Group in the electronic Data Package, scheduled for May 5. Your optional input to the Final Summaries is due to Signature Science NLT Monday, May 3. We anticipate that your contributions may include, but are not limited to:

- Pathogen-specific (of the eight) anecdotal information or experiences;
- Relevant BSL-3Ag, BSL-3, or BSL-4 insight on design considerations, operating practices, and/or mitigation strategies;
- Unpublished (but referenced) research or data of interest; and/or
- Pathway expertise (liquid effluent, solid waste disposal, carcass disposal, and air handling) experiences relevant to the SSRA overall objectives.

Appendix C: QRA SME Panel Meeting Notes

QRA SME Meeting Discussion Notes	Speaker(s)
Conclusions	
Pathogen	
Do these eight pathogens "bound the list" of foreseeable NBAF pathogens? Affirmative, in general (panel). Some discussion about the potential of need for research on pox viruses and hantaviruses and SARS-like pathogens. Panel agrees that no prion diseases will need to be included in NBAF research.	TT Panel
No H5N1 or H1N1 research should be conducted at the NBAF.	Panel
None of the eight would survive the engineered containment systems, if used properly.	WW, PK, JK
The panel suggests that, for modeling purposes, FMDv is an appropriate representative pathogen for a fomite transfer scenario.	Panel
The panel suggests that, for modeling purposes, FMDv is an appropriate representative pathogen for the human carrier scenario.	Panel
FMDv and RVFv are good representative (perhaps bounding) pathogens for the economic consequences of outbreak impact.	TM
Handling of large animals in BSL-4 (Hev, Niv) does present some additional risk.	Panel
Design	
NBAF autoclave specification will include a high temperature requirement of no less than 146ºC.	PL
There are no concerns about the efficacy of planned engineering systems to contain all eight of the pathogens.	Panel
No BSL-2 effluent decontamination system is needed at NBAF. (No consideration should be given to using the BSL-3 effluent decontamination system for BSL-2 effluent.)	Panel
Floor drain strategy is acceptable. (Panel) Strategy is for no floor drains, except showers, in BSL-3E (including "Special Procedure" rooms), capped floor drains in BSL-4, open floor drains with removable strainers and grating in BSL-3Ag (and BSL-4 and ABSL-4) animal holding rooms. Eyewash stations have no drains.	SF
Fire escapes from BSL-3 will not lead directly outdoors but into a containment area.	PK
The currently proposed backup carcass disposal system, and alkaline hydrolysis digester, should be effective in destroying all eight pathogens.	Panel
Current NBAF design strategy for air handling systems is acceptable to the panel. This includes the following strategy elements: • BSL-3 containment area: no intake HEPA/single exhaust HEPA • BSL-3E: no intake HEPA/single exhaust HEPA • BSL-3E "Special Procedure" Rooms: single intake HEPA/double (series) exhaust HEPA	Panel

QRA SME Meeting Discussion Notes	Speaker(s)
• BSL-3Ag: single intake HEPA/double (series) exhaust HEPA (no parallel series path) • BSL-4: single intake HEPA/double (series) exhaust HEPA The endorsement of this air handling strategy followed discussion about a perceived design standard (referenced by the BMBL) described in the *ARS Facility Design Standards 242.1* , July 2002, that indicates BSL-3Ag exhaust air should have double (series) HEPA in a parallel redundant configuration. For reference, the relevant section of 242.1 (9.4.4.C.6) is provided below: *The most severe requirements for these modern, high level biocontainment facilities include HEPA filters arranged both in series and in parallel on the exhaust side, and series HEPA filters on the supply side of the HVAC systems serving "high risk" areas where large amounts of aerosols containing BSL-3Ag agents could be expected [e.g., large animal rooms, contaminated corridors, necropsy areas, carcass disposal facilities, etc.]* The panel expressed concern regarding the practicality (size, space, configuration, maintenance, costs, etc.) of parallel (fully redundant) series HEPA exhaust pathway.	
Operations	
The specific protocol for maintaining and operating the incineration system needs to be developed and validated.	Panel
Recommendations	
Design	
Some engineering (environment conditioning, ventilation, etc.) may have to be performed to accommodate small/medium animal caging systems.	PK
There is some concern over the "dual-use" necropsy suite. Converting between containment levels may be problematic. The panel suggests that additional design consideration be given to the incorporation of a dual-use necropsy suite.	SF, PK, Panel
Do not restrict potential research activities by lack of engineering. (Allow for equipment additions, procedural flexibility, etc., that can accommodate future research needs.)	PK
Do not design dedicated facility space/configurations for low-likelihood programs or speculations.	SF
Current design considerations do not specifically include (or exclude) the accommodation of bats, wild birds, lizards, arthropods, small rodents, and aerosol room facilities. The panel suggests that design consideration be given to ensure that nothing in design would preclude the addition of such systems in the future.	SF, Panel
BSL-4 should have a dedicated decontamination room, which could also be used as an emergency exit, with VHP decontamination.	Panel
Containment design strategy should ensure that emergency exits from BSL-4, BSL-3Ag, and BSL-3E suites and facilities should flow into the BSL-3 containment area. Placement of BSL-3 containment area emergency exits should be well considered and accessible to emergency responders and, possibly, portable decontamination equipment.	Panel

QRA SME Meeting Discussion Notes	Speaker(s)
Special design consideration should be given to minimizing the potential for loss of containment via the dunk tank well(s) between BSL-3 and BSL-2.	Panel
The panel suggests that design consideration be given to the incorporation of dampers and HEPA caissons into the containment ceiling. Such designs are currently being incorporated into other facilities.	PL, panel
Special design consideration should also be given to the reduction/removal of all facility and equipment (penning, gating, etc) hazards (pinch points, sharps, etc.) that could damage/compromise PPE while workers are in the BSL-4 animal handling areas.	Panel
Special design consideration should be given to sizing the chemical showers in the BSL-4 area. Showers should be able to accommodate 2 persons to permit 360° inspection of PPE by each person. Shower size should also take into consideration the potential need for emergency decontamination in the case of injury or sudden illness.	PK, Panel
The panel suggests that the BSL-4 animal handling spaces, in particular, provide for “full squeeze” chutes as opposed to “head squeeze” chutes—to reduce the potential of staff injury.	Panel
Special design consideration should be given to all animal transit pathways to provide “rounded” (or radiused”) corners and proper lighting to assist in animal movement motivation.	AH, SF, Panel
The panel suggests that all animal matting systems be free of sharp edges or corners in the traction pattern to help minimize the potential of airborne feces spray, “build-up” and the subsequent need for more labor intensive (and potentially high risk) matt cleaning. Matt adhesives must provide complete and long-term attachment to subfloor. Suggest a combination of SOP changes and harder floor surfaces to get feces flow and to prevent animals from lying in their own waste. An alternative is straight hard epoxy floors with floating mats that can be pulled out (without getting in pen) and cleaned on both sides.	PL, SF, Panel
The panel suggests that designers consider washdown system fixtures or other solutions that will minimize the potential for repetitive stress injuries to animal care workers. (Risks may increase if worker injury/discomfort influences application of full cleaning protocols.)	PK, Panel
The panel suggests that designers include (or at least don’t preclude) the use of two-way communication systems for the encapsulation suits to be worn in BSL-4. Also suggested that modified suits be used with large animals in the BSL-4.	DD, PL
It is suggested that design consideration be given to escape routes for workers in large animal BSL-4.	PL
The panel suggests that design consideration be given to a relatively new decontamination system that uses a reverse polymerization (a product/process being marketed by Environmental Waste International, a Canadian company) process for “red bag” waste and other contaminated materials. Process would provide redundancy to incinerator, while reducing waste and producing energy.	Panel, PL
The panel recommends that no skirts be used around the hydraulic lifting components of the necropsy table. It is more difficult to clean and less likely to be cleaned if skirt is in place.	Panel

QRA SME Meeting Discussion Notes	Speaker(s)
It is suggested that design consideration be given to the accommodation of the potential for temporary use of organic bedding for research that may involve the use of neonatal large animals.	SB
The panel suggests that design consideration be given to features that connect the throat/chute of any carcass disposal options to any containment area.	Panel
The panel suggests that additional consideration (renderer, digester, RP, other) be given to the selection of carcass disposal systems, particularly for the BSL-4. Is there intent to provide redundant carcass disposal systems?	Panel
Operations	
Risk assessments should be on ongoing part of NBAF operations and prior to starting work on any new research program. (panel)	Panel
Procedural training and biosafety training specific for each research program and for each pathogen must be frequent and rigorous. (panel)	Panel
NBAF policy should include arrangements with local medical facilities (Mercy Regional Health Center, perhaps) and providers for human medical services specifically related to zoonotic pathogens and potential laboratory-related injuries. Panel suggested on-site medical area housing nine quarantine (isolation) beds in the event that workers are exposed during a spill scenario. Staff rehearsals of potential scenarios are also suggested. (panel)	Panel
NBAF procedures must include validated protocols for the transfer of inactivated materials from a higher containment level to a lower containment level—including BSL-2.	Panel
Dunk tanks (included in current design) are effective for surface decontamination of a triple bagged product only. Decontamination solution (active ingredients, additives, temperature, etc.) should be determined by protocol and validated for contact time, concentration, and effectiveness.	Panel
Design and procedures should minimize the likelihood of having containment boundary failure when the volume of dunk tank solution is too low to maintain containment between both sides.	Panel
The panel suggests that design consideration be given to providing “360°” access to penned animals in the BSL-4 area. Additionally, design consideration should be given to a supplied breathing air system that accommodates worker movement for the “360°” access while keeping air supply air supply lines from the reach of penned animals. Penned animals should also be unable to reach any wall-mounted systems.	PL, Panel
The panel suggests that NBAF policies include provisions for the hiring/development/maintenance of EMT certifications for some staff members. This suggestion is intended to help mitigated risks associated with assisting injured or ill personnel while in containment, and stabilizing such patients while be decontaminated for removal from containment.	JK, Panel
Consideration should be given to the validation of the digester with each of the pathogens, as well as pH and temperature of the residue released into the waste water treatment system.	Panel, PK, BE

QRA SME Meeting Discussion Notes	Speaker(s)
Adequate and frequent training programs are needed to ensure that personnel are familiar with the complicated building automation systems.	DD
Observation or Question	
Pathogen	
ASFv and CSFv may be the most "robust" or "survivable" pathogens of the eight.	WW, PK, JK
CBPP is very difficult to transmit.	PK
Current FADD Course and PIADC includes infections with ASFv, CSFv, CBPP, and FMDv. Additional FADD diseases that are currently demonstrated at PIACD include African Horse Sickness (AHS) (causative agent: AHS virus), Sheep and Goat Pox (SGP) (causative agent: sheeppox virus, SPv), Heartwater (causative agent: *Ehrlichia ruminantium*), Rabbit Hemorrhagic Disease (causative agent: Rabbit Hemorrhagic Disease virus RHDv), velogenic (Exotic) Newcastle Disease (ND) (causative agent: Newcastle Disease virus, NDv), Highly Pathogenic Avian Influenza (HPAI) (causative agent: H5N2), and possibly Peste des Petits Ruminants (PPR) (causative agent: Peste des Petits Ruminants virus (PPRv). Notably, none of these pathogens cause significant human disease.	Panel, WW, TT
Future research needs for all 8 pathogens may involve pathogenesis, routes of entry, viremia, and countermeasure studies.	WW
ASFv and CSFv research needs may include: strain characterization, pathogenesis, countermeasures, vaccine efficacy studies, transmission studies (with vectors, including arthropods for ASFv), aerosol, infectious does, route of entry studies, and specialty contamination issues. (panel)	Panel
FMDv research needs may be much the same as other programs (like those mentioned for ASFv and CSVv) but will include more on DIVA vaccines, sterile immunity, carrier state in animals (impacts on outbreaks) evaluation and development of diagnostics, and immunity duration.	Panel
JEv may have some special facility needs. Transovarial studies could require BSL-3 insectary. Current NBAF design has Insectary in BSL-3E. Such research may be done at other facilities (Laramie, BRI), however. Which vectors (mosquitoes) in U.S. are susceptible and will amplify virus?	Panel
Hev and Niv research may involve smaller animals (fruit bats?). If we accommodate such animal models with equipment, design needs to include considerations consistent with containment and capture of small animals. North American bats can get potentially get infected. Niv is a potential agent of terrorism.	PK DD, WW PK
CBPP research needs include differential diagnoses and vaccine development/testing.	Panel
Are American Bison susceptible to CBPP? More data needed.	PK
CBPP eradicated from America in late 19th century. CBPP is low risk for entry to US. It is difficult to get a "take" at FADD school. Even 100-200 mL direct injection to lungs may only result in a 50% infection rate.	WW

QRA SME Meeting Discussion Notes	Speaker(s)
NBAF feasibility study has a description of future programs that should be consulted—includes Cyril Gay input.	PK
Peste des Petits Ruminants (PPR) may be an interesting disease for study at NBAF. This virus may soon be "eradicated" but it remains in many freezers around the world. However, rinderpest is on the rise in small ruminants.	WW PK
RVF research with mosquitoes may be more appropriate for BRI.	WW
The need for an Insectary at NBAF (question posed by EC) may be to study vesicular stomatitis (answer by WW).	EC WW
A possible animal model for the study of Hev is ferrets. Would ferrets be an animal that could be accommodated by current NBAF plans? (AH) Yes, with additional equipment—but no required design changes. Make use of ABSL-3 or add caging systems to BSL-3Ag.	AH SF
Swine Vesicular Disease is another pathogen of potential research interests at NBAF. Conventional (as designed) systems (and disinfectants like Virkon™ S) will effectively inactivate SVDv.	PK
The introduction (outbreak) of any exotic (new) disease will have an economic impact. The magnitude of the impact is influenced by actual and effective trade bans. It is not clear that an outbreak of each of the eight pathogens would result in actual trade bans; although, it's likely that Swine Fevers, FMD, and RVF would have significant trade impacts. Most of these diseases are formerly listed as "List A" pathogens the OIE's list. Niv and Hev would probably not trigger automatic actual trade bans but may trigger effective trade bans.	TM
Manhattan, KS wants to have capability to diagnose and treat locally for quicker response. The need for advanced diagnostics in the local community is recognized.	TT, BP, BE
Further discussion is needed on Lab Response Network (LRN). None of the eight pathogens are in LRN.	NP
Design	
There have been no infected animal escapes at Plum Island or Winnipeg. (WW)	WW
Necropsy is the highest risk activity/facility due to generation of large amounts of infectious liquids. Consideration should be given to mitigating splash and spray hazards. Should necropsy be performed in BSL-4 or carcass disposal only?	JK, WW, SF
Band saw at Ames is not used for segmentation very often and is not suggested on a level 4 animal.	JK
Will NBAF be able to do large animal studies with insects? (PL) Maybe in smaller animal holding rooms with additional equipment and some minor engineering. Such rooms may require low ceilings.	PL SF PL
The exposure of large animals to an aerosol is usually accomplished with a mask for the animal as opposed to creating an aerosol in a space.	WW

QRA SME Meeting Discussion Notes	Speaker(s)
Is it possible that other animal models will be used at NBAF? (WW) It is possible, but other animal models may require specialized equipment and procedural modifications—large animal models are part of the core NBAF mission.	SF, DD
Floors will be covered with a high-performance resin finish. (SF) One suggested product is Septiplex, a polyurethane.	PL
BSL-3Ag waste and effluent are much more difficult to manage that BSL-3 waste and effluent because of the animal waste products (including solid fraction), feed waste, and other miscellaneous small solids.	Panel
UV decontamination systems should not be included as part of containment practices or as part of the engineered containment systems.	Panel
Flooring systems, such as the Tenderfoot® system may need to be accommodated in the BSL-3Ag and BSL-4 animal handling areas. Design should not preclude the safe and practical use of such systems.	SF
Vapor decontamination systems should be included in ductwork design.	PL
There has been no “red bag” accident (known loss of containment) reported by the failure of engineered systems in the last 20-30 years.	PL
Animal weighing systems can be problematic. A suggested approach is to use portable scales.	SF
Large animal handling in a BSL-4 area adds to design considerations for doors. Ambulatory animals will step over thresholds but non-ambulatory animals and large equipment may be difficult to navigate with large thresholds. In addition, doors must be able to withstand a blow from a large animal moving at high speed (withstand impact at 35mph from 1500lb animal). Some door providers have had high failure rates (welds, seals) in the past and NBAF should develop thorough inspection and testing protocols for all doors.	Panel, DD
An observation was made that compressible door seals do require power to reseal. (anon.)	
Discussion of potential washing systems include the following example: 1) initial wash with high volume/low pressure hose to get solids to drain, 2) second wash with high pressure to get packed solids off, 3) decontamination, 4) final high pressure wash after animals are gone.	SF
The clean/dirty corridor system will be compartmentalized to minimize the impact/response needed if a “dirty” animal is accidently introduced into a clean corridor.	SF
Design should include non-ambulatory animal movement systems (winches and hoists)—current design features appear to include these features.	SF, Panel
Observations were made on the importance of isolation and flexible mounting for the throat (of loading chute) of any carcass disposal system. Movement between the throat and the containment floor can cause damage and potential leaks in the containment area.	PL

QRA SME Meeting Discussion Notes	Speaker(s)
The panel has mixed opinions and experiences with the inclusion of maceration systems in effluent decontamination pathways of animal holding rooms. Animal waste solids and other miscellaneous solids (feed, rubber, detritus, etc.) complicate the inactivation process but macerators are prone to failure and require maintenance.	Panel
Operations	
Some procedure additions, such as necropsy splash shields, may provide some risk reduction benefit by reducing the spread of infectious liquids, aerosols and tissue.	JK, DD
Should animal caretakers wear respiratory protection (N-95) in BSL-3Ag?	WW
Blood from exsanguination (common first step in necropsy) goes directly into floor drains.	SF
Can arthropod work be done in BSL-4? (DD) None currently anticipated.	Panel
NBAF is not intended to be a universal research facility. There are other research facilities in the US that are better equipped to handle some research programs. Selectivity of mission will help minimize risks.	Panel
Mecuric chloride should not be used as a disinfectant at NBAF. (DD) Acids and oxidizers (like Virkon™™ S) work well against most pathogens. (JK) Virkon S may damage concrete.	BE
Vapor decontamination pathways should be validated for efficacy of transfer material decontamination and for facility/fixture decontamination (door seals, closures, etc.)	Panel
All vapor decontamination sources and liquid decontamination solutions should be validated prior to use/incorporation into SOPs.	Panel
FedEx currently provides a “white glove” service for delivery of important samples to PIADC. FedEx may be able to offer a similar service for NBAF but this need may be mitigated by the geographic location selected for NBAF.	WW, Panel
Some problematic issues have been noted regarding the shipment of infectious materials between eligible facilities. Such issues should be resolved to minimize the potential for “workarounds” that may result in unsafe or illegal transfer activities.	PK, Panel
Other than commonly used BSL-4 practices, the handling and care of large animals in BSL-4 will require significant investment in the development of protocols and procedures. A few examples of BSL-4 animal management include: feces collection and management, a staff “buddy” system, outer footwear selection (non-slip capabilities consistent with floor finish and animal operations, steel toe, shank, etc.), cleaning, etc.	PL, JK, Panel

Appendix D: QRA Final Report Reviewers

Larry Barrett, Ph.D. Director, Plum Island Animal Disease Center DHS, Science and Technology Directorate
John D. Clements, Ph.D. Professor and Department Chair, Microbiology and Immunology, Tulane University School of Medicine Director, Center for Infectious Diseases, Tulane University
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Appendix D: Draft Plan for Preparing the NBAF Emergency Response Plan (ERP)

1. Scope of the Effort

The Department of Homeland Security Science & Technology Directorate (through the Office of National Laboratories) has the primary responsibility to develop the National Bio and Agro-Defense Facility (NBAF) emergency response plan (ERP) covering preparedness, response and recovery. The NBAF ERP will follow components in the National Incident Management System (NIMS; http://www.fema.gov/emergency/nims/). The NBAF ERP will provide guidance and direction to assure an integrated and coordinated response to emergency situations (e.g., an accidental or intentional release of foot-and-mouth disease virus or other hazardous pathogen from the facility, hazardous chemical spill, weather-related event, etc.). It will support/define the response efforts both horizontally across the Federal Government and vertically among Federal, State, and local entities.

In addition the ERP will address NBAF's response to emergencies and other incidents occurring at nearby facilities (e.g., Kansas State University, Biosecurity Research Institute) or within the local community that could impact the operations and/or security at NBAF.

The ERP will build upon the documents prepared, or to be prepared, in support of the NBAF site selection and the pre-construction/construction of the actual facility. The ERP will be developed and implemented prior to beginning operations of the NBAF.

2. Organizations who will be Engaged in the ERP Development

The NBAF ERP will be the responsibility of the ONL Operations and Oversight Group working with appropriate NBAF staff (e.g., Laboratory Director, Operations Director, and Responsible Official [RO] for biological select agent and toxins [BSTA]). ONL will reach out for support/expertise in developing the ERP to other organizations such as:

- S&T ChemBio Division and S&T Laboratories (PIADC and NBACC)
- Other DHS Components (e.g., Office of Security, Office of Health Affairs, and Federal Emergency Management Agency)
- U.S. Army Garrison, USAMRIID, and other National Interagency Biodefense Campus (NIBC) partners at Ft. Detrick
- U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service-Veterinary Services (APHIS–VS) and Agricultural Research Service (ARS) at HQ and

  field operations/laboratories
- State of Kansas (e.g., KS Emergency Management Director, State of KS Division of Emergency Management, KS State Veterinarian, KS Public Health Director, KS Homeland Security, KS Homeland Security Advisor, KS USDA, and KS Secretary of

  Agriculture)
- Biosecurity Research Institute (BRI) personnel
- Kansas State University (e.g., Director, Environmental Health and Safety; Public Safety; Emergency Management Coordinator, and KSU Police Chief)

- City of Manhattan, KS
- Riley County, Pottawatomie County
- Ft. Riley (Police Department, EMS, etc.)
- FBI (Manhattan, KS office), KS Bureau of Investigation (Intelligence Fusion Center), KS Threat Integration Center

- KS Highway Patrol
- Mercy Regional Health Center, University of Kansas Hospital Medical Center

3. NBAF ERP

3.1 ERP Table of Contents (Appendix A shows more detail for topics to be included in the ERP)

- Overview (scope and purpose)
- Preparation and Mitigation (e.g., annual update of plans, staff education, new employee orientation and refresher classes, systems and resources to minimize a potential release of infectious agents or hazardous materials, emergency exercises and drills, evacuation instructions for evacuation, fitness for duty, how employees will be vaccinated or prophylaxed before or during an event, emergency supplies [clothing, footwear, respiratory protection], employee identification badges, mutual aid agreements, emergency communication system, regional hospital disaster planning, emergency weather preparations, risk vulnerability assessment with mitigation strategies, establishment of a site Emergency Operations Center, etc.)
- Response (e.g., response to internal or external emergency; Incident Management System to manage emergency conditions in cooperation with external public service agencies; evacuation plans; reporting an emergency incident; communication via media including discontinuation of emergency operations and return to normal operations; implement mitigation strategies [including establishing effective area quarantine, animal movement controls, surveillance and response zones if necessary], etc.)
- Recovery (e.g., damage assessment of building spaces, equipment and personnel impacts and repairs; documenting emergency outcomes; debriefing the incident; NBAF business continuity; etc.)
- Acronyms and Glossary of Technical Terms
- Appendices

3.2 Events to be Covered in the ERP

The emergency response plan for NBAF will incorporate the breath of activities that may be encountered at such a facility including animal health, human (public) health, security, and environmental issues. The emergency response plans will include, but not be limited to, clearly indentifying and articulating the procedures for the following:

- Emergency notification
- Medical emergency
- Evacuation of buildings and/or site (including those with disability)
- Fire
- Tornado, earthquake, or flood
- Criminal or violent behavior including demonstration/civil disturbance, bomb threat, etc.
- Hazardous materials release (e.g., biological select agents and toxins, pathogens other than BSAT, flammable/ combustible gases in labs and storage areas, radioactive material, oil spill or leak) including shipments to the NBAF
- Utility failure
- Building system failure (e.g., response actions to discharge scenarios such as ventilation

problem resulting in loss of negative pressure in containment spaces, effluent waste

discharge problem, natural gas leak, breaches of primary biocontainment)

The ERP will address an emergency at facilities in proximity to the NBAF (e.g., K-State TRIGA Mark II research reactor used to train nuclear reactor operators) that might affect NBAF operations.

3.3 NBAF Operational Plans

The ERP will be integrated with the appropriate NBAF operational plans including, but not limited to:

- Incident Response Plan (IRP) for biological select agents and toxins (BSAT) per 42 CFR 73.14, 7 CFR 331.14 and 9 CFR 121.14 (including plans for theft, loss or release of BSAT in compliance with Federal statutes; accidental releases or occupational exposures will be immediately reported to APHIS Agricultural Select Agent Program via Form 3; BSAT-exposed animals will be handled in the same manner as the agent or toxin itself for the purpose of reporting a BSAT theft, loss or release to appropriate Federal, state and local agencies). The IRP will address pathogens other BSAT.
- Biological Safety Plan
- Biosecurity Incident Response Plan for Non-Biological Incident
- Occupant Emergency Plan for the laboratory/animal room sections and for administrative sections of the NBAF
- Security Plan (facility, physical, policies for personnel, data and cyber)
- Emergency Preparedness (drills, training and documentation, securing building contents, building evacuation diagram and plan)
- Spill Prevention Control and Countermeasures Plan

3.4 Supporting Agreements for the Plan

Effective implementation of the NBAF ERP will require MOU's or formal agreements with local, state, and Federal authorities (and others as necessary) for mutual aid and sharing/ utilization of resources (personnel, equipment, and facilities). In order to assure effective emergency management operations, there exists the need to coordinate activities of government agencies or other entities which provide mutual aid and have their own incident response plans. Per the NIMS model, protocols must be in place to designate the overarching authority to manage and coordinate structure and concurrent implementation processes consistent with their responsibilities. These may include:

- Kansas State University (KSU)
- KSU's Biosecurity Research Institute (BRI)
- City of Manhattan, KS
- Riley County
- Ft. Riley (Chemical unit, Bomb Unit, Irwin Army Community Hospital, possibly setting up special immunization program [SIP] with new hospital being built, etc.)
- Hospital/Facility emergency plan at local and regional hospitals (e.g., Mercy Regional Health Center, Irwin Army Community Hospital at Ft. Riley, and University of Kansas Medical School)
- State of Kansas
    - Kansas Secretary of Agriculture
    - Kansas Director of Emergency Management and Homeland Security
    - Kansas State Veterinarian - Kansas Animal Health Department

- Kansas State Fire Marshall

3.5 Implementation of the Plan (Training, Drills, and Reviews)

Effective implementation of the NBAF ERP will also include on-going training, coordination, and drills for preparing for actual events. Potential FMDV scenario-based workshops, meetings exercises and/or drills for assessment and finalization of the Plan (may also include other BSAT) including:

- Emergency FMD vaccination strategy exercise (scenario-based discussion)
- FMD standstill exercise (scenario-based discussion)
- Functional FMD exercise (rapid response team from local and state level simulation of a hypothetical FMD outbreak) to include mitigation strategies (e.g., may include establishing an area quarantine, animal movement controls, and response zones; may involve diagnostics, surveillance, depopulation/ disposal, cleaning/disinfection; spraying for infected insect release)
- FMD communications strategy (information management) workshop
- Resourcing workshop
- Sectional coordination workshop (KS local and regional counties)
- Incident Command training and workshops
- Veterinary investigations, restricted area movement and security, infected premises operations workshop
- Directors, operations managers, etc. meetings

4. Review and approval (distinctions will be made for review and approval) of the ERP

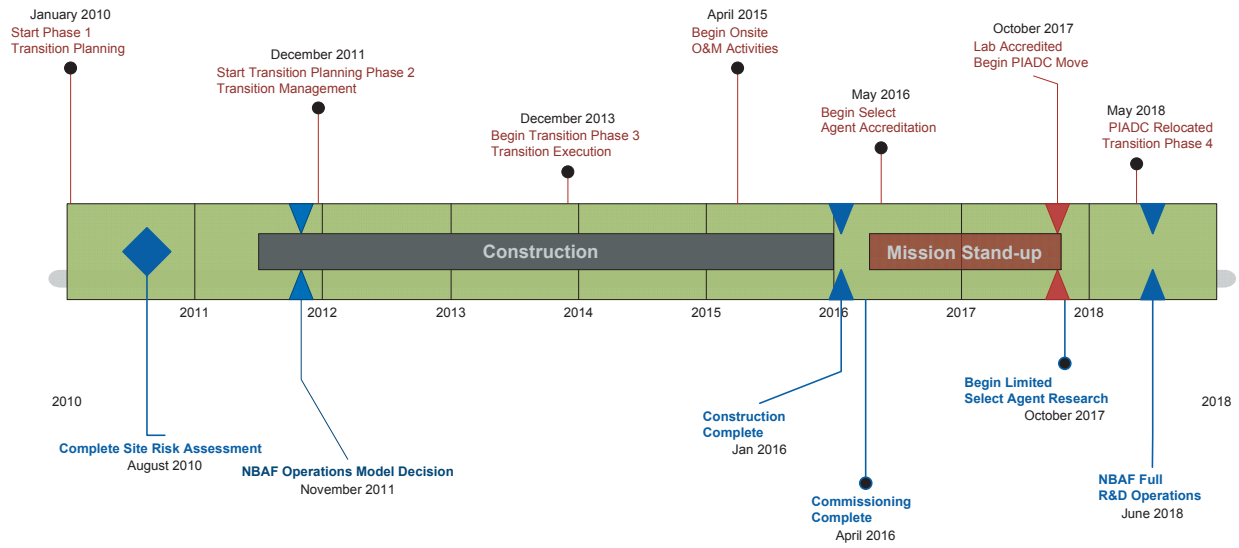
The NBAF ERP will be reviewed by:

- NBAF Laboratory Director and appropriate NBAF Management
- S&T (ONL and ChemBio)
- DHS Office of Security
- USDA (ARS and APHIS)

5. Schedule for Preparation of the NBAF ERP

The NBAF ERP will address the specific requirements of NBAF operations and memorandums of understandings (MOUs).

- Late 2015/2016: ERP will cover NBAF initial operations including the CUP, main lab building, trans-shipping building and out-buildings as the facilities are transferred from the construction contractor to DHS.
- 2016/2017: ERP will be updated by DHS ONL for the operations of the NABF site including the security plan, biosurety plan, incident response plan (IRP), and contingency/business continuity plans (a possible off-site continuity of operations or COOP location).



6. References

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B. Kansas Incident Specific Plan for Foreign Animal Diseases- Prevention, Preparedness, Response and Recovery (March 2008)

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D. Risi, G.F., M.E. Bloom, N.P. Hoe, T. Arminio, P. Carlson, T. Powers, H. Feldmann, and D. Wilson. 2010. Preparing a community hospital to manage work-related exposures to infectious agents in biosafety level 3 and 4 laboratories. Emerg. Infect. Dis. 16:373-378.

E. "The Medical First Response to Bioterrorism," Tara O'Toole, M.D., M.P.H., *Medicine and Global Survival*, Volume 6, No. 2.

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7. Attachments

Appendix A (examples of details to be included in the ERP)

Acronyms and Glossary of Technical Terms

For example:

- BSL — Biosafety Levels (there are 4 levels of biosafety used to designate and regulate lab work with microorganisms; the range is BSL-1 in which the microbes are not know to cause disease in healthy adult humans to BSL-4 in which the microbes pose a risk of life-threatening disease and for which there is no known vaccine or therapy; BSL-3Ag refers to research involving large agricultural animals; increasing levels of personnel and environmental protection are provided for by the different biosafety levels; the higher the level of the biosafety lab, the more stringent the level of protection)
- DHS — Department of Homeland Security

- FADs — Foreign Animal Diseases (Diseases not present in the United States that are capable of rapidly spreading and causing high numbers of deaths and/or devastating economic consequences; e.g., foot and mouth disease)
- PIADC — Plum Island Animal Disease Center (US laboratory for the diagnosis, research, vaccine and other countermeasure development for foreign animal diseases, as well as training veterinarians in the recognition and diagnosis of these diseases)
- USDA APHIS — United Stated Department of Agriculture Animal and Plant Health Inspection Service
- USDA ARS — United Stated Department of Agriculture Agricultural Research Service
- Zoonotic — A term for diseases transmitted by animals to humans

Facility Description and Facts

- Characteristics of surrounding area (college campus including buffer zone around the stadium sports complex and student recreation center across from the NBAF site, neighborhood, rural)
- Building plans and floor plans (NBAF, CUP, Trans-shipping, etc.)
- Construction information (year completed, exterior material, total square footage, total number of floors with number above and below ground, etc.)
- Total number of typical building occupants along with estimate of total number of daily visitors
- List of emergency equipment (fire extinguishers, fire alarms, AEDs, protective clothing, etc.) and spill response materials (biological, chemical, petroleum, radiological) at the facility including location, physical description and capabilities
- Types of access/egress from buildings on NBAF campus including shelters and evacuation shelters adjoining NBAF biocontainment facilities
- Security (e.g., fences, lighting, alarms, guards, emergency cut-off valves and locks)
- Weather tracking strategy
- Plume modeling scenarios

Training, Simulation Exercises and Drills:

- Local "First Responders" NBAF lab access and response coordination training. Because of the understandable concern that EMS and hospital medical staff may/will have about their risk of exposure to a zoonotic (BSL-3 or -4) pathogen, training will be ''end-to-end'' and include first responders (firefighters, law enforcement officers, emergency medical service providers), clinical laboratory staff, hospital healthcare providers, and security personnel.
    - For zoonotic pathogens handled at the NBAF: provision in advance for the medical care of any employee potentially infected during the course of research, in a setting that minimizes the risk of transmission of infection to others (e.g., care and isolation units)
- Employee emergency response training (ERT) reviewed annually including evacuation plan for facility (audible and visible alarms, key building contact information, emergency assembly area location, etc.)
- Incident Command Structure
- Provide life safety ("man down"), fire extinguisher training and fire safety training (including building evacuations) to NBAF campus personnel

Emergency Notification

- Names, addresses, email and phone numbers of emergency coordinators (include primary designees; emergency coordinator at facility or on call, NBAF security, ES&H, etc.)
- 24-hour emergency medical contact information (e.g., competent medical authority for the NBAF, local and regional medical facilities (e.g., Mercy Hospital Medical Center, U. of KS Hospital, Irwin Army Community Hospital at Ft. Riley)
    - For zoonotic pathogens handled at the NBAF: provision in advance for the medical care of any employee potentially infected during the course of research, in a setting that minimizes the risk of transmission of infection to others (e.g., care and isolation units)
- Contact information of other authorities and resources such as KSU University Police and ES&H; City of Manhattan police and fire, Riley EMS; local and regional medical facilities (e.g., Mercy Hospital Medical Center, U. of KS Hospital, Irwin Army Community Hospital at Ft. Riley), KS Health Department (Riley County), Center for Disease Control and Prevention (CDC), USDA APHIS Agricultural Select Agent Program, FBI Topeka Field Office, DOT, Ft. Riley bomb unit, etc.
- Non-life threatening emergency phone numbers (e.g., chemical or biological spill during business hours and during off-hours/weekend).

Response

- Protocols for major emergency situations and activation of emergency management plan(s)
    - Situation (e.g., biological agent release) affects livestock, wildlife, human health (disease reporting, epidemiology, vaccination), environment, etc.
    - Incident Management System to manage emergency conditions (e.g., roles and responsibilities with local, county, state, and Federal agencies)
- Communications plan to coordinate and manage all official notices and alerts; collect, prepare and disseminate information to NBAF staff, KSU faculty/staff/students, news media and the public, etc.
    - Emergency news plan (e.g., coordinate and manage all official notices and alerts; collect, prepare and disseminate information to NBAF staff, KSU faculty/staff/students, news media and the public; resources available include KSU campus emergency information line/campus emergency web site/campus radio station, City of Manhattan emergency radio station, etc.)
    - What to Do When You Hear Campus Warning Sirens (shelter, listen for campus emergency information)
    - State-wide Kansas 800 system for crisis communication

Recovery Activities

- Plan for the transition of emergency operations to normal laboratory management.
- Consideration of circumstances, if any, that might require the emergency relocation of BSAT to another secure facility
- Conduct damage assessment and identify critical needs for repair (capture and determination of costs with financial impacts, burdens and compensation, if any)
- Record keeping and documentation (logs, forms, photos, final report, etc.) and their distribution
- Critique of emergency response and follow-up
    - Upon resolution of an emergency event, the NBAF RO (and others as appropriate) will conduct a debriefing with all personnel involved including the facility manager, the facility director, local

emergency responders, etc. Possible prevention of future events (e.g., lessons learned to identify areas of improvement) and appropriateness of the response actions will be discussed. Shortcomings and improvements to preventative and response actions will be discussed, documented and implemented.

- A follow-up report will be prepared and reviewed by the NBAF RO (facility Manager and others as appropriate). This report will be sent to the appropriate Entities (e.g., the USDA APHIS Select Agent Program, CDC Division of Select Agents and Toxins, OSHA, etc.).

Appendix E: Proposed Procedure for Select Agent Registration Permitting (including Foot and Mouth Disease Virus) for the National Bio- and Agro-Defense Facility (NBAF)

I. Purpose

The purpose of this report is to provide an outline of the procedure that will be used to obtain the registration and permit for biological select agents and toxins (BSAT) for the NBAF. The NBAF will be sited at Manhattan, Kansas on the Kansas State University. The FY10 appropriations language requires that Department of Homeland Security (DHS), in coordination with U.S. Department of Agriculture (USDA), submit to Appropriation Committees a report that describes the procedure that will be used to issue the permit to conduct live Foot and Mouth Disease virus (FMDV) research at the NBAF under Section 7524. The BSAT registration and permit process will follow the established USDA Animal and Plant Health Inspection Service (APHIS) Agricultural Select Agent Program procedures.

II. Background on NBAF

A. Mission of NBAF (extend the research and diagnostic capabilities of the Plum Island Animal Disease Center [PIADC])

DHS is charged with the responsibility and has the national stewardship mandate for detecting, preventing, protecting against, and responding to terrorist attacks within the U.S. These responsibilities, as applied to the defense of animal agriculture, are shared with USDA and require a coordinated strategy to adequately protect the Nation against threats to animal agriculture. Consultations between DHS and USDA on a coordinated agricultural research strategy, as called for in the *Homeland Security Act of 2002* (Pub. L. 107–296) and Homeland Security Presidential Directive 9 (HSPD–9), *''Defense of U.S. Agriculture and Food,''* dated January 30, 2004, revealed a capability gap that must be filled by an integrated research, development, test, and evaluation infrastructure for combating agricultural and public health threats posed by foreign animal and zoonotic diseases.

The DHS Science and Technology Directorate is responsible for addressing the identified gap.

Accordingly, to bridge the capability gap and to comply with HSPD–9, DHS proposed to build the NBAF, an integrated research, development, test, and evaluation facility. Co-locating DHS with USDA's Animal and Plant Health Inspection Service-Veterinary Services (APHIS–VS) and Agricultural Research Service (ARS) at the NBAF would enable research, diagnostics, and responses to outbreaks in agricultural animals (i.e. cattle, swine, and sheep) at a U.S.-based facility. Co-locating these functions in a single secure facility would maximize synergies and provide enhanced capabilities for the detection and prevention of foreign animal diseases in the U.S.

The NBAF would meet the capabilities required in HSPD–9 by providing a domestic, modern, integrated high-containment facility containing laboratories and animal rooms for an estimated 250 to 350 scientists and support staff to safely and effectively address the accidental or intentional introduction into the U.S. of high consequence foreign animal, emerging and zoonotic diseases. Currently, the Plum Island Animal Disease Center (PIADC), where much of the research on foreign animal diseases is performed, is an essential component of the national strategy for protecting U.S. agriculture from threats caused by intentional attack (i.e., agro-terrorism) or unintentional introduction of foreign animal

disease viruses such as foot and mouth disease virus (FMDV). However, PIADC was built in the 1950s, is nearing the end of its lifecycle, and does not contain the necessary biosafety level facilities to meet the NBAF research requirements. The NBAF would fulfill the need for a secure U.S. facility that could support collaborative efforts among researchers from Federal and state agencies, academia, and international partners to perform necessary research at the required biosafety level (BSL)-3Ag/4. Additionally, as discussed in the *Report of the Commission on the Prevention of Weapons of Mass Destruction (WMD) Proliferation and Terrorism* (December 2008) and *Prevention of WMD Proliferation and Terrorism Report Card* (January 2010), the U.S. should continue to undertake a series of mutually reinforcing domestic measures to prevent bioterrorism.

Prior to passage of the Food, Conservation, and Energy Act of 2008 (H.R. 6124 [2008 Farm Bill]), which became law on May 22, 2008, the U.S. Code (21 U.S.C. Section 113a) required that live FMDV could not be studied on the U.S. mainland unless the Secretary of Agriculture made a determination that such study was necessary and in the public interest and issued a permit for such research to be conducted on the mainland. Section 7524 of the 2008 Farm Bill directs the Secretary of Agriculture to issue a permit to the Secretary of Homeland Security for work on the live FMDV at any facility that is a successor to PIADC and charged with researching high consequence biological threats involving zoonotic and foreign animal diseases. The permit is limited to a single successor facility.

DHS conducted a competitive site selection process to identify and evaluate potential candidate sites for the NBAF. The site selection process was initiated by publication of a Notice of Request for Expressions of Interest (EOI) submissions for Potential Sites for the NBAF in the **Federal Register** on January 19, 2006 (71 FR 3107–3109). DHS developed and implemented a rigorous process for the evaluation of the EOI submissions received, against DHS's four evaluation criteria (i.e., Proximity to Research Capabilities relevant to the NBAF mission, Proximity to Workforce, Acquisition/Construction/Operations Requirements, and Community Acceptance) and associated sub-criteria. These criteria and their associated sub criteria were developed by an interagency working group to ensure that the NBAF would meet the interdependent needs of DHS and USDA to adequately protect the Nation against biological threats to animal agriculture.

In July 2007, DHS identified five site alternatives that surpassed others in meeting the DHS evaluation criteria, sub-criteria, and DHS preferences, and determined that they, along with the Plum Island Site and a No Action Alternative, would be evaluated in the Environmental Impact Statement (EIS) as reasonable alternatives for the proposed NBAF. DHS published the *Preferred Alternative Selection Memorandum* in December 2008 (see the DHS Web site at *http://www.dhs.gov/nbaf*), which describes the basis for the selection of the Preferred Alternative. DHS's Preferred Alternative to construct and operate the NBAF is the Manhattan Campus Site in Manhattan, Kansas (Record of Decision in the **Federal Register** on January 16, 2009; 74 FR 3065-3080).

B. NBAF Facility Design Process

DHS will implement specific risk mitigation measures in the design, construction, and operation of the NBAF. The facility will be designed to meet containment requirements set forth in USDA guidelines and BMBL guidelines, as well as the National Research Council and the Association for Assessment and Accreditation of Laboratory Care (AAALAC). In addition, the design process takes into account the construction and operations lessons learned from other similar bio-containment laboratories in the U.S. and around the world. Laboratory visits and interviews were conducted to gather the necessary information that can be used to inform the present NBAF design process. PIADC, the current facility where live FMDV research is currently conducted, has provided significant input into the design using their 50+ years of operating experience. In addition, architectural design features, biocontainment technologies, operational procedures, training and protocols, and waste management technologies and procedures to minimize operational and environmental risks will be incorporated.

Risk assessments are performed as part of the design process to ensure robust design and operating procedures are developed. For example, a *Threat and Risk Assessment* was done for the NBAF site in Manhattan, KS that will be used to develop a comprehensive risk-based physical and personnel security program for the NBAF. A site-specific risk assessment has been conducted for the NBAF that identifies facility and operational risks that require mitigation strategies. The mitigation strategies will require robust physical containment barriers, such as specialized air handling systems for contamination control.

Additionally, DHS will consider, where applicable, recommendations from other reports that provide lessons learned information to improve or enhance design for biosafety and biosecurity. For example, NBAF will consider the recommendations of the Government Accountability Office (GAO) on perimeter security found in the September 2008 Report to Congressional Committees entitled *Biosafety Laboratories: Perimeter Security Assessment of the Nation's Five BSL–4 Laboratories* (GAO-08-1092).

C. Biosafety and Biosecurity

In addition to implementing robust design features, DHS will have site-specific standard operating procedures and response plans in place prior to the initiation of research and diagnostic activities at the NBAF to minimize risks of select agent release. The operating procedures will cover both biosafety and biosecurity. Biosafety refers to the application of combinations of laboratory practices and procedures, laboratory facilities, safety equipment, and appropriate occupational health programs when working with potentially infectious microorganisms and other biohazards. Biosecurity and personnel reliability are related to laboratory biosafety and biocontainment. The principles of biosafety and biocontainment have been articulated in two key reference documents: the *NIH Guidelines for Research Involving Recombinant DNA Molecules* (first published in 1976), and the CDC/NIH manual *Biosafety in Microbiological and Biomedical Laboratories (BMBL*, initially issued in 1984; 5th edition released online in 2007). These documents have been amended and revised over the years to reflect advances in science and technology. The *BMBL* is generally recognized as the code of practice for biosafety and biocontainment in the U.S.

The DHS policies for biosafety and biosecurity comply with current Federal regulations, guidelines, and policies for DHS-sponsored activities involving biological agents including the Select Agent Regulations [7 *Code of Federal Regulations* (CFR) 331, 9 CFR 121, 42 CFR 73], the current edition of the BMBL and the *NIH Guidelines for Research Involving Recombinant DNA Molecules*, as appropriate. The Instruction Handbook for DHS Personnel Suitability (121-01-007) serves a general role in personnel reliability across the Department by establishing screening requirements and processes for all individuals who require unescorted access to DHS-owned facilities, DHS-controlled facilities, or commercial facilities operating on behalf of DHS.

Various Biological Personnel Reliability Program (BPRP) and biosurety-related elements are implemented at PIADC, as well as the other DHS-operated laboratory, the National Biodefense Analysis and Countermeasures Center (NBACC) under their specific policies and procedures. PIADC and NBACC have developed facility-wide policies and operating procedures pertaining to biosafety, biosecurity, and personnel reliability. These policies and procedures comply with Federal regulations on select agents, support the overall DHS policies and apply to all staff, subcontractors, or visitors that have access to BSAT. DHS will utilize the operational expertise from the policies and procedures at these laboratories, as well as other applicable operating laboratories, in the final development of its permit application process for NBAF. When the NBAF is operational, it will comply with all applicable Federal regulations, guidelines and policies.

PIADC had a 3-day inspection by the USDA APHIS Select Agent Program on January 5-7, 2010 (inspection team included the Deputy Director for the CDC Select Agent Program). The inspection covered the biosafety and biosecurity laboratory procedures used to manage live FMDV in the laboratory. The out brief comments from the USDA APHIS inspector were very positive for the select agent program and no major deficiencies were noted. The NBACC BSAT programs are currently being conducted at USAMRIID (until the new facility is operational) and NBACC employees are working under USAMRIID's BPRP. DHS has a full time biosurety officer engaged in the day to day oversight of the DHS biocontainment laboratories and advising the laboratories on their biosafety and biosecurity practices.

II. Background on Biological Select Agents and Toxins (BSAT)

Under the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (Public Law 107-188), entities that possess, use, or transfer biological toxins or agents deemed a threat to public health must register with the Secretary of the U.S. Department of Health and Human Services (HHS). The Centers for Disease Control and Prevention (CDC) has been designated by the HHS Secretary as the agency responsible for implementing the provisions of the law for HHS. This Act includes the Agricultural Bioterrorism Protection Act of 2002 (ABPA; subtitle B) where entities that possess, use, or transfer agents or toxins deemed a severe threat to animal or plant health or products must notify and register with the Secretary of the U.S. Department of Agriculture (USDA). USDA APHIS has been designated by the Secretary as the agency responsible for implementing the provisions of the law for USDA. The FMDV permit falls under the USDA APHIS Agricultural Select Agent Program purview.

The Federal Select Agent Program (FSAP) is a joint program from HHS/CDC and USDA APHIS that regulates Federal and non-Federal entities that possess, use or transfer biological select agents and toxins (BSAT). Although CDC and APHIS differ in their overall scope, the BSAT regulations are the same. The regulations [Title 7 CFR Part 331: Plant select agents, Title 9 CFR Part 121: Animal and overlap select agents and toxins, Title 42 CFR Part 73: HHS select agent and toxins] require certain conditions to be met in order to possess, use, and transfer BSAT.

Per 7 CFR Part 331.7(g), 9 CFR part 121.7 (g), and 42 CFR 73.7 (g), the entity registration number will be valid only for the specific select agents and toxins, and the specified activities and locations provided by the entity in the application package (APHIS/CDC Form 1).

BSAT registration for the NBAF

USDA APHIS is responsible for implementing both the ABPA (registration of entities according to select agent regulations) and the Animal Health Protection Act (AHPA; permitting regulations). Entities wishing to possess, use, or transfer select agents and toxins listed by APHIS must be in compliance with regulations pursuant to both Acts. DHS, in coordination with USDA, will work with APHIS staff to meet regulatory requirements of both Acts in the permit application process.

1. <u>DHS will submit the BSAT registration after the NBAF is commissioned</u>

DHS and USDA have identified 8 diseases that would potentially be studied at the NBAF. The bioagents causing these diseases are select agents: foot-and-mouth disease virus, classical swine fever virus, African swine fever virus, Rift Valley fever virus, contagious bovine pleuropneumonia (caused by the bacterium *Mycoplasma mycoides* subsp. *mycoides* small colony), Japanese encephalitis virus, Nipah virus, and Hendra virus. This list may change based upon continued evaluation of risks to the U.S. agricultural system including threats to the food supply and public health.

DHS will register the BSAT for the NBAF with USDA APHIS Agricultural Select Agent Program and any needed CDC involvement (e.g., NBAF research on overlap select agents such as zoonotic agents that can be transmitted from animals to humans) will be managed by APHIS according to APHIS-CDC standard operating procedures. Overlap select agents (e.g., in the NBAF, examples include Hendra virus, Nipah virus and Rift Valley Fever virus) and HHS select agents require the participation of the CDC Division of Select Agents and Toxins in the review and approval process, which APHIS will facilitate.

DHS will be obtaining the certificate of registration for the NBAF to possess, use and transfer BSAT under the conditions that will be specified in the entity registration application submitted to APHIS. Registration of an entity requires:

- that an “Application for Laboratory Registration for Possession, Use, and Transfer of Select Agents and Toxins” (APHIS/CDC Form 1) be completed and submitted to APHIS;

- that the U.S. Department of Justice's Federal Bureau of Investigation (FBI), Criminal Justice Information Service (CJIS) complete a security risk assessment (SRA) for the designated Responsible Official (RO), Alternate Responsible Officer (ARO), and all individuals who will have access to BSAT; and

- an inspection of the facility by FSAP.

Before registration is granted, the facility must also meet biosafety requirements that are commensurate with the risk that the agent or toxin poses and must establish security measures that provide graded protection in accordance with the threat that the agent or toxin poses.

For the NBAF Form 1 submission, the DOJ number section will be left blank since the NBAF is a new entity (a new entity must get DOJ numbers assigned to their employees regardless of whether the employees have had a DOJ number with another entity such as PIADC). The following is a general summary of the process:

- After the Form 1 has been submitted to APHIS, the entity Responsible Official (RO) submits a request to the FBI for fingerprint packets for all employees working with BSAT;

- APHIS will issue the entity a letter with the unique DOJ identifying numbers for each individual listed on the registration;

- The RO forwards to each individual their unique DOJ identifying number;

- The RO provides everyone with their own DOJ number and each individual fills out FBI form (FD-961) and puts their unique identifying number in block 11;

- When fingerprint packets arrive, each individual follows all of the FBI instructions (http://www.fbi.gov\hq\cjisd\cjis\htm) for submitting fingerprints and returns fingerprints to the entity RO;

- The RO will mail in bulk batches the completed fingerprint packets and FD-961 forms to the FBI, CJIS.

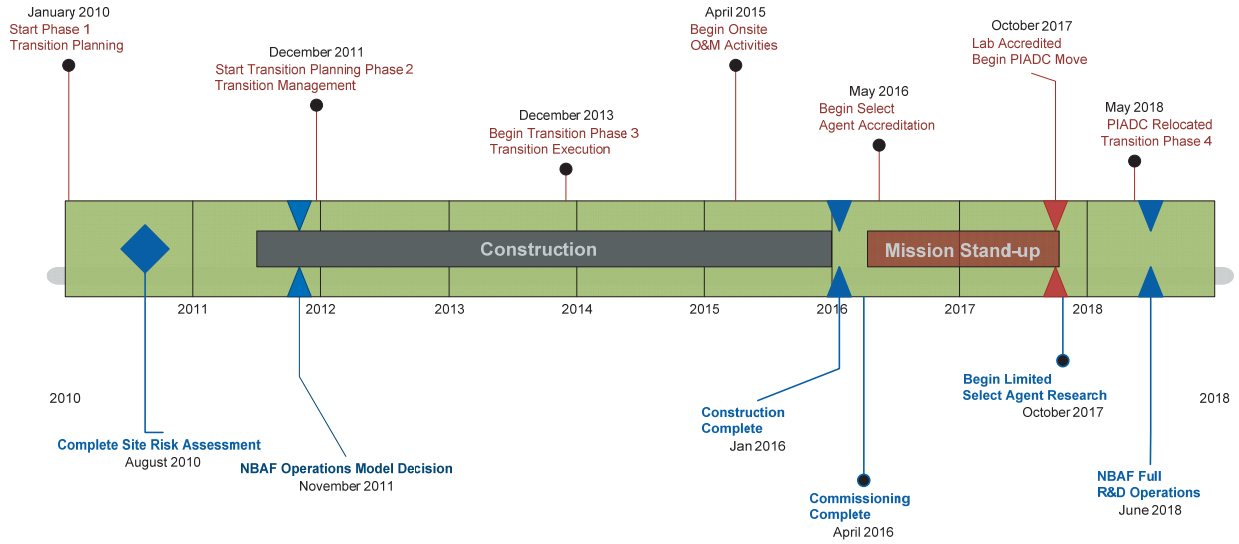
2. Timeline

Approximately 24 months before the NBAF is operational, DHS (working with USDA staff from PIADC will begin the planning, preparation and work needed for the submission of the Application for Laboratory Registration for Possession, Use, and Transfer of Select Agents and Toxins" (APHIS/CDC Form 1). FMDV is a part of this select agent list. This activity will require the biological safety officer (BSO) to be on-site and working with each future NBAF principal investigator that will be working with BSAT in BSL-3/3Ag/4 (laboratory and animal rooms) to gather the detailed information needed for the Form 1 submission.

Extensive documentation must be prepared before the application can be submitted including the development of a statement of work objectives/planned use for each BSAT, description of the methods/procedures that will be used for each BSAT, list of BSAT storage room numbers, and BSAT use

room numbers for each biosafety level (BSL) with a list of BSAT planned to be used in each of these rooms. Biosafety and security planning for select agents and toxins must consider graded protection commensurate with the risk of the select agent or toxin. The NBAF biosafety, security and incident response plans will incorporate the provisions of 9 CFR parts 121.11, 121.12 and 121.14. These plans will be reviewed as part of the registration and inspection process.

Before the inspection is scheduled, DHS will: (1) assemble the trained staff, (2) develop standard operating procedures (SOPs) and plans (e.g.,safety, security, incident response, etc.), (3) install and certify IT infrastructure (e.g., laboratory information management system for BSAT inventory control), (4) stand up the Institutional Biosafety Committee (IBC) and the Institutional Animal Care and Use Committee (IACUC), and (5) obtain the voluntary accreditation from AAALAC.



3. <u>Other requirements for FSAP registering (site-specific facility risk assessment)</u>

The entity application must include a site-specific risk assessment of the facility that addresses vulnerabilities and threats (not limited to man-made events, but must include natural events as well).

DHS, through the NBAF Design Partnership (NDP), has had Sandia National Laboratories' International Biological perform a threat and risk assessment (TRA) for the NBAF facility in Manhattan, KS. The TRA focused on a technical risk assessment of 418 different security scenarios with a technically robust risk assessment methodology. This report covers risk identification, risk assessment and risk characterization. The site-specific TRA, along with applicable regulatory requirements and agency-specific requirements, will be used to implement the necessary physical security system to meet the performance requirements of risk reduction for a BSL-3/3Ag/4 facility. In addition to the security risk assessment, DHS has completed a site-specific risk assessment to identify mitigation strategies needed for safe and secure operations of the NBAF facility.

III. Permitting for the NBAF

After a certificate of registration is granted, a permit according to the AHPA will be required for each select agent that the NBAF will possess. An APHIS/CDC Form 2 (transfer form) will be completed and approved by USDA/APHIS prior to any movement of live FMDV (and other select agents) to the NBAF. To plan accordingly and to ensure a thorough application process, DHS has already been in discussions with APHIS/VS Select Agent Program office to ensure that the AHPA permitting requirements are in place before live FMDV (and other BSAT) is moved from PIADC to NBAF. The permit process schedule is as follows:

FY 2010	Complete plans for BSAT permit process (includes live FMDV)
FY 2011	Finish NBAF design
FY 2012	Start NBAF lab construction
FY 2014	Begin NBAF BSAT registration application process
FY 2016	Submit BSAT registration for NBAF (after commissioning of the facility)
FY 2018	Begin live FMDV research at NBAF

Appendix F: A Review of Recent Outbreaks of Foot and Mouth Disease (FMD) and Rift Valley Fever (RVF)

1. Foot and Mouth Disease Case Study Review

Introduction

Foot and mouth disease (FMD) is a serious, highly contagious, viral disease that affects cloven-hoofed animals. Although it typically does not cause death in healthy adult livestock, the disease can leave domestic and wild animals severely debilitated. FMD can reduce milk and meat products from animals, but the disease is most devastating on the agricultural structure and economy of the country affected. An outbreak of FMD can result in severe losses in production of milk and meat and in movement restrictions, completely stopping many agricultural exports. An FMD outbreak can affect the country's agricultural economy for many years.

Clinical signs

Presence of FMD within a group of animals is usually characterized by fever and blister-like lesions followed by erosion on the tongue, lips, mouth and on the teats, and in between the hooves. The damage to hooves can cause lameness in the animal (APHIS Veterinary Services, 2007) and thus affect its ability to move, eat, and reproduce. Young animals experience a higher mortality rate, with a 20 percent or higher mortality rate in young calves, piglets, and lambs (US Animal Health Association Committee on Foreign and Emerging Diseases, 2008).

Animals of all ages with FMD may become anorexic and experience a sudden rise in temperature (FMD Info.org, 2010), which can often be mistaken for other more common diseases, and thus FMD can go undiagnosed and can spread the disease rapidly. In addition, some animals not exhibiting clinical signs can serve as virus hosts and spread the disease prior to veterinarian notification. Thus, the critical response time to an FMD breakout is limited (Rivas A.L., 2002). Thus, FMD is a particularly dangerous disease to the U.S. agricultural community because it has the potential to enter the country and spread prior to detection.

Risk factors for disease spread

An FMD outbreak has the potential to cause one of the largest U.S. agricultural losses of any foreign animal disease because of its ease of spread and ability to infect many species. FMD is likely the most contagious of all animal diseases due to (Ekboir, 1999):

- The small amount of infected dose required for effective transmission;
- The short incubation period of three to eight days;
- The release of the virus before the onset of clinical signs;
- The massive quantities of virus excreted from infected animals;
- The ability of the disease to spread rapidly over large distances; and
- The ability of the virus to survive in the environment.

Because FMD is so easily spread, the primary defense against FMD within the United States has been to prevent the disease from entering the country. The U.S. Department of Agriculture (USDA) and partner agencies work together to ensure that imported meat and animal products are FMD free. The USDA

actively monitors for occurrence of FMD and other foreign animal diseases worldwide and works to evaluate the risk of exposure.

Introduction into livestock populations

Introduction of FMD into a livestock population can have severe impacts on the entire country's agricultural community. FMD can be introduced into a group of animals by infected animals or materials that have been exposed to the disease. FMD is a hardy virus that can easily contaminate vehicles, facilities, hay, or food; in the right environment, it can persist in contaminated items such as soil or manure for months (Government Accountability Office, 2002). While humans do not contract FMD, they can contribute in its spread when in contact with infected animals (FMD Info.org, 2010). Humans can act as carriers for the disease since FMD can survive 24 hours in the human respiratory system and for several weeks on clothing (Ekboir, 1999). Coupled with the fact that clinical signs can be mild or masked by other conditions, it can be difficult to rapidly diagnose FMD in order to prevent further spread.

2. Control strategies

Prevention

The primary control strategy employed by the U.S. agricultural community is prevention, using a two tier strategy: border control and active surveillance. Because FMD is usually introduced into a country by an infected animal or contaminated feed, the U.S. prohibits entrance of food products or animals and animal products from FMD endemic areas or countries that have not proven to be FMD free (Bashiruddin). All animals imported into the U.S. are monitored prior to entering the country (FMD Info.org, 2010).

Disease control once in the country

In case of confirmation of FMD on a farm within the U.S., many states, in coordination with the USDA, would activate emergency response plans that include measures to limit spread and exposure. Prompt identification is key to containing disease spread, so farmers and veterinarians are routinely educated on clinical signs and watch for signs of FMD. In addition, the USDA has tried to eliminate negative incentives for reporting of FMD by ensuring that farmers are fairly compensated for depopulated animals, including considerations for the short and long-term costs of the disease.

Once FMD is confirmed, the goal is to eliminate the disease as quickly as possible, investigate the source, and trace all animals that may have been in contact with the disease. The USDA's first response to an outbreak would be "stamping out" or imposing animal movement restrictions, depopulation, and eradicating the disease immediately (APHIS- Veterinary Service, 2007). Response operations could include securing the affected site and establishing quarantine zones, tracing all contacts with the index farm, and establishing movement control (FMD Info.org, 2010).

Response

The manner and speed in which FMD develops in livestock depends on which strain of FMD virus is involved, as well as livestock characteristics (Veterinary Exotic Disease Division, 2004). Thus, the response to an outbreak of FMD within the United States would be tailored to the characteristics of the outbreak. The USDA has a prescribed response to an FMD outbreak, but this has not been tested on an actual FMD occurrence within the U.S.

Once FMD has been controlled, APHIS would assist producers to recover from losses and evaluate the disease situation throughout the U.S. In order to be considered disease free, the U.S. must observe the World Organization for Animal Health (OIE) rules on surveillance and disease eradication, and destroy all infected and vaccinated animals (OIE, 2005).

Vaccination

Because there are seven different serotypes of the FMD virus, all of which have similar symptoms, it can be difficult to prepare for a vaccine strategy on a large-scale basis. Vaccination is also a controversial disease control technique because vaccine technology is rapidly evolving and due to economic effects of vaccination. Vaccination of livestock can help contain the disease if it is used strategically to create barriers between the infected and disease-free areas. (APHIS- Veterinary Service, 2007)

Currently, the U.S. vaccine bank stores several serotypes of FMD and its associated antigens and can provide hundreds of thousands of doses of FMD vaccine within days. There are several justifications for employing a vaccine strategy in case of an outbreak, and these include:

- Reducing the incidence of clinical disease in livestock when exposed to the virus;
- Reduction of the number of animals needing depopulation during an outbreak;
- Reduction of the amount of virus produced by the infected animals, thereby reducing the likelihood of disease spread (Veterinary Exotic Disease Division, 2004); and
- Rapid containment of the disease.

In addition, new vaccines have many benefits, including being relatively inexpensive to produce and not requiring FMD materials to be made (McGinnis, 2007). In addition, new vaccines also allow scientists to determine whether an animal found to have FMD antibodies acquired them through vaccination or infection. This is a relatively new development that supports the use of vaccines.

3. Select examples of outbreaks of FMD across the world

Although the United States has not experienced an outbreak of FMD since 1929, several countries have experienced outbreaks that have greatly the effected their economies. These examples provide an opportunity for education on containing and eradicating the disease, and show best practices for disease management.

FMD in the United States

FMD has been introduced into the U.S. on eight occasions on record. One of the larger outbreaks occurred in 1914 in Michigan. From Michigan, it spread to 22 states and contaminated the Chicago

stockyards. During the outbreak, over 172,000 animals were depopulated (Ekboir, 1999). This incident was one of the first large-scale foreign animal disease outbreaks to affect U.S. agriculture, and therefore widespread surveillance and notification mechanisms were not yet in place to prevent the spread of disease.

Another serious outbreak occurred in 1924, when FMD was found in cattle in Alameda County, California (near the San Francisco Bay Area). The outbreak soon spread to 16 more counties before quarantines were established to prevent movement of animals, animal products, and vehicles to and from affected areas. Although this particular county in California is no longer primarily livestock, many California counties still have very large herds and are susceptible to disease. This outbreak greatly affected cattle, goats, swine, and sheep, as well as wild deer. Overall, over 109,000 herds were infected or depopulated with an approximate value (in nominal dollars) of $4,350,000. This would be the equivalent of over $54,000,000 in 2010 dollars. During this outbreak, 63 days elapsed before diagnosis and 90 days elapsed before declaration of an emergency, which contributed to the widespread nature of the disease. The cost of eradication was estimated at approximately $7 million (over $87 million in 2010 dollars); including compensation for destroyed animals. This cost does not include production or trade losses (Ekboir, 1999). Thus, the combined cost of this outbreak would equal over $1 billion in 2010 dollars, despite the limited spread of the disease. The current cattle population in California is over 4.7 million head (Juan Guerro, 1991), significantly more than in 1924, and more concentrated due to increased urbanization. Thus, an outbreak today would have an even greater impact on the state of California's economy and the U.S. export economy as well.

Although reimbursement to farmers was considered in the calculation, the USDA today also calculates the cost of re-population of the farm as compensation, so today's cost of an FMD outbreak would be relatively higher.

The 1929 outbreak of FMD, the last domestic FMD outbreak, shows how improved surveillance and decreases in diagnosis delays are effective in reducing the impacts of the disease. The disease was diagnosed within three days of the emergence of clinical signs and an Emergency Declaration was issued within 10 days (Ekboir, 1999). Likely because of early recognition, only just over 3,000 animals were culled in this outbreak (or three percent of the number culled in 1924), and no wild deer showed clinical signs.

Issues surrounding the U.S. outbreaks

The 1924 outbreak and associated response shows how late identification and response increases the possibility for extended spread and economic effect on the agricultural sector. Because this outbreak was one of the earlier extended outbreaks of FMD, farmers were not acutely aware of the clinical signs of FMD and thus could not alert officials due to their lack of ability to identify the disease. It would be highly unusual for 63 days to elapse before the disease is diagnosed now because of better disease surveillance, and improved disease awareness and communication. In addition, although the disease had been diagnosed, three months passed before an emergency declaration was made. This time lag thwarted Federal officials from effectively coordinating and informing local farmers of prevention

practices, movement control methods, and proper depopulation activities to be taken. In the U.S. today, federal assistance to coordinate these activities would arrive sooner.

In addition, lack of rapid quarantine measures greatly affected the disease spread. In the 1914 outbreak, movement of animals was largely not controlled or monitored on the Federal and State levels, and this enabled the disease to spread across many states and regions of the country. When the disease was identified, quarantines were not put in place, thus the disease made the livestock industry less viable across the U.S., including the Chicago stockyard.

Best practices and lessons learned

The 1929 outbreak shows how improvements in disease eradication methods are effective in containing an outbreak. During the 1924 outbreak, farmers and government officials were aware of the threat and were able to correctly identify and eventually contain the disease. The rapid disease identification during the 1929 outbreak led to a swift emergency declaration, and thus movement control measures were put in place. The progression of emergency response that took place between the U.S. outbreaks also illustrates how close coordination between state, local and Federal officials can be an effective tool in disease eradication. During the 1929 outbreak, an Emergency Declaration was issued which allowed Federal, State, and local officials to work together and communicate on disease control efforts.

The 1929 outbreak was the last recorded case of FMD within the U.S., but these outbreaks showed how improved surveillance greatly decreases the disease spread. Early disease identification and containment greatly decrease the number of clinical cases of FMD and reduce the spread through several groups of livestock. This reduces the overall economic burden that the U.S. would face in the event of an FMD outbreak. In both the 1924 and 1929 outbreaks, the Agriculture Departments responsible for foreign animal diseases did not have extensive experience with FMD and could not correctly identify the disease early in the outbreak. Currently, the U.S. conducts routine surveillance within the U.S. and abroad to ensure that any cases of FMD would be identified quickly and appropriate disease control measures would be in place. The USDA also conducts hundreds of field inquiries domestically each year for early detection purposes (FMD Info.org, 2010). If a U.S. farmer suspects a case of FMD, either by contact or by clinical signs presented in an animal, the farmer would contact the USDA or state veterinarian's office that would then deploy a Foreign Animal Disease Diagnostician (FADD) to officially diagnose the case. The FADD would question the farmer about animal contact and movement, examine the animal(s), and send specimens to a laboratory for analysis (Lenhoff, 2006).

Increased domestic and foreign travel by the general public has created a new susceptibility to foreign animal disease for U.S. agriculture. Therefore, another surveillance method (which was not in place during the 1924 and 1929 outbreaks) occurs at U.S. borders to ensure that FMD does not enter the country. Currently, travelers into the U.S. are prohibited from bringing agricultural products into the country and are questioned about close contact with farm animals. In addition, ports of entry and airports are regularly surveyed, and passengers, luggage, and cargo are checked as deemed necessary. These inspections include Customs and Border Patrol officers and dog teams.

In addition, the USDA conducts an aggressive public education campaign with tools to inform the public about how to prevent introduction and spread of foreign animal diseases. There were no multi-state disease control measures (e.g., organized communications systems between states, or between State and Federal agricultural personnel) to prevent FMD outbreaks throughout the 1920s. The public education campaigns used now ensure that agriculturists at all levels have the same information on disease status and prevention, as well as disease eradication strategies.

The USDA also places staff internationally to conduct routine surveillance in both FMD endemic and FMD-free countries. USDA has animal health experts stationed in over 27 countries and has agricultural trade officials stationed in 129 countries (Government Accountability Office, 2002). This measure helps alert the USDA of any potential outbreaks or sources of FMD that may come into the country. The USDA personnel stationed abroad also assist with preparedness and eradication strategies in their host nations to help reduce the risk of international spread of the disease. By helping other countries eradicate and control FMD, the USDA reduces the probability of the disease reaching U.S. ports of entry (Government Accountability Office, 2002). The USDA places restrictions on imports of animal products from FMD affected countries; other products from those countries, such as feed hay, fresh meat, and some dairy products, are completely prohibited (Government Accountability Office, 2002).

FMD in Asia

Taiwan

Another relevant outbreak occurred in Taiwan. Between March and July 1997, an outbreak of FMD serotype O occurred in pigs in the Hsinchu province (western Taiwan). The disease was first detected on 14 March and successive cases were reported on the same district within three days. A total of 6,147 pig farms were infected, affecting over 4 million pigs. (FAO) The epidemic peaked five weeks after the disease was identified. In addition to quarantine and depopulation, the Taiwanese government instituted a two-dose, blanket vaccination program which led to a significant reduction of new outbreaks. Pigs and susceptible zoo animals were vaccinated by authorities to control the spread of the disease and to help protect zoo animals. Except for two cities, the entire island of Taiwan was declared an FMD infected zone. This outbreak resulted in the death of 37 percent of pigs in Taiwan from either infection or depopulation.

A large portion of the Taiwanese pig population was affected by FMD, and thus affected the export potential for Taiwanese swine. Since pigs can excrete vast quantities of the virus, they are a potentially significant source of air dissemination of the virus. Therefore, pigs can be described as amplifying hosts, while cattle can be indicators of infection (Ekboir, 1999).

Although the disease was eradicated relatively quickly, export bans to countries like Japan and the U.S. were extended because of the vaccine used to control the disease. Although only a fraction of the pigs on the island were actually infected, millions were affected by depopulation efforts or quarantine. The total economic cost of the epidemic was estimated at $1.6 billion, including market losses (including the ban on exports to Japan), vaccines, carcass disposal and other indirect costs (P.C. Yang DVM, 1999). Over 10 million pigs were affected by the outbreak even though less than half of the farms were

infected with only 21.7 percent of pigs on infected farms showing clinical signs. Taiwan's agricultural sector is considerably smaller than that of the U.S, contributing to 1.4 percent of the $383 billion GDP (The World Bank). Of this value, livestock accounts for 30% of the total. This is very small considering the U.S. GDP of over $14 trillion where agriculture represents 1.2 percent of the GDP, or over $168 billion in total. Thus, this relatively small outbreak still presented a considerable cost to the Taiwanese agricultural economy and a similar sized outbreak would impact the U.S. agricultural sector even more.

Unique features of the Taiwan outbreak

One of the unique features of this outbreak was the fact that the disease was relatively limited due to the physical movement restrictions of the animals. Because Taiwan is an island that occupies over 13,000 square miles (between the sizes of Maine and Indiana), the disease spread was greatly limited and due to depopulation efforts and vaccination programs, the disease was eradicated relatively swiftly. However, the outbreak occurred during the traditional Chinese New Year, which is traditionally marked with increased animal movements. This cultural difference allowed the disease to be more widespread in a short amount of time. (P.C. Yang DVM, 1999)

China

Recently, China confirmed that an FMD (Serotype O) outbreak occurred on April 7, 2010 in Gansu. A total of 640 cases were reported and 831 animals were shown to be susceptible to the disease due to proximity to infected farms. These animals were destroyed. As of April 15, the source of the outbreak had not been identified (oie.com, 2010). This may have been in relation to a recent outbreak of FMD confirmed in South Korea originating on a farm on Ginghwa Island and has since spread to the South Korean Mainland. This outbreak also involved Serotype O and authorities have since depopulated over 30,000 animals on more than 225 farms (oie.com, 2010). According to the OIE, the cause of this outbreak still remains unidentified, but farmers are working to depopulate farms to limit the spread of disease. This outbreak has since been detected in Hong Kong where a total of 1,240 cases were found and over 2,000 animals showed signs of susceptibility to the disease due to proximity to infected animals (OIE, 2010). This outbreak has been relatively well controlled by rapid depopulation of infected farms, but still persists in several areas of China due to continued export and movement of pigs.

Relevance of Asian outbreaks to U.S. cases

The lessons learned in the Taiwan outbreak can be relevant to the U.S. agricultural system because Taiwan is a highly industrialized area that also has a large agricultural sector. In addition, it is believed that the FMD infection could have been present on Taiwan six weeks before the disease was detected on the island. This could have been due to the fact that Taiwan had been FMD free since 1929, and thus there was a general lack of awareness regarding the risk of disease (P.C. Yang DVM, 1999). The U.S. has a similar lack of awareness and/or lowered perception of risk since 1929 was the last year of an outbreak in this country.

Overall, this case is relevant because it shows the large economic cost of an outbreak and the effective deployment of vaccine. Because countries like Japan and the U.S. rapidly ban imports of meat and meat products from FMD countries, despite the extent of the outbreak, the total economic costs and losses greatly exceed the costs to eradicate the disease. In the case of an FMD outbreak in the U.S., export to

the top four markets for U.S. beef, Japan, Mexico, South Korea, and Canada (Background Statistics USDA), would be greatly reduced.

Best practices and lessons learned

The Taiwanese outbreak also shows how effective movement control of animals, as well as blanket vaccination can effectively eradicate the disease. The use of vaccines greatly reduced the number of new outbreaks on the island, which helped contain the disease over time. Many countries, including the U.S., are hesitant to employ vaccination strategies because of the long-term economic impacts of export restrictions. The Taiwan outbreak shows how an effective vaccination strategy, even one limited in scope, can help eradicate the disease quickly.

Although the benefits to vaccination are apparent and have been shown in previous outbreaks, the USDA has many reservations about implementation of a vaccine program because:

- Maintaining immunity requires re-vaccination of each animal (most vaccinated cattle retain immunity for 21 days); (McGinnis, 2007)
- There is a risk of disease spread through and outside the vaccination zone;
- Vaccine used in mass prophylaxis would have to match the exact serotype of the disease infecting the livestock, which can be a risk early in the outbreak, prior to serotype distinction (typically four days);
- If a vaccinated animal is exposed to the disease, that animal could possibly act as a host for an extended period of time; and
- Finally, if a vaccination program were implemented, the U.S. would lose FMD-free status which would severely compromise international trade values of livestock and would impose severe restrictions. (APHIS- Veterinary Service, 2007)

These scenarios would all greatly affect U.S. livestock value and thus affect the export community in general. FMD free countries (like the U.S.) are required to undergo a three-month waiting period between the time of slaughter of the last vaccinated animal and the time that they can achieve FMD free status, assuming ongoing surveillance and serological testing have demonstrated that the country is in fact FMD free (APHIS- Veterinary Service, 2007). Thus, there is little incentive to vaccinate infected livestock because it may slow down the recovery process. Countries should weigh the benefits of faster eradication versus the drawbacks of extended export controls.

FMD in North Africa

FMD is endemic in many countries in Africa and has surfaced among farms for several decades. Although the Sahara desert has played a role as protective barrier from disease spread into West Africa, many countries throughout the continent have faced exposure to FMD (FAO).

In 1999, FMD was detected in beef cattle in Algeria, near the capitol of Algiers. A limited spread eastward and westward was also reported and a total of 165 farms and 139 communities were infected. In all, 1,605 animals were destroyed, 2,153 slaughtered, and 1,270,685 vaccinated. This strain was

recognized to have a close relationship with strains found in West Africa and this showed a new route of virus introduction into the Meghreb region represented by the Sahara desert.

Unique features of the outbreak

The disease spread was generally limited due to the blanket vaccination implemented earlier (during the 1997 and 1998 outbreaks in Morocco and Tunisia) and because Islamic festivities led to an increase of slaughter of several million susceptible animals. These festivities also led to an increased slaughter of several million susceptible animals, thereby limiting the extent of the disease spread (FAO). This would not be as much of a consideration for commercial livestock within the U.S. because there are no large cultural events governing the movement of animals. Cultural activities could have an effect on small groups of animals owned by individuals or families, and could affect live animal markets, but would not have a large impact on commercial operations.

This outbreak was also an illustration of disease spread through new routes of introduction. This case illustrates how new or unexpected modes of transmission (i.e., across the Sahara desert) should now be considered as viable. With the increase in trade exchange between countries and improved means of communication and transportation, the previously assumed disease barriers may not be effective in preventing disease spread (FAO). In general, increase in trade exchanges, including improvement on means of communication and transportation; create opportunities for FMD to enter new populations and areas (FAO).

Relevance to U.S. cases

Although FMD attacks all cloven-hoofed animals, cattle are the most susceptible animal species and are also extremely high value species within the U.S. economy. Cattle are particularly susceptible to the airborne virus and they may excrete the virus for at least four days prior to symptoms appearing in the animal.

Although the U.S. and Northern African cattle sectors vary in size and scope, they are both important to the agricultural economies of the countries. The U.S. cattle market is a high value agricultural market and is susceptible to foreign animal disease. The beef industry in particular is an important enterprise in U.S. agriculture. The 2008 cattle inventory within the U.S. was estimated at 94.5 million head domestically (USDA, 2009). The retail equivalent value of the U.S. beef industry (both domestic and international sales) for 2008 was $76 billion, with 2008 exports totaling $2.987 billion. Over one million farms and ranches within the country benefited directly from the sale of cattle and calves in 2000 and gross sales in that year totaled over $40.76 billion. This accounted for 20% of overall agricultural receipts, making the beef sector the largest single domestic agricultural enterprise (Lawrence D. O., 2001). Although this was a record sales year, the industry has been relatively stable since the 1990s. Cattle are produced in all 50 states and they are significant economic drivers especially in rural communities. In many areas of Northern Africa, cattle represent livelihoods for both families and communities, as they are often the main source of both income and food. The U.S. economy is not as reliant upon individual cattle for livelihoods, but the cattle industry does contribute to a large sector of the economy. Thus any damage to the industry would greatly affect people's livelihoods and the larger U.S. economy.

The African outbreak examples illustrate a new route of introduction and how this can create a large disease outbreak in a large geographical community. The greatest diversity of FMD viruses is located in Africa and relatively few vaccines are available to protect against these strains (OIE/FAO, 2009).

Best practices and lessons learned

This outbreak also showed how vaccines can affect an outbreak. The local populations surrounding these outbreaks were partly protected by blanket vaccination implemented following the 1997 and 1998 FMD occurrences in Morocco and Tunisia (FAO). Fortunately, livestock exports were not a large part of the agricultural economies affected by this outbreak because vaccination of these populations reduced their export potential. However, this would be the case in the U.S., where approximately 10 percent of U.S. beef is exported, and exports have dramatically increased since 1980. (Lawrence D. O., 2001)

Vaccination also prevented the extended spread of disease throughout North Africa. Although vaccines are typically difficult to obtain and distribute across the region, livestock were not as susceptible due to previous vaccination efforts. Although vaccines may not be the most rapid method for stopping disease spread, it can contribute to long-term disease spread prevention.

Denmark

In March and April of 1982, Denmark experienced an outbreak of FMD. During this outbreak, there were 1,700 herds within a radius of 15 miles from the first index herd, which was misdiagnosed initially (Ekboir, 1999). This experience is comparable to a U.S. outbreak because the density of cattle in Denmark is similar to areas of cattle density in California, a large cattle producing state. During this outbreak, an initial surveillance zone of 750 foot radius was established around each heard showing clinical signs. In addition, movement control was established, affecting both people and animals in and out of the infected herds. A control area of 6.25 mile radius was also established around the herd showing clinical signs, with no movements of animals among farms and controlled movement to slaughter; only infected herds were quarantined and slaughtered.

The dissemination rate of the disease was significantly reduced after four weeks and the epidemic was stamped out after two months, with only 20 herds affected. According to studies, the success rate of the stamping out procedure and eradication of disease was due to individual farmer's actions. Each farmer on affected farms and farms within the disease risk zone depopulated their own livestock, which helped reduce the incidence of disease throughout the region. The farmers were well informed of the FMD situation through public media such as television and radio. Although the weather conditions in Denmark were favorable for windborne spread, this type of spread did not occur because a sharp drop in disease dissemination rate reduced the overall virus circulating in the area. Most of the virus was excreted early in the disease before there was a chance of depopulation and thus prompt quarantine was more effective than depopulation in this case (Ekboir, 1999).

Unique features of the outbreak

Denmark was relatively lucky because of limited airborne spread, but stamping out was effective in disease eradication. The Denmark outbreak also shows how unconventional spread methods (e.g., windborne spread) pose a threat to groups of livestock under quarantine. If windborne spread had been

a factor, this would have counteracted the "stamping out" efforts, therefore extended the spread of the disease. Although experience has shown that long distance spread of FMD is mainly due to transport of animals and their products, rather than windborne spread, this threat should be factored into disease control planning.

Best practices and lessons learned

This case highlights effective coordination and communication between federal officials and local farmers. One of the primary reasons that the stamping out effort was so effective was due to the fact that farmers were well informed of the state of the disease through public media campaigns.

If FMD were detected in livestock within the U.S., the APHIS Emergency Operations Center (EOC) would be activated to begin coordination efforts between Federal, State, and local officials and communicate disease eradication efforts. In addition, the EOC would ensure that proper information was disseminated across jurisdictions to ensure that proper action would be taken.

In addition, U.S. Federal officials would immediately notify animal health officials in both Canada and Mexico about the FMD outbreak and response efforts, showing international cooperation and coordination. These countries would work together to establish movement control to limit the inter-country movement of livestock and prevent further spread of disease. In addition, the three countries would work together to ensure that farmers in all countries received proper disease spread information and knew the correct actions to take across borders. APHIS would also notify the OIE of the outbreak, last animal depopulated, and all steps taken to control the disease. The effective communication and coordination at all levels would hopefully reduce the spread of disease and reduce the threat of FMD spreading across international borders.

United Kingdom

The United Kingdom (U.K.) experienced two relatively recent outbreaks that greatly affected the livestock population and the agricultural economy. The U.K. examples illustrate the potential economic devastation that FMD can have on both a developed nation's livestock industry and other sectors such as tourism.

2001 outbreak

Although the most recent outbreak of FMD occurred in 2007, the U.K. experienced a serious outbreak in 2001. The introduction of FMD virus was confirmed to have occurred in late January or early February, with clinical detection occurring on February 20, 2001, just three weeks after the initial introduction. During the eight month outbreak, the disease spread rapidly resulting in over six million animals depopulated (i.e., sheep, cattle, and pigs) which resulted in over $6 billion in losses to agriculture and the food industry in the U.K. In addition, about $5 billion was paid by the government in compensation for slaughtered animals and carcass disposal. In addition, the FMD outbreak had serious negative consequences on both city and country tourism industries. (DEFRA) In the U.K., agriculture represents 1.4 percent of the $2.76 billion GDP, and is significantly smaller than that of the U.S., but still represented a large financial impact to the country.

2007 outbreak

In August of 2007, an FMD outbreak was confirmed in cattle on a farm in a county in Southeast England. Four days later, FMD Serotype O was diagnosed on a nearby farm and by mid-August, fewer than 600 animals were depopulated. The virus was quickly isolated and was found to be a subtype referred to as BFS, which was used in the nearby Pirbright laboratory. (Perlez, 2007)

A government investigation found a "strong probability" that the FMD strain involved originated at a laboratory complex where the virus is used for research and vaccine production (Nolen, 2007). Investigators speculated that human movement of the virus, either accidental or intentional, was a possibility.

In addition, British officials rapidly shut down animal movement after the disease was detected during the 2007 outbreak. This, as well as rapid surveillance of surrounding farms and zoos, ensured that the disease was quickly contained. The U.S. also has effective surveillance methods and can implement regional quarantine, stopping animal and human movement between infected and uninfected farms.

Early detection and quick response to the outbreak were key factors in the containment of the disease spread during the 2007 outbreak. British authorities identified the virus and confirmed that it was Serotype O two days after initial clinical signs presented in cattle. British authorities quickly shut down all movement of animals after a cow from another nearby farm tested positive as well. Several further outbreaks of FMD on nearby farms, as well as at a nearby zoo were investigated in August, and many tested negative for the disease. On August 24, no further disease outbreaks were reported since the initial discovery and the protection zones were lifted in the surrounding farms. The surveillance zone was removed soon after. Despite this, in September, a second outbreak of FMD was found on a farm 30 miles from the original case and a three kilometer radius protection zone was established, as well as a surveillance zone. This helped contain the disease spread and restrictions were soon lifted. (Wikipedia)

Relevance to U.S. cases

The U.K. outbreaks illustrated how susceptible a large industrialized country can be to a foreign animal disease. Although the U.K. does not have an agricultural based economy, a large sector of their economy is livestock export. In 2007, agriculture represented 0.6 percent of the national GDP, much less than the 1.6 percent that agriculture represents of the U.S. GDP (The World Bank). Despite having a smaller relative impact size, the U.K. experienced significant economic losses during both outbreaks because FMD affected many areas of the agricultural sector, as well as the tourism sector. Thus, an FMD outbreak could cause a larger economic impact to the U.S., including supporting sectors and regional tourism. This illustrates how devastating an FMD outbreak could be on the overall U.S. economy.

Agriculture, especially the livestock industry, is an important part of the U.S. economy; therefore, any disruption to this sector could greatly affect the U.S. economy. In 2007 (the most recently available year for data), agriculture contributed to 1.3 percent of the total U.S. GDP (The World Bank) and since 2001, the livestock and poultry sector have been valued at over $100 billion (Government Accountability Office, 2002).

An FMD outbreak causes both direct and indirect costs to producers and those associated with the agricultural industry. The direct costs include animal and animal product losses (including milk sold). The value of the depopulated animal is directly reimbursable by either the State or Federal government, but many indirect costs are not considered in this process. These costs include (Lawrence D. O., 2001):

- Eradication costs, including the cost of slaughter, disinfection of housing facilities, and carcass disposal;
- Production losses arising from lost production during the outbreak and post-outbreak in depopulated premises and industries linked to livestock; and
- Long-term value reduction of agricultural products due to public perception both domestically and overseas. The price difference between meats from a previously infected country versus an FMD free country can be as high as 50%.

In one study conducted by the American Veterinary Medical Association (AVMA), the largest impacts of an FMD outbreak would be from the loss of export markets and a reduction in domestic demand due to consumer fears. The study estimates that an FMD outbreak could cause an estimated decrease of $14 billion in U.S. farm income. As the largest affected market, the live swine industry would likely experience the largest losses, followed by the beef industry as the second most affected market. (Philip Paarlbert, 2002)

Best practices and lessons learned

The rapid response and containment of this outbreak shows great improvement over response techniques from the 2001 outbreak. Due to quick government response and the use of rapid polymerase chain reaction (PCR) techniques, the British government was able to quickly diagnose the disease and minimize the loss of unaffected animals in the surrounding farms. In addition, due to the severity of the 2001 outbreak, the British government's Department of Environmental, Food, and Rural Affairs (DEFRA) conducted public awareness campaigns to educate and inform local farmers and issued hour-by-hour updates that effectively communicated the situation to the stakeholders. Because of these and other related efforts, affected farmers and producers cooperated with the detection and eradication process which helped limit the spread of disease. (Adams, 2007)

Typically in Europe, FMD has been detected on average 21 days after introduction (The role of vaccination in a future outbreak of FMD, 2006), but current U.S. surveillance mechanisms have improved and decreased time between introduction and detection. This may vary due to different disease spread mechanisms or routes of introduction, but overall, surveillance methods have improved both within the U.K. and in the U.S.

Current U.S. disease control measures

Although the U.S. has not experienced an outbreak of FMD since 1929, the USDA and other agencies have implemented several control strategies to help protect domestic agriculture from widespread exposure.

Wildlife as a virus source

In all of the cases studied and mentioned above, wildlife did not play a significant role in introduction or spread of FMD, and it is not known the extent to which wildlife contracted the disease. The role of wildlife in an FMD outbreak is not completely understood and thus is a consideration for many studying the disease.

Currently, U.S. Geological Survey (USGS) scientists are concerned about the potential threat that FMD may pose due to spread through North American wildlife, particularly through deer, wild pigs and other cloven-hoofed wildlife populations. (U.S. Geological Survey) Both USGS Wildlife Disease specialists, as well as wildlife service's personnel from the USDA regularly monitor wildlife for disease, especially those in close proximity to livestock. Because the virus can also be transmitted mechanically through animals such as rodents and birds, these animals are also monitored closely. In addition, these USGS staff members routinely work with wildlife specialists from both Mexico and Canada to maintain situational awareness on foreign animal diseases. This information is routinely used to develop contingency plans for informing DOI, state, and local resources of the disease risk posed to wildlife.

Cloven-hoofed wildlife are also susceptible to FMD, however the clinical manifestations can vary greatly from severe clinical signs to unapparent infections (US Animal Health Association Committee on Foreign and Emerging Diseases, 2008). Thus, wildlife also has the potential to spread FMD because of their contact with livestock. Currently, USGS scientists are concerned of the potential threat the FMD may pose to North American wildlife, and subsequently to other livestock the wildlife contacts. Wildlife can harbor the virus, even with vaccination and control effects on livestock. The virus can easily be transmitted mechanically by animals (e.g., rodents or birds) that frequently come in contact with livestock. While these vector rodents do not become infected by the virus, studies have shown that FMD can survive for a short time on their bodies and pass through birds' digestive systems. These findings show that although wildlife may not become infected, they can easily facilitate the spread of the virus and overcome quarantine and movement restrictions. In addition, the disease can spread between livestock and carrier animals when and where they drink from a common source. (Mclean, 2007)

In general, relatively little is known about the effects of FMD in major North American wildlife populations, although experimental infections of bison, elk, pronghorn antelope, and mule deer have been conducted by the USDA. These tests have shown that these animals, even with vaccination, do exhibit clinical disease when exposed to FMDv; intra- and inter-species transmissions have occurred in all species except elk. (US Animal Health Association Committee on Foreign and Emerging Diseases, 2008). Countries that have eradicated FMD from domestic animals have done nothing systematic to control FMD in wildlife; yet, no recurrence of disease in wildlife was observed. Although FMD is a risk to wildlife, studies have shown that once FMD is eradicated from the domestic livestock population, FMD also disappears from wildlife. (US Animal Health Association Committee on Foreign and Emerging Diseases, 2008).

Case study conclusion

Overall, each case study demonstrates differences in disease spread and detection and shows how differing cultural and economic practices affect disease eradication effectiveness. The case studies all show that early detection and depopulation of infected animals are effective practices in preventing further disease spread. In addition, some countries have implemented vaccination rings around infected herds to control disease spread. Although in some cases it has shown to reduce FMD spread to farms beyond the vaccination ring, the FMD-free status of the country is affected. In countries that are considered FMD free, this consideration is critical. Current U.S. surveillance techniques are expected to increase the probability of rapid detection and eradication, and fortunately the United States has not been faced with a recent outbreak.

Since the U.S. values its FMD-free status, the use of vaccine in a contained outbreak is unlikely. In the case of a large FMD outbreak, vaccination is an option for containment, but policy and state politics will likely determine the extent of its use.

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5. Rift Valley Fever Case Study Review

Introduction

Rift Valley Fever (RVF) is currently one of the most prominent animal disease problems in Africa and poses a risk to U.S. livestock. Not only does it adversely affect the health of livestock, it can also be highly contagious and dangerous to human populations close to livestock. Additionally, RVF impacts the livestock trade and the countries' economy that relies heavily on livestock sales.

Epidemiological Factors of RVF

RVF is an arthropod-borne viral disease that presents in ruminants as well as in humans. In livestock, the disease is most severe in sheep, goats, and cattle, causing high mortality rates in young animals and abortions in pregnant animals (USAHA Committee on Foreign and Emerging Diseases, 2008).

The incubation period for RVF ranges from 12 hours (newborn livestock) to 17-24 hours in adults. Age has been shown to be a significant factor in an animals' susceptibility to the severe form of the disease. Morbidity is typically high (70-100 percent) in young and newborn animals, but significantly lower (10-70%) in older livestock (USAHA Committee on Foreign and Emerging Diseases, 2008).

Disease Characteristics

RVF is primarily found in regions of eastern and southern Africa, the predominant areas where sheep and cattle are raised (Centers for Diseaes Control - CDC), although recent RVF outbreaks have occurred outside of these regions. RVF can spread to areas that were previously unaffected, this spread has typically occurred when infected animals have introduced the virus into areas where vectors were present (World Health Organization, 2007). The virus is typically spread through several modes of transmission, including (F. Glyn Davies, 2003):

- Mosquito bites
- Biting flies
- Aerosol of blood from infected tissue
- Meat at time of slaughter of infected animals, and
- Raw milk from infected animals

Three major factors increase the likelihood of RVF spread (Rift Valley Fever Outbreak Northern Cape Province, 2009):

- The pre-existence or introduction of the virus in the area
- The presence and susceptibility of livestock in the area
- Climatic or environmental conditions that encourage massive vector populations

Although RVF is not endemic in the U.S., changes in climate or the introduction of infected hosts could increase the likelihood of infection. Outbreaks of RVF are typically observed during years in which heavy rainfall and local flooding have occurred. In Africa and the Middle East, RVF outbreaks are typically

associated with periods of above-average rainfall and increased amounts of vegetation. Flooding severity is increased by development in areas around water (F. Glyn Davies, 2003). Although flooding and climate conducive to RVF have typically occurred in Eastern and Southern Africa, RVF also has spread to Northern Africa and to the Middle East, indicating that many more countries are susceptible than just the RVF-endemic nations.

Climactic factors can all be easily monitored and outbreaks predicted using remote sensing satellite imagery and thus many agencies have successfully developed forecasting and early warning models for RVF (World Health Organization, 2007). Accurate monitoring has allowed authorities to implement disease abatement measures when heavy rains are reported in order to avert impending epidemics (F. Glyn Davies, 2003).

RVF and the Relationship to Climate

Typically, disease spread into new areas has been the result of human social or behavioral changes. However, some diseases and vectors are more likely to be affected by global climate change. Scientific predictions of global climate change include changes in precipitation and ambient temperature in several global regions.

In addition, changes in precipitation will impact the flow of rivers and lake levels and may affect the duration and severity of dry and wet seasons. RVF outbreaks have also been associated with the El Nino Southern Oscillation (ENSO), which is a climate pattern that affects the tropical Pacific Ocean. ENSO is best known for its association with floods and other weather disturbances in many global regions, which may vary with each. East Africa and the west Nile basin often experience wetter than normal conditions from March to May due to the warmer cycle of the ENSO. RVF can be combated through environmental sanitation as well as health education, but this will not totally eliminate the possibility of introduction of RVF in the U.S. (Shope, 1992).

The spread of RVF to new areas is highly dependent on climatic factors as well as ecological change. Currently, RVF is limited in its spread because of limits in the ecology of the animal or insect reservoir, but this may change with climate change. Mosquito-borne viral diseases are among the diseases that have been predicted to become more severe and move into North America due to global climate change. RVF is a candidate disease to be affected by global climate change (Shope, 1992). RVF is a threat because the virus is capable of being transmitted by a wide variety of mosquitoes and can maintain itself in a non-immune population.

Vaccination

There currently is no course of treatment for RVF. However, vaccines for veterinary use are available. Therefore, the prevention of the disease is one of the most effective methods for addressing an RVF threat. Early warning systems using remote sensing data can support strategic vaccination campaigns by identifying areas having a high risk for disease. Outbreaks of RVF in animals are most effectively prevented by a sustained vaccination program in endemic areas. A sustained vaccination program should be considered by the government if needed as it has been proven to be an effective method for controlling RVF.

However, vaccines may cause birth defects and abortions in sheep, similar to the symptoms of RVF, and some vaccines provide only low-level protection for cattle (CDC). The vaccine currently in use is a live attenuated strain of an RVF virus, which has been used in South Africa since 1952. Inactivated vaccine is also available, however, cattle vaccinated with the inactivated virus have poor antibody response (USAHA Committee on Foreign and Emerging Diseases, 2008) and annual boosters are usually required before the rainy season to maintain immunity. The need for boosters that significantly increase the cost of vaccine programs coupled with the risk of defects and abortions, potentially make vaccination a less desirable option for farmers.

Vector and Disease Control

A number of challenges exist for the control and prevention of RVF. In order to effectively reduce the spread of RVF, how the virus is transmitted among mosquitoes and the role of vertebrates in propagating the virus must be understood (CDC). Several insect species are involved in the transmission of the RVF virus by both biological and mechanical means. Biological vectors include hematophagous insects, such as several species of mosquitoes, and mechanical transmitters include biting flies and other biting insects (USAHA Committee on Foreign and Emerging Diseases, 2008).

There are several control measures that can be taken to prevent the introduction and spread of RVF. These include (OIE, 2009):

- Control of animal movements
- Control of slaughterhouses and animal products
- Draining of standing water to reduce and eliminate vectors and breeding sites
- Disinfection of insect breeding sites

These prevention methods have varying success rates, but when used together, can be effective in stopping or preventing an RVF outbreak in livestock and in humans.

RVF in Humans

Although RVF primarily affects livestock, humans can contract RVF through bites from infected mosquitoes and possibly other biting insects. There is evidence that humans also can become infected with RVF by ingesting raw milk or uncooked meat from infected animals (World Health Organization, 2007), from exposure to tissue or fluids from infected animals (CDC), or infection through aerosol transmission that has occurred in the laboratory environment. There is no evidence that RVF spreads from person-to-person.

RVF in humans presents with an onset of abrupt malaise with fever, chills, rigors, diarrhea, vomiting, retro-orbital pain, severe headache and generalized aching (USAHA Committee on Foreign and Emerging Diseases, 2008). A small percentage of humans infected develop a much more severe form of the disease that can include hemorrhagic fever (World Health Organization, 2007).

There is no established course of treatment for RVF in humans, but a human vaccine has been developed, although with limited availability (The Center for Food Security and Public Health, 2007). Therefore RVF presents a public health risk within the U.S. as well.

An RVF outbreak has a particularly negative impact on individuals in many countries in Africa because many incomes are predominantly derived from the sale of mature sheep and goats for religious festivities. Cessation of this trade has had disastrous effects on the livelihoods, particularly of vulnerable populations. Although the subsistence farming and livestock trade is not nearly as prevalent within the U.S., an outbreak of RVF would greatly harm export values and availability of many livestock and thus affect large sectors of the U.S. economy.

6. Case Studies

Index Case – Rift Valley, Kenya

RVF was first identified in 1931 during an investigation into an epidemic of abortions in sheep on a farm in the Rift Valley of Kenya. This outbreak occurred after significantly heavy rainfall in 1930-1931 (FAO EMPRES Animal Health Service). It was observed that European livestock introduced to Africa were more severely affected than the native African stock (Jeffery Musser DVM, 2006). The disease was first identified in sheep as several thousand ewes aborted their fetuses. In addition there was a 90 percent mortality rate for young lambs (F. Glyn Davies, 2003). Cattle were also affected by this outbreak, but abortion and mortality rates were significantly lower than for sheep. Humans associated with the infected herds suffered from influenza-like symptoms and with fever, headaches, and muscle and joint pain. An initial investigation of the outbreak indicated that the disease was being transmitted by mosquitoes.

Best Practices Implemented

In response to the outbreak, local farmers moved their livestock to an area above the Rift Valley. The relocation of livestock resulted in the cessation of transmission of the disease, resulting in no new cases. Moving livestock was an effective disease control measure because the livestock were moved to a climate not conducive to the vector transmitting the disease. This is an important lesson learned that could be applicable to U.S. livestock as many large cattle raising areas in the U.S. have several micro-climates where cattle can be relocated to in order to prevent disease spread.

Kenya 2006

In mid-December of 2006, the Kenya Ministry of Health received reports of several unexplained human fatalities associated with fever and generalized bleeding. These reports were originating in the Garissa District in the North Eastern Province of Kenya. Reports of livestock deaths and unexplained animal abortions were also reported in this region. By December 20th, 11 human deaths had been reported and RVF was confirmed and an investigation was immediately launched by the Ministry of Health, the Kenya Medical Research Institute, the Kenya Field Epidemiology and Laboratory Training Program, and the Walter Reed Project. The investigators conducted patient interviews and performed field surveys to collect blood samples from patients and livestock. It was determined that the index case was a patient who had symptoms onset on November 20, 2006. Early in the outbreak, most of the cases occurred in young men who herded livestock, but later in the outbreak the distribution of cases was broader included both sexes and a larger age range. Two thirds of the total patients who provided information

regarding risk factors reported having an animal that was recently ill and the most frequent reported RVF risk factor preceding illness onset was the drinking of raw milk.

This outbreak was closely associated with heavy rainfall, which produced massive flooding throughout Kenya. In October through December of 2006, Kenya experienced three times the average rainfall for that period during the preceding 8 years.

Kenya 2006 Best Practices Implemented

This outbreak peaked on December 24 of that year and the number of daily cases reporting declined. A ban on livestock slaughtering in the district went into effect on December 27 and was expanded as RVF was detected in additional districts. Vaccination of animals with live, attenuated RVF vaccine began on January 8 2007 for apparently unaffected herds of livestock in the districts in which either human or livestock RVF cases were confirmed. During an outbreak of RVF, vaccination of animals in the surveillance zone can prevent further spread of the virus and protect people as well as animals. Antibody response to an RVF infection in livestock appears four to five days following infection and offspring of immune mothers may have a passive maternal immunity for the first three to four months of life as well (USAHA Committee on Foreign and Emerging Diseases, 2008). However, once an outbreak has occurred though, it is not recommended that vaccination measures be taken on the infected herd because there is a high risk of intensifying the outbreak (World Health Organization, 2007) and causing further spread. Vaccines can cause similar symptoms to RVF and therefore it can be difficult to discern between infected and vaccinated animals. Additionally, vaccinated animals can act as hosts and further the spread throughout livestock.

Widespread messages on prevention were developed in the three widely used languages (English, Kiswhali, and Somali) and public meetings were held to spread information rapidly to the community. Messages were also widely disseminated via radio. Village elders, chiefs, and religious leaders were consulted on livestock movement control measures.

The outbreak was quickly detected with help from the Integrated Disease Surveillance and Response Program, which was active within most of the affected districts. Another factor that aided the timely detection was the laboratory-supported field surveillance of febrile patients at outpatient clinics. Ongoing epidemiological and veterinary studies continue to identify factors associated with severe forms of RVF illness, characterize the role of mosquitoes in disease transmission, assess the economic impact of the outbreak, and investigate vaccine measures (CDC, 2007).

West Africa

The first epidemic of RVF in West Africa was identified in 1987 and was linked to construction of the Senegal River Project.[1] RVF was reported in Mauritania in September of 1998. This outbreak resulted in very large livestock losses as well as many human deaths. This outbreak also caused considerable damage to the East Africa livestock export trade to the Near East and resulted in severe sociological problems, especially in Somalia, where the livestock trade is the primary means of livelihood for many communities and families (FAO).

[1] CDC Rift Valley Fever Fact Sheet

Issues Surrounding this Outbreak

RVF can have a significant negative impact on a country's livestock. An RVF outbreak could result in livestock export bans that last for several years, severely affecting many livelihoods and commerce streams (F. Glyn Davies, 2003). Many countries refuse to import livestock or animal products from a country experiencing an RVF outbreak, regardless of how large or extensive the outbreak is. If an RVF outbreak is discovered, many of the animals are culled to prevent the further spread of the disease and thus the livestock and their products are lost to the market. Export bans are of particular concern to the U.S.

Best Practices Implemented

In this outbreak, RVF was first detected in humans while the disease was circulating in the local livestock population. RVF outbreaks in livestock are often accompanied by human disease (The Center for Food Security and Public Health, 2007) and human disease has often been an indicator of epizootic RVF activity. This observation has led to the conclusion that early detection in domestic animals is essential to avoid the widespread disease in the human population (FAO). In addition, this case also showed how surveillance of human populations in conjunction with animal disease surveillance serves to accurately detect how the disease is spreading.

South Africa

1951 – Rift Valley Fever was first identified in South Africa around 1951 when several outbreaks of an unknown disease were reported in the Western Free State by the State Veterinarian. In several of the outbreaks, very young lambs died in large numbers and adult ewes either died or aborted. Cattle were also affected by this outbreak and experienced abortion, hypothermia, and abdominal pain and some of these cases ended in death. The similarity of this disease to RVF was quickly recognized and blood and organs from affected animals were examined and laboratory tested. In addition, samples from human patients (who had handled infected animal material) exhibiting clinical signs were examined by the South African Institute for Medical Research and were determined to have contracted RVF as well (Rift Valley Fever Outbreak Northern Cape Province, 2009) (Rift Valley Fever Outbreak Northern Cape Province, 2009).

1974 – During the summer and fall of 1974, most of South Africa experienced exceptionally heavy rains, particularly the western region of the Cape Province, creating conditions favorable for mosquito breeding. This resulted in RVF presenting throughout the country in a severe disease spread. The sheep and cattle farming districts of the Orange Free State and Cape Province were particularly affected. The outbreak caused the loss of thousands of animals and caused significant human health issues throughout the country. Ten to twenty thousand people were infected between 1974 and 1986 and several people died from the disease (IRIN , 2010). This was the first time in South African that human deaths due to RVF were recognized (Rift Valley Fever Outbreak Northern Cape Province, 2009).

2009 – The most recent outbreak of RVF in South Africa occurred in Kwazulu Natal where cattle died within the district and many people became ill from the virus. This outbreak caused significant damage to the cattle industry in the area and claimed the lives of two people (IRIN , 2010). The index case was reported in the Northern Cape in October of 2009 on a grape farm where cattle were also kept. There

had not been animal movement into the farm three months prior to the outbreak, but the farm had been irrigated and the dam which fed the irrigation pipe had leaked for months with drainage water pooling where cattle were grazing. In addition, changing land use was another major factor in the emergency of disease and this was reflected in the construction of the dam for irrigation. Anecdotal evidence suggests that this was the same area affected during the 1974 and would indicate that the virus in the area was not introduced from the outside.

None of the farmers had ever vaccinated for RVF in the area and they did not have vaccine in stock (Rift Valley Fever Outbreak Northern Cape Province, 2009). The inactivated RVF vaccine was ordered for the farm with the index case and immediately surrounding farms. Other farms in the area were encouraged to vaccinate at their own cost using live attenuated vaccine. In addition, vector control was performed at the index farm using larvacides. Vector control is typically a less commonly used method of disease spread prevention because use of pesticides often has negative effects on livestock and surrounding wildlife and because during flood seasons the extent of breeding sites exceeds local capacity to control (World Health Organization, 2007).

Best Practices Implemented

During the 1974 outbreak, the Rapid Response Team was immediately activated when the news of diagnosis reached the Department of Health. The team met up with local response teams for initial assessments and sampled the infected sites. The index farm was immediately placed under quarantine and a veterinary attention zone with a 3km radius from the index farm was delineated. Health information was disseminated to farm personnel on exposure and clinical signs.

Several recommendations came out of this outbreak including (Rift Valley Fever Outbreak Northern Cape Province, 2009) (Rift Valley Fever Outbreak Northern Cape Province, 2009):

- Maintaining a physical presence in the area to conduct clinical surveillance
- Continuation of vaccination of all livestock surrounding the index farm
- Intensify awareness about the disease through a media campaign, information sessions, and a hotline for general inquiries
- Implement a vector control program at mosquito breeding sites
- Maintaining a health monitoring program for veterinary officials involved in the outbreak.

RVF in the Middle East

In September 2000, RVF was reported in Saudi Arabia and Yemen. This was the first time that RVF was reported outside the African continent. In addition to significant animal losses, this RVF outbreak also caused human disease and deaths (FAO). The Ministry of Health in Saudi Arabia and subsequently Yemen began receiving reports of unexplained hemorrhagic fever in humans and some animal deaths in 2000. By October of that year, 216 people were suspected to have contracted RVF (MMWR, 2000). On September 15, the U.S. Centers for Disease Control and Prevention (CDC) confirmed the diagnosis of RVF.

It is almost impossible to prevent RVF spread in regions where outbreaks have previously occurred, thus the Middle East is now more susceptible to recurring outbreaks of RVF. Because RVF is maintained in livestock as well as mosquitoes, it is very hard to stop an epidemic in progress. In addition, current international travel patterns, new development and construction projects, and possible changes in climate and precipitation have changed disease introduction methods and thus disease can be introduced to non-endemic areas. The U.S., where RVF is not endemic, faces risk of RVF because of these new methods of introduction on multiple fronts, including air travel, ships carrying infected animals or animal products, live animals, and possibly wind transfer of vector (Levings, 2010).

Further east in the riverine delta systems of Pakistan and India, animal populations are considered to be at risk for a potential extension zone for RVF (F. Glyn Davies, 2003). Wildlife including the Springbok, African Buffalo, Camels (in Egypt), and Water buffalo (also in Egypt) are susceptible to RVF infection. Wildlife can become infected with RVF but there is a large range of severity of illness. Water buffalo experience severe illness much like cattle and sheep while camels only experience abortions (Jeffery Musser DVM, 2006). Camels are likely the best indicator animals for RVF in Africa because virtually all pregnant females abort if there is a high level of RVF virus associated with extensive flooding (F. Glyn Davies, 2003) and therefore can indicate presence of RVF in the area.

While not manifesting any clinical signs, many wild ruminants in endemic areas exhibit antibodies for RVF. Wild animals can thus act as carriers for the disease without presenting any clinical signs and can spread the disease to livestock if they share common drinking, eating, or sleeping locations. Scientific experimentation indicates that rodents and carnivores are also susceptible to experimental infection with some deaths occurring. However, no mortality has been observed in the wild (F. Glyn Davies, 2003). Rodents are of particular concern to U.S. farmers due to the risk of infected rodents traveling between endemic and non-endemic countries while acting as carriers of the disease. Typically, U.S. farmers cannot control rodent population imports as closely as they can livestock imports and this presents a risk of disease spread.

Best Practices Implemented

The Ministry of Health and Ministry of Municipalities of Saudi Arabia instituted an intensive mosquito control program and restricted movement of domestic livestock. Restricting and banning movement of livestock may be effective in slowing the distribution of the virus spread to unaffected areas (World Health Organization, 2007), but do not appear to have any effect upon the course of the outbreak in infected herds (F. Glyn Davies, 2003). Additional methods of prevention which could be implemented include moving livestock to higher altitudes and confinement of stock in insect-proof enclosures (The Center for Food Security and Public Health, 2007).

In addition, a comprehensive educational campaign to eliminate contact between humans and sick animals and mosquitoes was implemented and included the provision of free bed mosquito nets. The Ministries also encouraged people working with animals to seek early medical evaluation in person and provided information to health care providers on the clinical presentation and management of suspected cases (MMWR, 2000).

Case Study Lessons Learned

Early detection is important in preventing and controlling an RVF outbreak. Sentinel herd monitoring has been used throughout Africa to monitor viral circulation in susceptible populations. It is recommended that periodic surveillance be carried out by regular field visits and contact with livestock farmers. In order to be effective, sentinel heard monitoring should occur in conjunction with the monitoring of other risk factors for RVF, including climatic indicators. It is also recommended that field veterinarian and laboratory personnel be vaccinated against RVF.

Mass livestock vaccination campaigns of RVF should be considered where climatic and epidemiological evaluations suggest that there is a probability of RVF outbreak (FAO). Currently, the National Veterinary Stockpile has identified RVF as one of the 17 priority animal diseases (Levings, 2010). Thus, many states have created pre-established response plans that incorporate risk assessment, surveillance, and countermeasures (including vaccination strategies). Currently, there are no systematic surveillance strategies for RVF within the U.S., but an extension of the Kenyan Rift Valley Fever veterinary surveillance program will include wildlife species, which will help inform U.S. officials on potential disease risk (FAO).

In addition, the National Veterinary Stockpile has contracts in place for manufacturing of livestock vaccine for possible use if a threat became prominent.

When RVF activity has been confirmed, government authorities should (FAO):

- Define the extent of the infection and target population
- Define potential extension routes for further spread
- Monitor physical indicators of precipitation flooding and pooling
- Monitor mosquito populations in the affected areas
- Conduct surveillance for clinical disease in humans and animals
- Cease all trade for at least six months after the last evidence of RVF virus activity has been obtained
- Consider ceasing slaughter activities of animals to prevent spread to humans
- Implement vaccination measures on surrounding herds if appropriate

Countries like the U.S., that are currently free of RVF, should actively prepare contingency plans and have eradication plans as their goal. Active surveillance and forecasting should occur as well as continued public awareness campaigns on clinical signs.

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Appendix G: Source Term and Event Frequency Summary (Provided as electronic file: Source Term and Frequency Summary Table.xlsx)

Appendix H: NBAF SSRA Tornado Likelihood Analysis

1.0 Introduction

Since 1994, there have been on average approximately 1250 confirmed tornadoes per year in the U.S. Many of these tornados occur in the U.S. central plains, including Kansas. During this same period, within approximately 120 nautical miles of Manhattan, KS, there was on average approximately 58 tornados per year, and as recently as June 11th, 2008 a tornado hit the Kansas State University campus in Manhattan. Due to the plausibility of a tornado impacting the proposed NBAF facility, and the possibility of subsequent pathogen containment loss, the NBAF SSRA provides a detailed examination of the risks associated with this natural hazard. The climatological record is examined to characterize the frequencies that tornadoes occur in this region by intensity level. This information is combined with information from peer-reviewed scientific literature to ascertain how often tornados occur as a function of their intensity so that a risk of pathogen containment loss can be estimated and used in the overall SSRA findings. Lastly, characteristic weather patterns, associated with these tornado events, are extracted from the SOM analysis (described earlier in this report) to determine the likely plume dispersion patterns from tornado impact event.

2.0 F-Scale Based Tornado Frequency Analysis

Due to limited size and the relatively small area affected by any single tornado, its existence is one of the most difficult natural weather phenomena to document. The National Oceanic and Atmospheric Administration (NOAA) Storm Prediction Center (SPC) maintains an archive of all of the reported tornados since January 1, 1950 [available online at: http://www.spc.noaa.gov/wcm/]. This data set represents the most reliable accounting of tornado events, and is the "official" record of confirmed tornados in the U.S. The archive contains information on the intensity, touchdown time, initial touchdown location, tornado path, injuries, fatalities, and numerous other factors related to the tornado event.

In spite of the extensive effort that has gone into the collection of the information contained in the tornado event data-base, numerous studies have characterized its shortcomings. Studies by Galaway (1977), Kelly et al. (1978), Tecson and Fujita (1982), Doswell and Burgess (1988), and Ray et al. (2003) have identified and documented significant biases in the temporal record. Between 1950 and 1992 the number of confirmed tornados increased from approximately 200 per year to over 1000 per year. This increase in the number of tornadoes is widely attributed to an increase in population, improved awareness of tornados by the public, and improved detection and identification of tornados following the deployment of weather radars. Spatial biases, associated with population, have also been identified to be present in this data set (Schaefer and Galaway 1982; Grazulis and Abby 1983). While clear evidence of a positive bias in tornado frequency associated with population is present in the SPC tornado data base, McNulty et al. (1979), Grazulis and Abby (1983), King (1997), and Ray et al. 2003, all note that population centers are not consistently associated with higher tornado frequency. Ray et al. (2003) found that in the U.S. central plains, National Weather Service (NWS) Offices and NWS weather radar sites exhibited a strong correlation with the number of confirmed tornados in the SPC data set.

These findings indicate that some tornados in regions with low population density far from NWS facilities go un-reported, and that in general, the SPC tornado data-base under-represents the total number of tornados. In their study, the correlation between NWS facilities and the tornado reports was used to remove the apparent spatial bias, and improve the estimate of total tornado occurrence as a function of location. Their results indicate that the true total number of tornadoes is likely to be about 60% higher than the number of confirmed tornadoes that occurred between 1978 and 1992.

The NBAF SSRA leverages the work of Ray et al. (2003) described above to estimate the risk of pathogen containment loss associated with a tornado. Containment loss is likely to be associated with the intensity of the tornado and associated building damage. The risk of containment loss increases due to the increased likelihood of substantial damage to the facility, which is directly correlated with tornado intensity. The Fujita scale (F-Scale) is a widely-used community accepted tornado classification and damage definition metric. (Table 1). The F-Scale was recently updated (January 2007) to the Enhanced Fujita Scale (EF-Scale). Since the majority of the data-base and reference materials all use the original F-Scale, this study also uses the F-Scale wind and damage definitions instead of the newer metric.

Table 1. F-Scale Description

F-Scale	Highest 1/4-mile Wind Speed	3-Second Gust (mph)	Damage Description
F0	40-72 mph	45-78 mph	Minor damage
F1	73-112 mph	79-117 mph	Moderate damage
F2	113-157 mph	118-161 mph	Considerable damage
F3	158-207 mph	162-209 mph	Critical damage
F4	208-260 mph	210-261 mph	Severe damage
F5	261-318 mph	262-317 mph	Devastating damage

The original Ray et al. (2003) study computed tornado climatologies for all tornados and did not attempt to correct the spatial biases for each of the F-Scale tornado intensities. To address the need for accurate tornado occurrence estimates as a function of tornado intensity we have conducted an analysis that extends the work of Ray et al. (2003). One of the challenges of characterizing tornado occurrence as a function of F-Scale is that in addition to the documented biases in the climatological record discussed above, the more intense tornados F3-F5 are extremely rare events. For example, during the entire period of record (59 years), over the entire continental U.S., there were only 496 F4 and F5 tornado events (Table 2). The relative rarity of these strong tornado events is also illustrated in Figure 1. Here the tracks of all of the confirmed tornados between 1950 and 2009 are depicted over the central Great Plains region. As shown, black tracks represent F0-F1 tornados, blue tracks represent F2-F3 tornados, and the red tracks illustrate the F4-F5 tornado events. For reference purposes the red dot represents the NBAF location. Because tornados are rare events, and this is particularly true for intense tornados, it is difficult to produce a statistically relevant occurrence frequency for the immediate vicinity of Manhattan, KS. This point is illustrated in Table 3, which contains a summary of the confirmed tornados that occurred within approximately 10 nautical miles (nmi) of Manhattan, KS, and in Figure 2, which

depicts the paths of these tornados. Over the 59-year record, there have been only 14 confirmed tornadoes of any intensity documented in this area.

Since the climatological record is not long enough to capture a statistically relevant number of tornadoes at all of the intensity levels in the immediate vicinity of the NBAF, it is necessary to identify an area (as large as possible) where the overall tornado occurrence statistics are relatively uniform and representative of tornado frequency for Manhattan, KS. To accomplish this, we examined the tornado occurrence statistics in 1° longitude bands from west to east and 1° latitude bands from north to south to identify regions of uniform tornado occurrence and/or trends in the SPC database (Figures 3 and 4). The results illustrate that a region of higher tornado occurrence is present over southern Nebraska, most of Kansas and Oklahoma, and northern Texas between longitudes of 102° and 95° W and latitudes of 32° to 41° N. This area constitutes what is often referred to as a portion of "Tornado Alley". The local maximums in tornado frequency at 98° west and at 32°, 35°, and 39° north roughly correspond with localized regions of higher population associated with the cities of Dallas - Ft. Worth, TX, Oklahoma City, OK, Kansas City, MO, and smaller towns along the transportation corridors of U.S. interstate highways 20, 40, and 70. Outside of the 32° to 41° N latitude and 102° and 95° W longitude band, the number of tornados markedly decreases. Based on these findings, we chose the area illustrated by the dashed red box in Figure 1, to provide tornado climatology statistics used in this study. Using an area of this size significantly increases the total number of tornados in each of the F-Scale categories and provides tornado occurrence statistics that are both statistically relevant and representative of the conditions that can be expected at the NBAF facility. Table 4 contains a listing of the tornado occurrences by F-Scale for the area outlined by the red dashed-line box in Figure 1.

Table 2. U.S. Total Confirmed Tornados (1950-2009)

F-Scale	Tornado Count	Percentage of Total
F0	23054	45.20 %
F1	17188	33.70 %
F2	8169	16.01 %
F3	2095	4.11 %
F4	454	0.89 %
F5	42	0.08 %

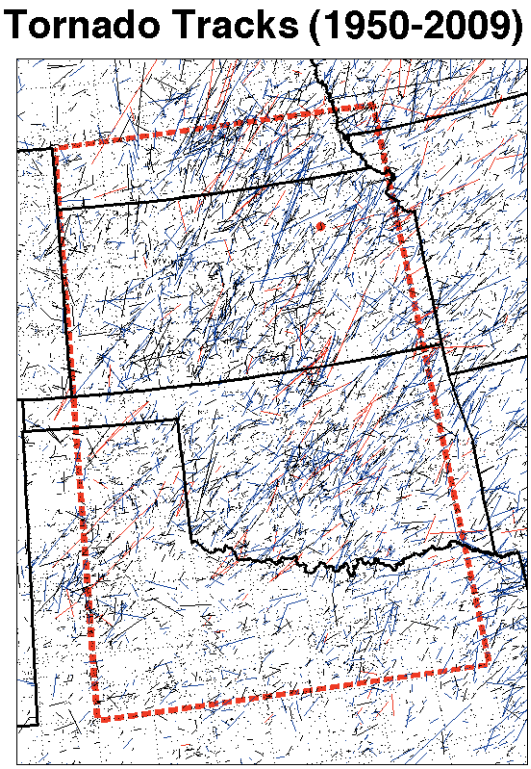

Figure 1. The tracks for all of the confirmed tornados from 1950-2009.

Black is used to depict the F0-F1 intensity tornados, blue is used to depict the F2-F3 intensity tornados, and red is used to denote the F4-F5 intensity tornados. The red dot in north-eastern Kansas is the location of the NBAF in Manhattan, KS. The box denoted by the dashed red line is the region from which the tornado climatological statistics are determined.

Table 3. Confirmed Tornados Within 10 nmi of NBAF (1950-2009)

F-Scale	Tornado Count	Percentage of Total
F0	7	50.00 %
F1	5	35.71 %
F2	1	7.14 %
F3	0	0.00 %
F4	1	7.14 %
F5	0	0.00 %

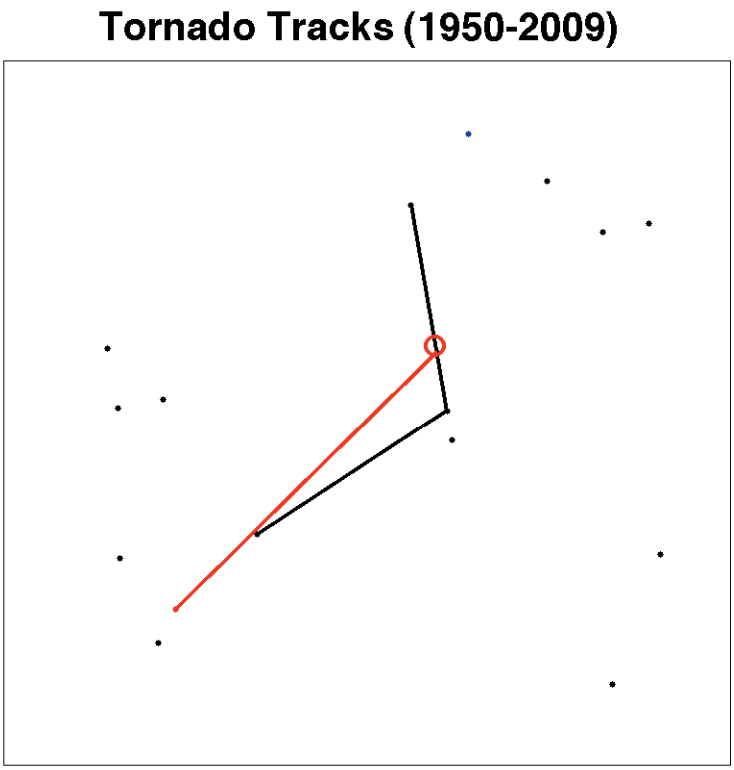

Figure 2. The touchdown location and/or tracks for all of the confirmed tornados from 1950-2009 within 10 nmi of the NBAF.

Black is used to depict the F0-F1 intensity tornados, blue is used to depict the F2-F3 intensity tornados, and red is used to denote the F4-F5 intensity tornados. The red circle denotes the NBAF location.

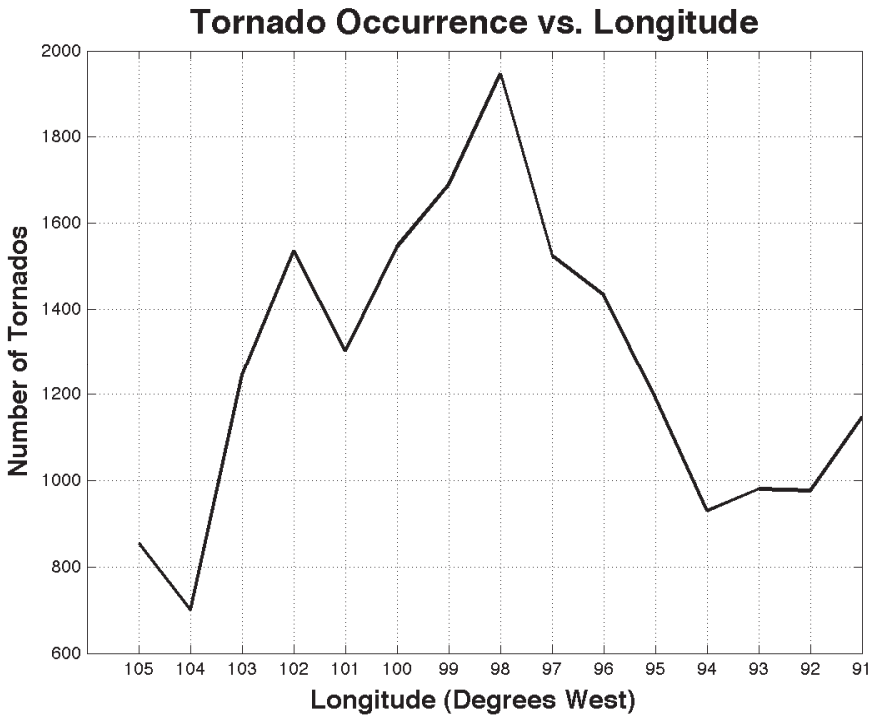

Figure 3. The number of tornados as a function of longitude inside a 1° longitude by 14° latitude region (29° to 43° N).

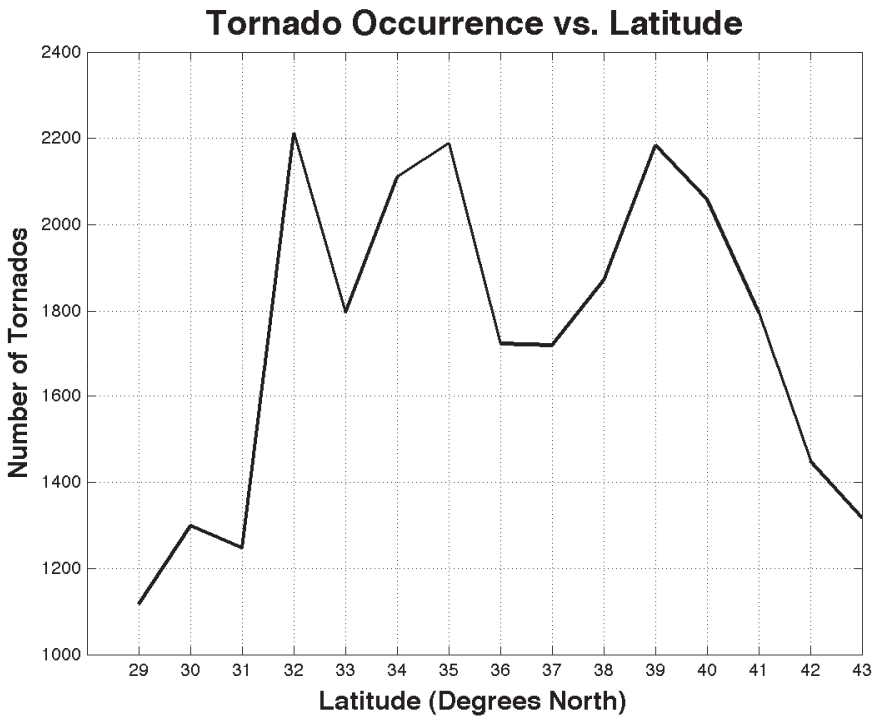

Figure 4. The number of tornados as a function of latitude inside a 1° latitude by 14° longitude region (105° to 91° W).

Table 4. Statistically Relevant Tornado Occurrences (1950-2009)

F-Scale	Tornado Count	Percentage of Total
F0	5429	50.80 %
F1	2932	28.38 %
F2	1601	15.49 %
F3	453	4.38 %
F4	89	0.86 %
F5	9	0.09 %

Ray et al. (2003) found that the adjusted true number of tornados is about 60% higher than those reported between 1978 and 1992 in the SPC tornado occurrence record. In particular, over Manhattan, KS, it was found that the average number of tornados (for all F-Scale intensities) was 0.0625 tornados per year per 100 square kilometers (y^{-1} $(100\ km^2)^{-1}$). Assuming that all locations inside the 100 km^2 are equally likely to be struck by the tornado, this corresponds to a return period of approximately 16 years. We extended this original analysis by computing the mean return period for tornados of a given intensity or higher. The mean return periods were determined by combining the probabilities of the tornado intensities with the adjusted probable number of tornados from Ray et al. (2003), using the formulation of Wilks, 2006 (Equation 1). Table 5 lists the results of this computation and provides the average return period for a given tornado F-Scale intensity or greater event. It is important to note that this measure does not guarantee that an event will occur within a particular return period. This measure is simply the average time between these events, assuming a very long sampling period (Wilks, 2006). These return periods are then used in Task 2 to characterize the corresponding pathogen containment loss risk associated with tornados across the full spectrum of tornado intensities.

Equation 1:

$$R(x) = \frac{1}{w\left[1 - F(x)\right]}$$

$$R(x) = \text{Mean Return Period}$$

$$w = \text{Annual Occurrence} \left({}^{1}\!/_{yr} \right)$$

$$F(x) = \text{Cumulative Probability}$$

Table 5. Statistically Relevant Tornado Occurrence and Average Return Period

F-Scale	Tornado Count	Percentage of Total	Mean Return Period
F0 or Greater	5429	50.80 %	16 Years
F1 or Greater	2932	28.38 %	33 Years
F2 or Greater	1601	15.49 %	77 Years
F3 or Greater	453	4.38 %	300 Years
F4 or Greater	89	0.86 %	1687 Years
F5 or Greater	9	0.09 %	18370 Years

It is well known that tornados preferentially form under certain atmospheric conditions. While we intuitively know that these conditions occur in the spring and early summer months, the corresponding atmospheric conditions that impact the subsequent transport and dispersion of any released pathogen are not necessarily intuitive. In order to determine the appropriate atmospheric conditions required to drive the plume modeling analysis, we combined the SOM analysis with the tornado climatological record for the 21-year period from 1985-2005. Tornado records within approximately 100 nmi of Manhattan were used to ensure that the SOM weather patterns are indicative of the conditions in which tornados form in the vicinity of Manhattan, KS. Within this range of the NBAF the tornado record contained 763 confirmed tornadoes, and was adequate to diagnose clear patterns in the SOM weather pattern classifying analysis. The SOM weather pattern for each event was determined by matching each tornado event with the date and time from the SOM map node members. Figure 5 depicts a histogram of the number of times that a given event fell into a particular SOM node. This frequency distribution was then mapped to the same SOM node configuration for Manhattan, KS to characterize the series of SOM weather patterns that should be used to represent the dispersion patterns following a tornado impact on the facility (Figure 6). The results of this analysis indicate the specific SOM nodes, which represent the larger scale atmospheric conditions, prevalent during these documented tornadic events. These nodes and the corresponding weather conditions, are then used as inputs for the subsequent plume modeling of the tornado release scenario (Scenario 11), described in Section 3.3.11 .

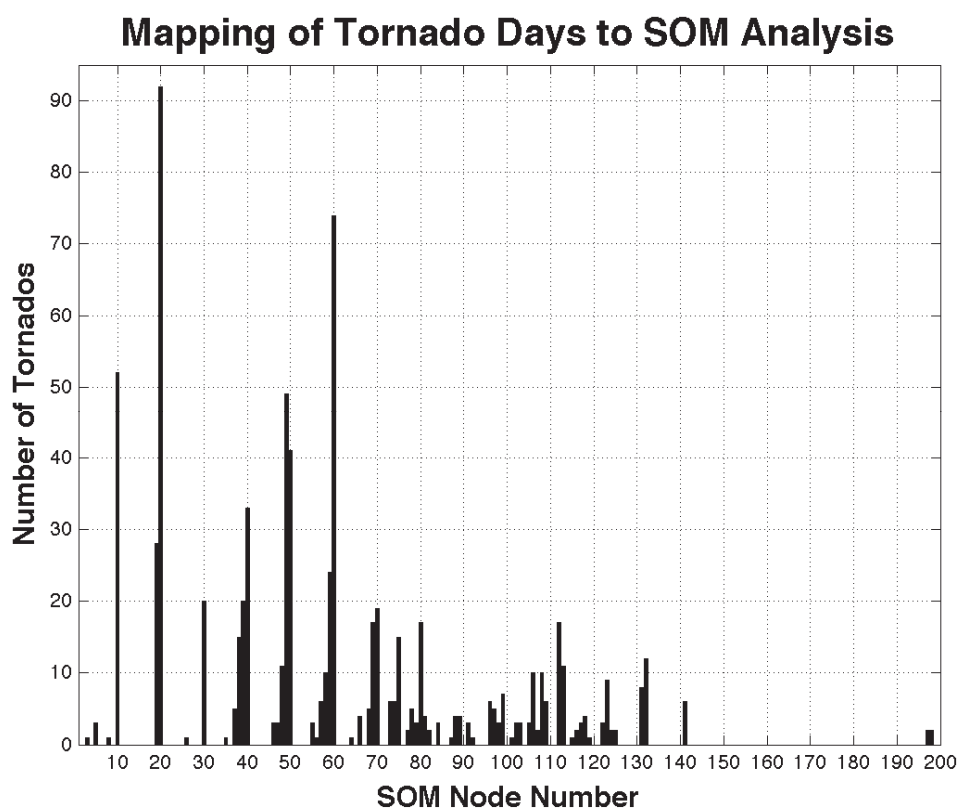

Figure 5. A frequency distribution depicting the number of tornado events that correspond to a given SOM weather pattern

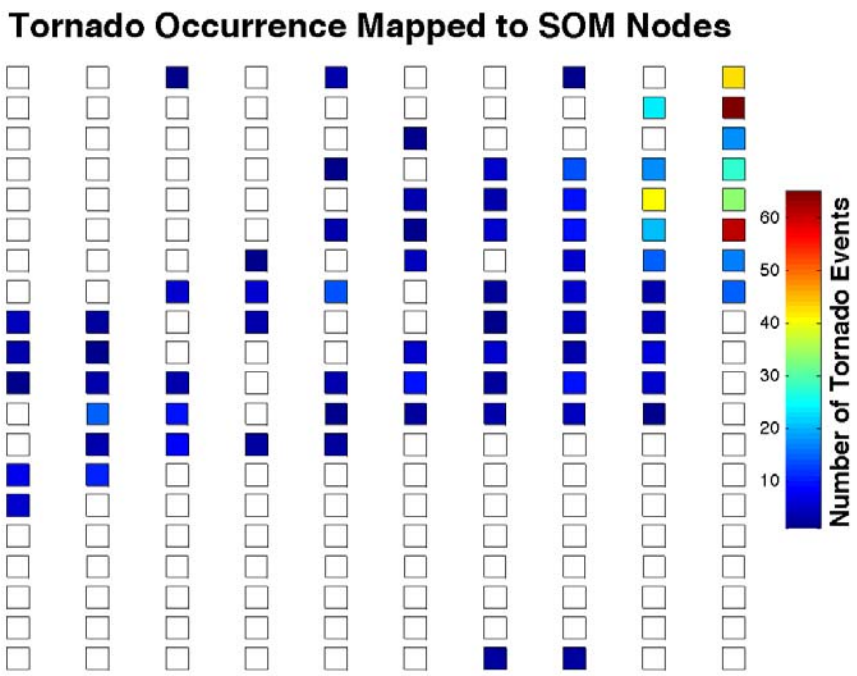

Figure 6. The tornado frequency distribution from Figure 4 mapped to the SOM "postage stamp" map

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Appendix I: FMDv and RVFv Stability Studies and Minute Tidal Volume Calculations

1.0 Aerosolized Foot-and-Mouth Disease Virus (FMDV) Stability Study

FMDV was suspended in Eagle's media for all data shown in this report, unless otherwise noted. Aerosolized FMDV shows similar stability in Eagle's Media (cell culture fluid), bovine nasal fluid, bovine milk, bovine fecal slurry and porcine fecal slurry. However, aerosolized FMDV shows a significant decrease in stability when suspended in bovine salivary fluid.[2,3]

The FMDV strain O1BFS 1860 was used in all cases; O1BFS 1860 is the most commonly used FMDV strain for research.[4] The stability of other FMDV strains may vary, but will follow similar trends. For example, FMDV strains isolated from dry climates (constant low humidity) show increased viral stability at low humidity over O1BFS 1860, but are still more stable at high humidity than low humidity.[5]

The Effect of Relative Humidity

Humidity is an important factor in the stability of aerosolized FMDV, with viral stability increasing as percent relative humidity increases. It should be noted that although relative humidity is high, during a storm some FMDV virus can be removed from the air by falling raindrops.[6] FMDV decays rapidly during the first five minutes following release of aerosolized virus. After five minutes, the virus decays more slowly. Following the examples in FMDV literature, the primary (first five minutes) and secondary decay rates have been modeled, separately (Figure 1 and Figure 2). In these charts, the Y-axis represents the decay of viral viability per period of time. The numbers indicate the log reduction of the virus over the described period of time at that humidity. The larger the number, the more decay is occurring (logarithmically). For example, in Figure 2, at 40% RH, the amount of virus viable at time 0 will decrease by four logs after one hour. That is, if there is 1,000,000 pfu of FMDv at time 0, there would be 100 pfu one hour later at 40% RH. In contrast, at high RH, the decay is near zero. The primary and secondary decay rates are similarly affected by relative humidity, with low decay rates at relative humidity in excess of 55% and high decay rates at relative humidity under 40%.

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[2] Barlow D., Donaldson A. "Comparison of the Aerosol Stabilities of Foot-and-Mouth Disease Virus Suspended in Cell Culture Fluid or Natural Fluids." *Journal of General Virology.* **20.** 1973.
[3] Donaldson A. "The Influence of Relative Humidity on the Stability of Foot-and-Mouth Disease Virus in Aerosols from Milk and Faecal Slurry." *Research in Veterinary Science*. **15.** 1973
[4] Cottom E *et. al.* "Transmission Pathways of Foot-and-Mouth Disease Virus in the United Kingdom in 2007." *PLoS Pathogens*. **4**(4). 2008.
[5] Donaldson A., Sellers R., Lacey J. "Quantitative Data on Airborne Foot-and-Mouth Disease virus: Its Production, Carriage and Deposition [and Discussion]." *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*. **302**(1111). 1983.
[6] Gloster J. "Long distance transport of foot-and-mouth disease virus over the sea." *The Veterinary Record*. **110**. 1982.

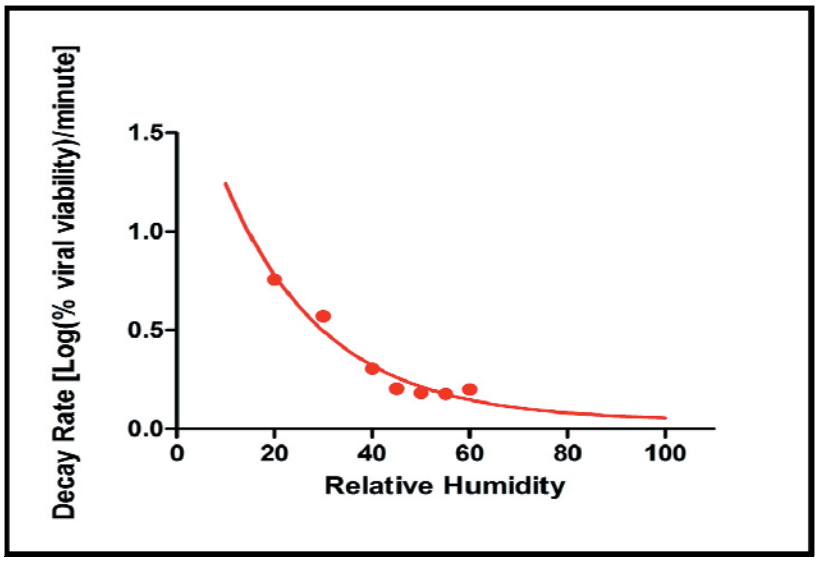

Figure 1. The effect of relative humidity on aerosolized FMDV Primary Decay Rate (during the first five minutes after release).[7]

A one-phase decay curve was fit to the data, y=1.9463e^(-0.04838x)+ 0.04070. The curve was a good fit to the data with an r^2 of 0.9582.

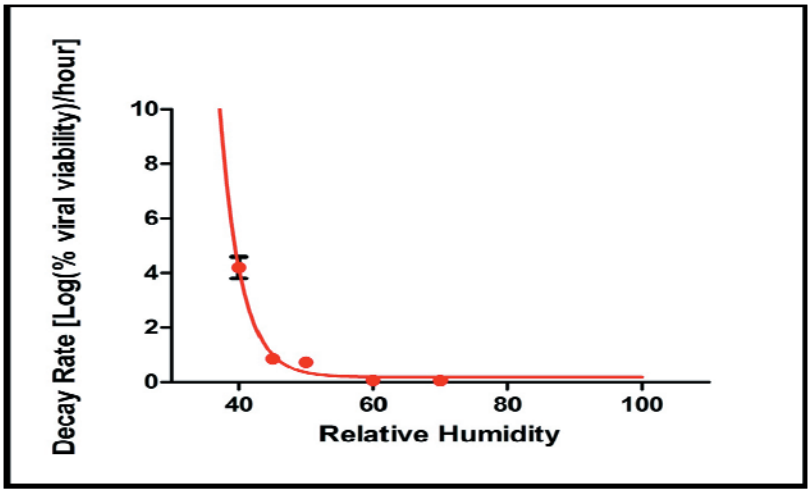

Figure 2. The effect of relative humidity on aerosolized FMDV Secondary Decay Rate (more than five minutes after release).[8,9]

Error bars express standard error. A one-phase decay curve was fit to the data, y=1243999.8218e^(-0.3162x)+0.1782. The curve was a good fit to the data with an r2 of 0.9833.

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[7] Barlow, D. "The Effects of Various Protecting Agents on the Inactivation of Foot-and-Mouth Disease Virus in Aerosols and during Freeze-drying." *Journal of General Virology.* **17.** 1972.

[8] Barlow, D. "The Aerosol Stability of a Strain of Foot-and-Mouth Disease Virus and the Effects of Stability of Precipitation with Ammonium Sulfate, Methanol or Polyethylene Glycol." *Journal of General Virology*. **15.** 1972.

[9] Barlow, D., Donaldson, A. "Comparison of the Aerosol Stabilities of Foot-and-Mouth Disease Virus Suspended in Cell Culture Fluid or Natural Fluids." *Journal of General Virology.* **20.** 1973.

The Effect of Ultraviolet light (UV)

Ultraviolet exposure also impacts the stability of aerosolized FMDV. While experimental data is available for UV decay of FMDV in suspension,[10] little is available for aerosolized FMDV. Donaldson and Ferris investigated aerosolized FMDV stability in open air conditions (including UV from natural light) using a micro thread technique. Their data showed weak correlation between mean UV intensity and viral decay, but this, by the author's own admission, was probably due to flaws in experimental design and uncontrollable environmental variables.[11] In the absence of experimental data, we used an estimated UV decay rate based on the UV sensitivity of viruses in the same family (Picornaviridae) as FMDV, as described by Lytle.[12]

The rate of decay due to UV exposure is significantly less than the rate of decay due to humidity under most conditions. The contribution of UV to FMDV decay rate during the first five minutes after aerosolization is insignificant, so we did not incorporate UV decay into our model for primary FMDV decay. UV significantly contributes to aerosolized FMDV decay after five minutes, especially at high levels of humidity. Using Lytle's estimates, for a virus of the family Picornaviridae with a genome of size of 8.1 kb, theUV_{254} D_{37} for FMDV is 45.7 J/m^2 (UV exposure at 254 nm resulting in 37% viable virus).

Lytle calculated total effective solar flux of noontime sun for locations across the United States during summer and winter based on solar radiometry data. The site of interest, Manhattan, Kansas has an elevation of 311 m and latitude of 39.2 °N. Lytle provides solar flux for the similarly situated Davis, California, which has an elevation of 18 m and lies at latitude 38.5 °N. Effective solar flux in Davis at midday on a clear day (15 July) is 0.35 J/m^2_{254}/min., and we used this number as a conservative estimate of the maximum effective solar flux in Manhattan, Kansas. We calculated UV decay rates for FMDV for effective solar flux between 0.05 J/m^2_{254}/min. and 0.4 J/m^2_{254}/min. (Table 1). Secondary decay rate curves of FMDV were generated taking into account decay as a result of both UV and humidity (Figures 3 and 4).

Table 1. Range of Decay Rates for Aerosolized FMDV due to UV exposure

Effective Solar Flux (J/m^2_{254}/min)	Approx. Decay Rate Log (% viral viability)/hour
0.05	0.028
0.10	0.057
0.15	0.085
0.20	0.114
0.25	0.142
0.30	0.171
0.35	0.199
0.40	0.228

[10] Nuanualsuwan S. *et. al.* "UV inactivation and model of UV inactivation of foot-and-mouth disease viruses in suspension." *International Journal of Food Microbiology*. **127**. 2008.
[11] Donaldson AI, Ferris NP. "The Survival of Foot-and-Mouth Disease Virus in Open Air Conditions." *The Journal of Hygiene.* **74**(3). 1975.
[12] Lytle C., Sagripanti J. "Predicted Inactivation of Viruses of Relevance to Biodefense by Solar Radiation." *Journal of Virology*. **79** (22). 2005.

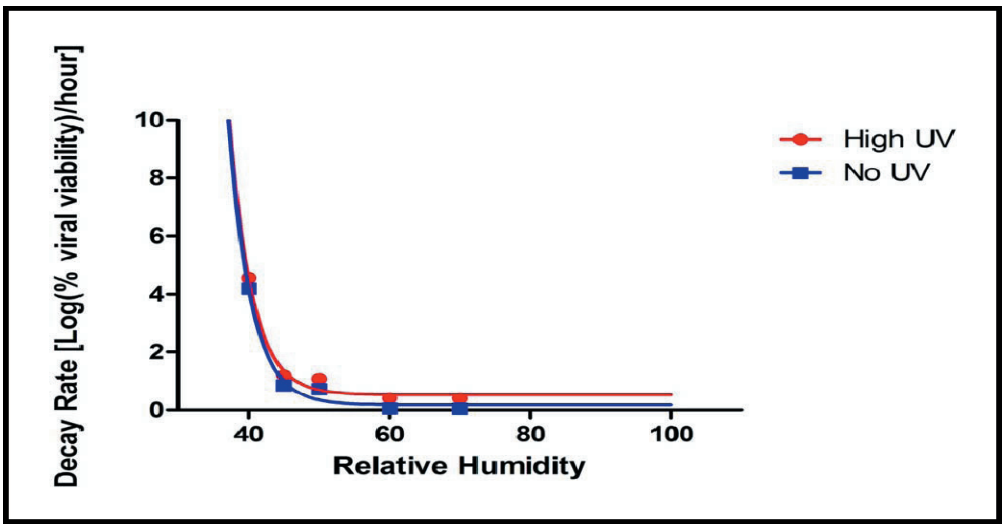

Figure 3. Aerosolized FMDV Secondary Decay Rate (5 minutes or more after release) taking into account UV and relative humidity.

We estimate the maximum effective solar flux in Manhattan, Kansas is 0.35 J/m^2_{254}/minute; this was used to generate the "High UV" set. One-phase decay curves were fit to the data with the following results:

High UV: y=1243999.4718e^(-0.3162x)+0.5282
No UV: 1243999.8218e^(-0.3162x)+0.1782
In both cases, $r^2 = 0.9833$

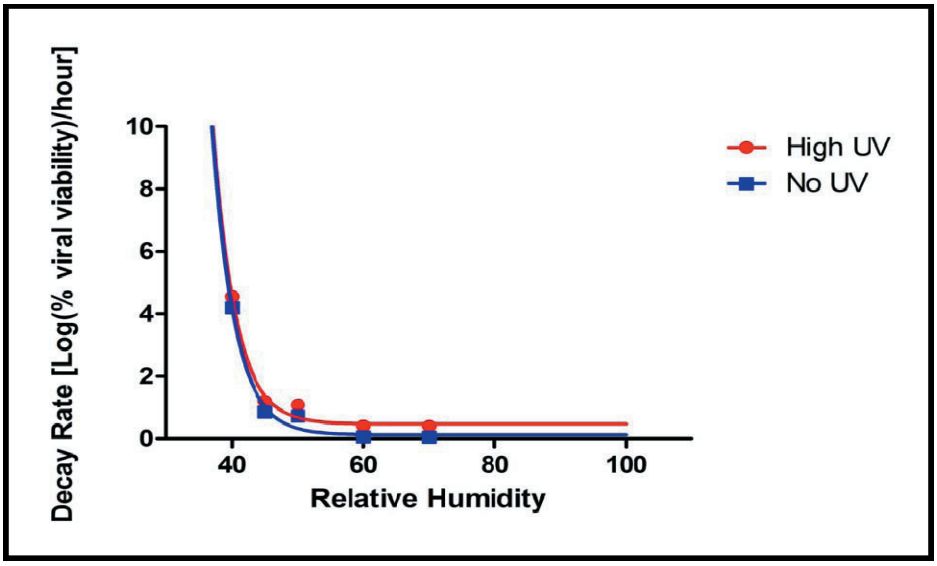

Figure 4. Aerosolized FMDV Secondary Decay Rate (5 minutes or more after release) taking into account UV and relative humidity.

We estimate the maximum effective solar flux in Manhattan, Kansas is 0.35 J/m^2_{254}/minute, this was used to generate the "High UV" set. One-phase decay curves were fit to the data with addition of a point

at 100% relative humidity estimating decay rate with a 0% contribution from humidity (0.35 for high UV, 0 for No UV). Results follow:

High UV: y=634993.5314e^(-0.2990x)+0.4686
No UV: y=634992.8814e^(-0.2990x)+0.1186
In both cases, $r^2 = 0.9832$

2.0 Aerosolized Rift Valley Fever Virus (RVFv) Stability Study

The Effect of Relative Humidity

We were able to find only two studies reporting experimental data on the stability of aerosolized RVFv, Miller et al. from 1963 and Brown et al. from 1982.[13,14] Miller found that there was no difference in aerosolized RVFv stability at 50% and 80% relative humidity. Notably, they did not show data for RVFv decay at 80% relative humidity, only at 50% relative humidity. Brown found that viral stability decreased with increasing humidity based on data at three humidity values: 30%, 55% and 80%. The aerosolized decay rates were roughly equivalent between the two studies (comparing 50% and 55% relative humidity.). Brown was unable to provide a clear reason for the disagreement between the two studies, hypothesizing that improved technologies, differences in suspension media, and differences in viral protein concentration might contribute to the different results. Given that the Miller publication only provided a decay rate for one relative humidity, and that the decay rate at this point was in agreement with Brown's data, we used the Brown data for our model of RVFv viral stability (Figure 5 and Figure 6; "No UV").

These results may seem surprising in light of the fact RVFv outbreaks have been linked with flooding and heavy rains. This is most likely due to the effect these conditions have on the RVFv mosquito vector population, not their effect on the stability of the virus itself.[15,16,17]

The Effect of Ultraviolet light (UV)

Ultraviolet exposure also impacts the stability of aerosolized RVFv. No experimental data is available for UV decay of RVFv. A study of inactivation of Hantaan virus, a virus in the same family as RVFv (Bunyaviridae), by UV exposure corresponding to 50, 140 and 240 J/m^2 showed that UV exposure

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[13] Miller FA et al. "Stability and infectivity of airborne yellow fever and Rift Valley fever viruses." *American Journal of Hygiene*. **77**. 1963

[14] Brown JL et al. "Airborne Survival of Rift Valley Fever Virus." *U.S. Army Medical Research Institute of Infectious Disease Report.* Fort Detrick, Frederick, Maryland. 1982.

[15] Linthicum KJ et al. "Climate and Satellite Indicators to Forecast Rift Valley Fever Epidemics in Kenya," *Science*. **285**. 16 July 1999.

[16] Birt BH et al. "Multiple Virus Lineages Sharing Recent Common Ancestry Were Associated with a Large Rift Valley Fever Outbreak among Livestock in Kenya during 2006-2007." Journal of Virology. **82**(22). 2008.

[17] Anyamba A et al. "Prediction of Rift Valley fever outbreak." PNAS. **106** (3). 2009.

significantly reduced the amount of viable virus over a period of three minutes.[18] This UV exposure was considerably more intense than UV exposure from natural sunlight, and these experiments were conducted on virus suspended in solution, not aerosolized virus. Therefore these data are not suitable for use in our model. We used an estimated UV decay rate for RVFv based on the UV sensitivity of other viruses in the Bunyaviridae family, as described by Lytle. [19] UV significantly contributes to aerosolized RVFv decay. Using Lytle's estimates, for a virus of the family Bunyaviridae with a genome of size of 12 kb, the UV_{254} D_{37} for RVFv is 12 J/m^2 (UV exposure at 254 nm resulting in 37% viable virus).

Lytle calculated total effective solar flux of noontime sun for locations across the United States during summer and winter based on solar radiometry data. The site of interest, Manhattan, Kansas has an elevation of 311 m and latitude of 39.2 °N. Lytle provides solar flux for the similarly situated Davis, California, which has an elevation of 18 m and lies at latitude 38.5 °N. Effective solar flux in Davis at midday on a clear day (15 July) is 0.35 J/m^2_{254}/min., and we used this number as a conservative estimate of the maximum effective solar flux in Manhattan, Kansas. We calculated UV decay rates for RVFv for effective solar flux between 0.05 J/m^2_{254}/min. and 0.4 J/m^2_{254}/min. (Table 2). Decay rate curves of RVFv were generated taking into account decay as a result of both UV and humidity (Figures 5 and 6).

Table 2. Range of Decay Rates for Aerosolized RVFv due to UV exposure

Effective Solar Flux (J/m^2_{254}/min)	Approx. Decay Rate Log (% viral viability)/hour
0.05	0.108
0.10	0.217
0.15	0.325
0.20	0.434
0.25	0.542
0.30	0.651
0.35	0.760
0.40	0.868

[18] Kraus AA, et al. "Inactivation of Hantaan Virus-Containing Samples for Subsequent Investigations outside Biosafety Level 3 Facilities." *Intervirology*. **48**. 2005.
[19] Lytle C., Sagripanti J. "Predicted Inactivation of Viruses of Relevance to Biodefense by Solar Radiation." *Journal of Virology*. **79** (22). 2005.

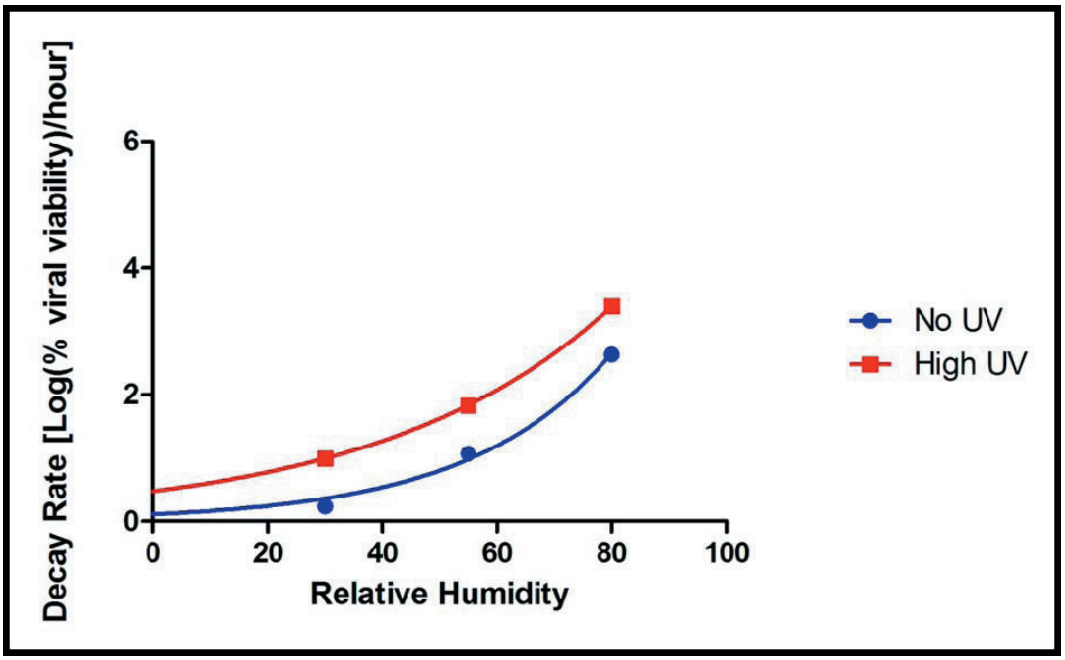

Figure5. Aerosolized RVFv Decay Rate taking into account UV and relative humidity. [20,21]

We estimate that the maximum effective solar flux in Manhattan, Kansas is 0.35 J/m^2_{254}/minute, this amount of UV exposure was used to generate the "High UV" decay rate set. Exponential growth equation curves were fit to the data. The "No UV" curve does not optimally model decay rate at high relative humidity because it gives decay rate values higher than the "High UV" model, which is incorrect. <u>This model should not be used for humidity in excess of 80%.</u>

Here are the results:

High UV: $y= 0.4732e^{0.02461x}$
$r^2 = 1$
No UV: $y=0.1084e^{0.03994x}$
$r^2 = 0.9917$

[20] Brown JL et al. "Airborne Survival of Rift Valley Fever Virus." *U.S. Army Medical Research Institute of Infectious Disease Report.* Fort Detrick, Frederick, Maryland. 1982.
[21] Lytle C., Sagripanti J. "Predicted Inactivation of Viruses of Relevance to Biodefense by Solar Radiation." *Journal of Virology*. **79** (22). 2005.

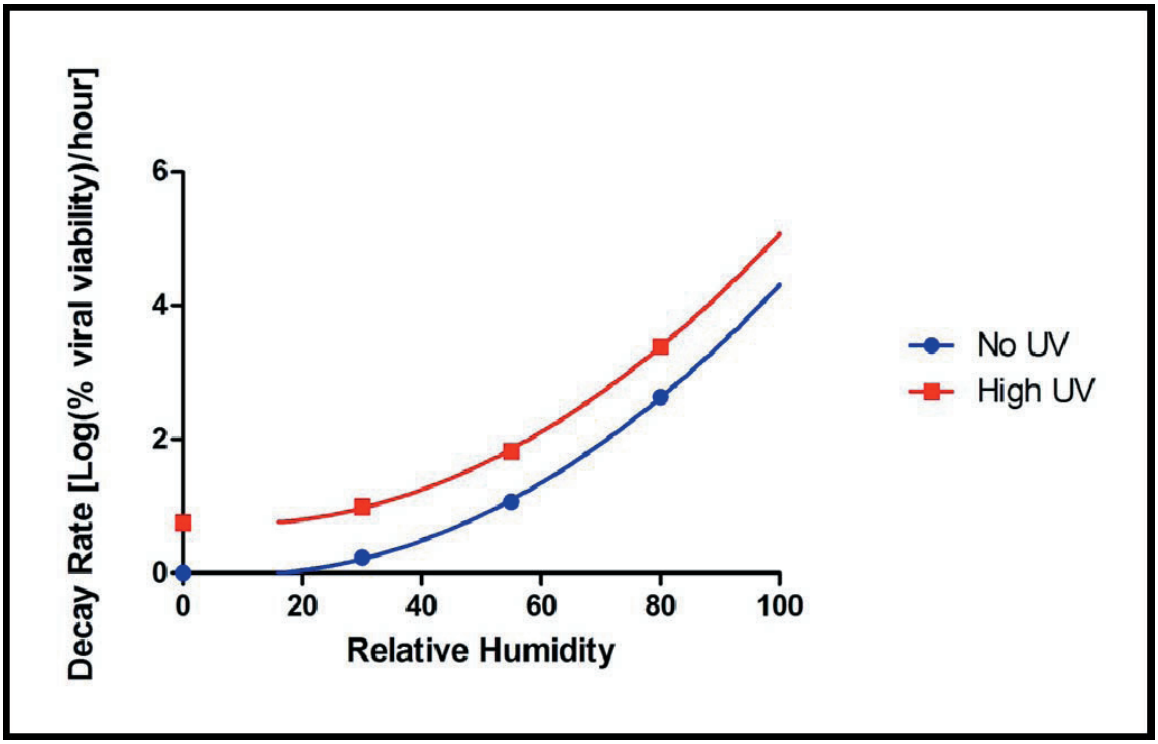

Figure 6. Aerosolized RVFv Decay Rate taking into account UV and relative humidity. [22,23]

As in Figure 3, we estimate that the maximum effective solar flux in Manhattan, Kansas is 0.35 J/m^2_{254}/minute, this amount of UV exposure was used to generate the "High UV" decay rate set. Second order polynomial (quadratic) curves were fit to the data with addition of a point at 0% relative humidity estimating decay rate with a 0% contribution from humidity (0.760 for high UV, 0 for No UV). The "No UV" curve does not optimally model decay rate at low relative humidity as it gives (very small) negative decay rate values. <u>When using this model, negative decay rate values should be rounded to zero or the model should not be used for humidity of less than 16.05%.</u>

Here are the results:

High UV: $y=0.7665-0.008716x+0.0005177x^2$
No UV: $y=0.006543-0.008716x+0.0005177x^2$
In both cases, $r^2 = 0.9997$

[22] Brown JL et al. "Airborne Survival of Rift Valley Fever Virus." *U.S. Army Medical Research Institute of Infectious Disease Report.* Fort Detrick, Frederick, Maryland. 1982.
[23] Lytle C., Sagripanti J. "Predicted Inactivation of Viruses of Relevance to Biodefense by Solar Radiation." *Journal of Virology*. **79** (22). 2005.

3.0 Minute Tidal Volume Calculation

Minute tidal volume (MTV)—the amount of air inhaled or exhaled from the lungs in one minute—is determined based on the relationship between respiratory rate (number of breaths per minute) and tidal volume (amount of air inhaled or exhaled). Literature values were not available for tidal volume in every animal considered; therefore, we used Dixon's model as a comparison, which studied the relationship between minute tidal volume and body weight.[24]

The Dixon model was designed primarily with smaller animals in mind, so in order to account for potential prediction limitations when considering animals of a greater weight, we took an average minute tidal volume from available literature values and completed our own calculations using numbers assembled from various journal articles, as noted below.

The average live weight for beef cattle was obtained from the *Livestock Judging Manual.*[25] While the tidal volume for cattle was not available in the literature, the average respiratory rate was found in the *Beef Cattle Handbook.*[26] Though we were unable to find the necessary values to perform our own calculation of minute tidal volume for cattle, the value for average weight was plugged into the Dixon model, which evaluates the relationship between weight and minute tidal volume. The article, "Effect of Heat Stress," by McDowell RE, et al[27] provided a minute tidal volume with which to compare to the Dixon model. Our final value for cattle minute tidal volume was determined by taking the average of the Dixon model output and the literature value from McDowell.

Krška P, et al.[28] provides the average slaughter weight for pigs. A pig's tidal volume value and average respiratory rate is calculated by Richard JC, et al.[29] We performed the minute tidal volume calculation for pigs by multiplying the average respiratory rate by the tidal volume and average weight. The typical weight of a pig was then plugged into the Dixon model and the output averaged with our calculation.

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[24] Dixon KR, Joab BM, Snyder FD. "A model for predicting ventilation rates in mammals." *Environmental Toxicology and Pharmacology*. **3** (1). 1997.

[25] "Beef Cattle Grading." *South Dakota State University Livestock Judging Manual: Designed for 4-H Seniors and Experienced Judges*. 2nd Edition. South Dakota State University.

[26] Le Viness EA. "Vital Signs in Animals: What Cattle Producers Should Know About Them." *Beef Cattle Handbook*. 1999.

[27] McDowell RE, et al. "Effect of Heat Stress on Energy and Water Utilization of Lactating Cows." *J. Dairy Science.* **52** (2). 1969.

[28] Krška P, et al. "Meat content in pigs estimated by various methods and compared with objective lean meat content." *Czech J. Anim. Sci.* **47** (5). 2002.

[29] Richard JC, et al. "Effects of Positive End-Expiratory Pressure and Body Position on Pulmonary Blood Flow Redistribution in Mechanically Ventilated Normal Pigs." *Chest Journal*. **122** (3). 2002.

The average weight, tidal volume and respiratory rate of sheep are noted by McKinley and Adams[30] We calculated the minute tidal volume using these data and determined an average minute tidal volume using the output from the Dixon model.

The average weight and tidal volume of White-tailed deer were found in Posner LP, et al.[31] Respiratory rate for deer at rest was obtained from Lance and Wolfe.[32] We multiplied these values to calculate the minute tidal volume and averaged it with the output from the Dixon model.

Mammal	Average Weight (kg)	Tidal Volume (L/kg)	Average Respiratory Rate (breaths/min)	Calculated MTV (L/min)	Literature MTV (L/min)	Dixon model MTV (L/min)	Average MTV (L/min)
Cattle (beef)	522	-	20	-	127	120.9	123.95
Pig	105	0.0100	17	17.85	-	18.7	18.28
Sheep	73	0.0065	28	13.29	-	12.24	12.77
White-tailed Deer	52	0.0140	18	13.10	-	13.82	13.46

Equations Used:

- *Minute Tidal Volume (MTV) Equation:*

  Tidal Volume (L/kg) * Respiratory Rate (breaths/min) = Minute Tidal Volume (L/min)

- *Dixon Model for relationship between Minute Tidal Volume (L/min) and Body Weight (kg) in Mammals:*

  $0.424*W^{0.648}$, W < 5 kg

  $0.083*W^{1.164}$, W >/= 5 kg

[30] Adams D and McKinley M. "The Sheep." ANZCCART Fact Sheet A9. 2009.

[31] Posner LP, et al. "Acid-Base, Blood Gas, and Physiologic Parameters during Laparoscopy in the Head-Down Position in White-Tailed Deer (*Odocoileus Virginianus*)." *Journal of Zoo and Wildlife Medicine*. **36**(4). 2005.

[32] Lance WR and Wolfe LL. Pharmaceutical Combination for and Method of Anesthetizing and Immobilizing Non-Domesticated Mammals. Greenwood Village, CO. Patent application number 20100010006.

Appendix J: Aerosol Fate and Transport (Plume) Modeling

1.0 Summary and Objective

In order to estimate the potential health and economic consequences from an accidental or intentional airborne release of pathogen, from the proposed NBAF facility, aerosol fate and transport simulations were performed to estimate downwind pathogen exposure to susceptible animal and human populations. Utilizing aerosol release parameters derived for each airborne transport scenario/pathway (Section 2.3), aerosol airborne concentrations and surface depositions were calculated for a range of representative meteorological conditions, for the Manhattan, Kansas region (Figure 1). Resulting inhalation exposure levels and surface deposition amounts were derived for all surrounding susceptible animal and human population locations (Section 2.2), and provided the initial conditions for the determination of any resulting infections and spread of the diseases (Section 2.5 Epidemiological Modeling). For each individual aerosol exposure result, an associated probability of occurrence was provided, based on the relative frequency of the driving meteorological condition. These probabilities were later folded into the final probabilities for each scenario, to determine an overall risk ranking. This approach is discussed in greater detail in Section 2, below.

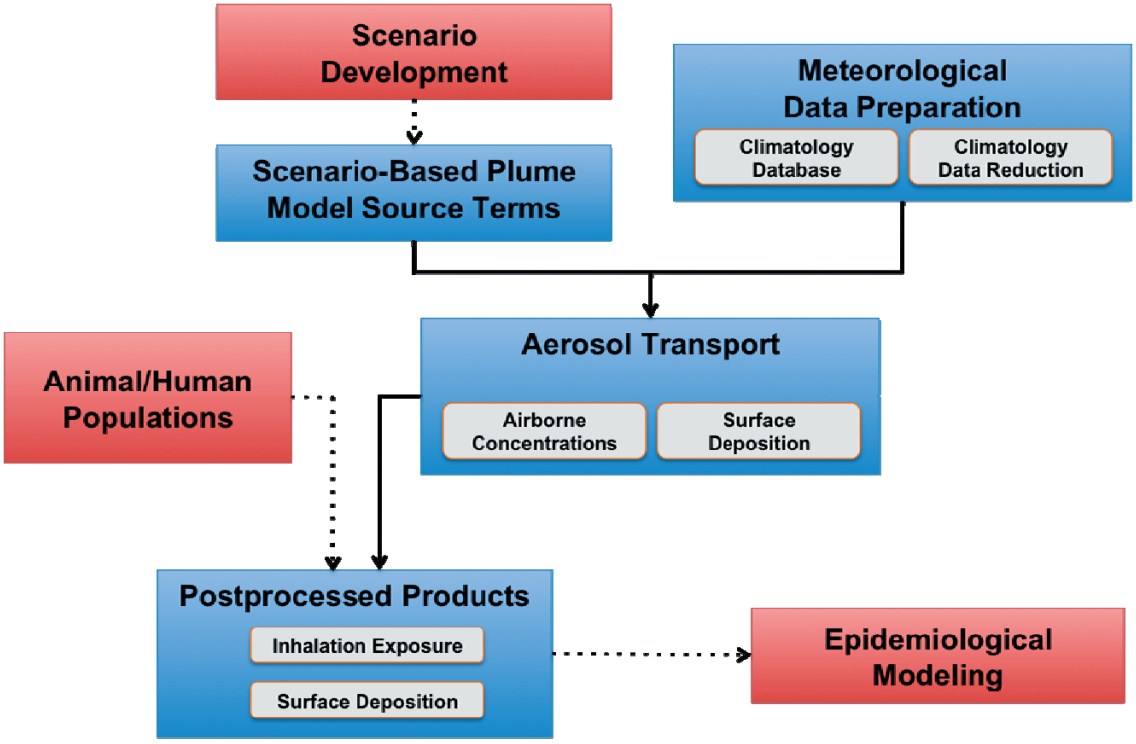

Figure 1. Aerosol Fate and Transport Work Flow

2.0 Technical Approach

2.1 Site Specific Meteorological Data Preparation

An analysis of the meteorological conditions, prevalent in the Manhattan, Kansas region, was performed using an existing climatological database, specifically developed to support aerosol transport modeling and simulation. The database provides hourly estimates of various meteorological parameters, including winds, temperature, and relative humidity. From this dataset, a subset of characteristic meteorological conditions, that most strongly impact aerosol decay and transport processes, were extracted and assigned representative frequencies of occurrence. Further details on this methodology are discussed below.

2.1.1 Climatological Database

The climatological database, used for this study, was originally developed by the National Center for Atmospheric Research (NCAR) to support aerosol transport modeling for the Department of Defense (DoD) Joint Effects Modeling (JEM) system and the Defense Threat Reduction Agency (DTRA) Hazard Prediction and Assessment Capability (HPAC). The database contains hourly, three-dimensional, analyses of all standard meteorological variables over a 21-year period (1985 – 2005) on a global 40-km horizontal grid that extends from the surface up to a height of approximately 60,000 feet (Rife et al., 2010).

This particular dataset was chosen over other existing historical datasets for a variety of reasons, including:

- Higher spatial resolution (40-km grid spacing) as compared to other available global climatology products (typically 50 to 250-km grid spacing). This allows for smaller scale meteorological spatial features to be resolved.
- Higher temporal resolution (hourly output) than other climatology products (output every 6 to 12 hours). This allows for the diurnal cycle to be fully resolved.
- More representative of regional and spatially variable weather conditions than those derived from a single meteorological observing site (e.g. Manhattan Regional Airport, KMHK).
- Specifically developed and subsequently validated to support boundary layer aerosol transport and dispersion modeling applications.

As noted in the last bullet point, above, the ability of this dataset to represent the mean and statistical behavior of the atmosphere, particularly within the planetary boundary layer, has been validated, utilizing a variety of observation datasets, which were not used to derive the original database. Of particular interest to this study, the dataset has been validated against observations from the National Oceanic and Atmospheric Administration (NOAA) Profiler Network (NPN), located in the central United States, to evaluate its ability to recreate the observed characteristics of the Great Plains Nocturnal Low Level Jet (NLLJ) (Rife et al., 2010). Additionally, the dataset's ability to replicate the observed spatial

patterns of rainfall (particularly the diurnal cycle of rainfall) has also been verified by Monahan et al., 2010. Both of these processes (boundary layer winds and moisture) are essential drivers for the aerosol transport/dispersion, deposition, and decay of both FMDv and RVFv.

In addition to the above database validation exercises, an SSRA specific validation of the database was performed for Manhattan, Kansas. In particular, wind velocity statistics (wind roses) from the Manhattan Regional Airport (KMHK) Automated Surface Observing System (ASOS) station (NCDC 2010), were compared to coincident wind velocity statistics derived from the NCAR database (Figure 2a and Figure 2b). For this comparison, only data from years 2000 – 2005, were used for this analysis. This choice was due to several factors, including:

- The KMHK ASOS site location has changed several times over the course of the full historical record, but remained stable over the 2000-2005 period.
- This period was considered long enough to extract a representative sample from each dataset for statistical comparisons.

The difference in total sample size (37,214 for KMHK and 50,520 for NCAR) can be attributed to either missing reports or observations that failed the National Climatic Data Center (NCDC) quality control (QC) processing. As shown in the summary statistics at the top of each figure, the NCAR database wind speed statistics compare favorably against those derived from KMHK (mean wind speed of 4m/s, with a standard deviation of 2m/s), although a wind direction bias of approximately 20° is apparent in the NCAR database (205° versus 182°). This directional bias is also apparent when analyzing the wind rose results. As illustrated in Figure 2a, the KMHK predominant wind direction is from the South (S, 180°) (~ 17% Frequency of Occurrence, FoC) followed closely by a South-South-West (SSW, 202.5^{o}) wind direction (~ 15% FoC), with average wind speeds of 6 and 5 m/s, respectively. A similar analysis of the NCAR database (Figure 2b) shows a predominant wind direction from the SSW (~ 17% FoC), with an average wind speed of 5 m/s. Although minor differences do exist, these differences are to be expected, and are likely due in large part to issues associated with comparing a single point observation location to a model reanalysis that represents the average value in that model grid cell.

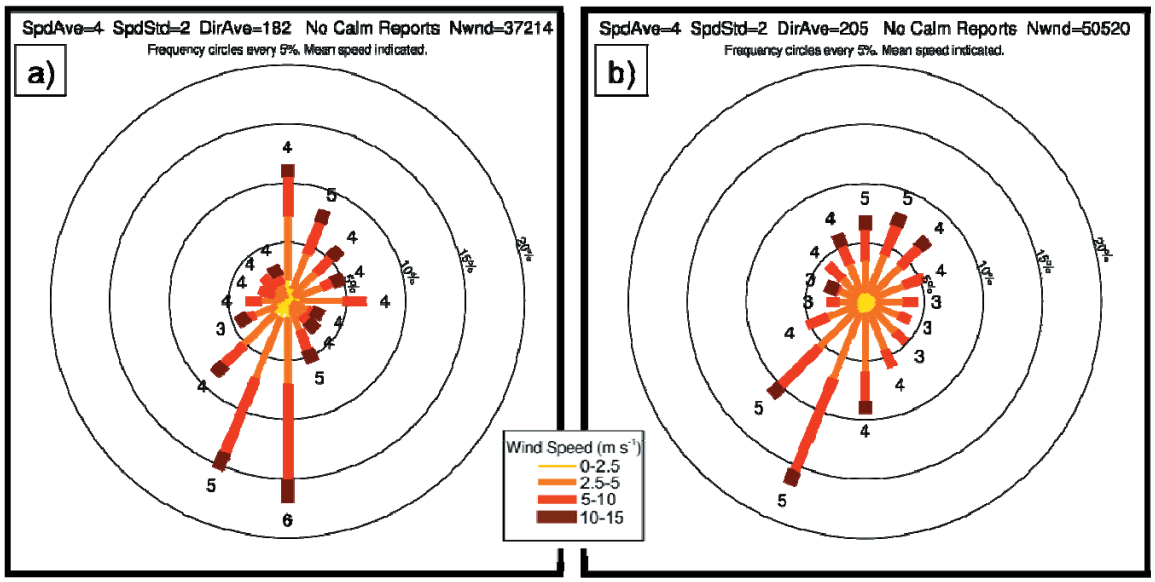

Figure 2. Wind roses for a) Manhattan Regional Airport (KMHK) and b) the NCAR gridded historical database.

Numbers at the end of each wind rose petal, represent the average wind speed (m/s) for that particular wind direction bin.

2.1.2 Climate Data Reduction and Frequency Analysis

2.1.2.1 Overview

Ideally, in order to accurately account for the effects of all possible meteorological conditions on the resulting aerosol transport, transport simulations would be performed for every hour, contained in the full 21-year database, or approximately 183,960 simulations (21-years x ~365-days/year x 24-hours/day) per release scenario and pathogen. Although comprehensive, this technique is computationally expensive, as noted by the large number of simulations. When combined with the fact that transport simulations were required for two separate pathogens and up to 6 release scenarios, the number of required simulations quickly grows to over 2 million, which is infeasible to complete in a reasonable timeframe. Additionally, this technique is wasteful, when one realizes that meteorological conditions or patterns tend to repeat themselves over the course of the 21-year database record. Therefore, to reduce the computational burden and associated waste, the original 21-year hourly database was decomposed into a smaller set of representative meteorological conditions using a feature extraction and classification technique know as the Self Organizing Map (SOM) (Kohonen, 1982, 1998). The SOM is an artificial neural network technique, which uses an unsupervised iterative learning technique to group large amounts of data into smaller set of clusters or “nodes”, with similar characteristics. These nodes are then organized into the final map or SOM. The SOM technique has been widely used in a variety of scientific disciplines (Joutsiniemi et al 1995, Palakal et al. 1995, Chen and Gasteiger 1997, Kaski et al. 1998) and, more recently, has gained wider use within the synoptic climatology community (Hewitson and Crane 2002, Cassano et al. 2006, Schuenemann et al. 2009). In particular, SOMs were utilized by Cassano et al (2006) to analyze arctic circulation patterns, from an ensemble of global circulation model predictions, while Schuenemann et al (2009) used the SOM technique to identify Sea Level Pressure

(SLP) patterns over Greenland from the 40-year European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA-40 database). Liu et al. (2006) performed an extensive evaluation of the SOM technique's ability to extract features from known patterns and provided a list of recommended SOM configurations, when developing a SOM.

2.1.2.2 Methodology

For the NBAF SSRA, the SOM analysis was performed using the freely available SOM-PAK software package (Kohonen et al. 1996). The details of the SOM configuration are summarized in Table 1 below.

Table 1. NBAF SSRA SOM Configuration

SOM Configuration Option	NBAF SSRA SOM Configuration Choice
Map Lattice Structure	Hexagonal (10x20)
Map Node Size	200
Initialization Method	Evenly distributed random values
Neighborhood Function	Bubble
Neighborhood Radius (1st and 2nd Stages)	10, 3
Training Weight (1st and 2nd Stages)	0.5, 0.03
Training Iterations (1st and 2nd Stages)	1000, 10000

As shown, a 10x20 hexagonal lattice of nodes was used to construct the NBAF SSRA SOM. A hexagonal lattice was chosen over a rectangular lattice structure for several reasons.

- It provides more neighbors within a given radius of a node, which can potentially strengthen the relationship between adjoining nodes.
- The overall rectangular shape of the mapping, 10 in the x direction 20 in the y direction, helps to ensure the stability of the learning process.

The map size of two hundred was chosen because it is the nexus between a manageable number of meteorological scenarios, in terms of aerosol transport simulation computational expense, and a sufficient oversampling of meteorological patterns contained in the historical record.

Several methods were available to initialize the SOM nodes, including:

- Randomly selecting data vectors from the whole data set.
- The selection of random values that are evenly distributed through the input data set.

- A more mathematically rigorous method, which ensures that the nodes span the sub-space defined by the two main eigenvectors of the input data set.

The second initialization method, listed above, was chosen based on the fact that it is more computationally efficient than the eigenvector method and because the final result is insensitive to choice of initialization method.

Each SOM node was initialized randomly from a sample in the training data, which consists of 21 years of 24-hour periods of output for a 1000 x 1000 km domain (Figure 3) centered over Manhattan, KS. The choice of domain size was based on initial estimates of the maximum plausible downwind distance for an infective dose of FMDv. Based on the work of Sorensen (2003), and some conservative dispersion calculations (not shown), the maximum downwind distance for an infective dose of FMDv was estimated to be approximately 250 km. In order to add another layer of conservatism and be sure that the SOM domain was sufficiently large to cover a large scale FMDv release, the estimate was doubled and set equal to 500km, thereby defining the 1000 x 100 km domain shown.

The data vectors used to initialize and train the SOM were composed of 2-dimensional arrays of meteorological variables that most strongly impact the aerosol transport, dispersion, and decay of FMDv and RVFv (Table 2). As shown, the variables chosen included boundary layer winds (U_{10m}, V_{10m}, U_{850mb}, V_{850mb}), relative humidity (RH_{2m}), and surface sensible heat flux ($SH_{surface}$).

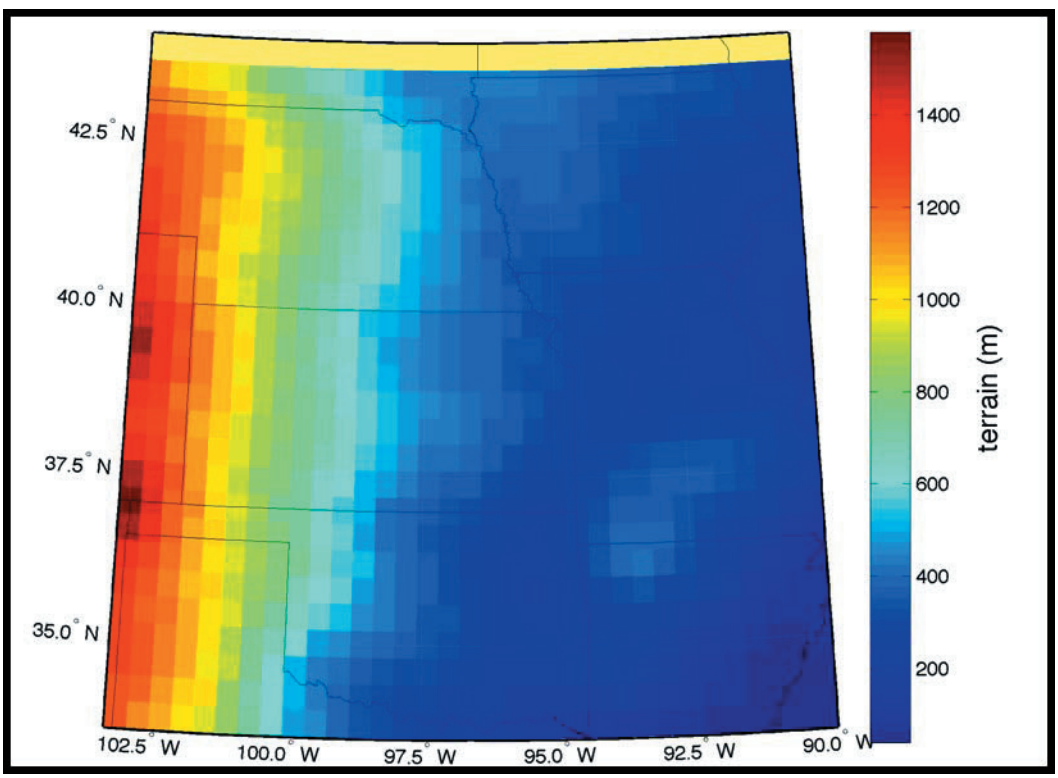

Figure 3. NCAR Climatological Database spatial domain used in NBAF SSRA SOM analysis. Also shown is the NCAR database terrain elevation, for the specified domain (color filled contours).

Table 2. NCAR Database meteorological variables, used to initialize the NBAF SSRA SOM.	
SOM Meteorological Variable ID	**SOM Meteorological Variable Description**
U_{10m}	U component of the wind at 10 meters Above Ground Level (AGL)
V_{10m}	V component of the wind at 10 meters AGL
U_{850mb}	U component of the wind at 850 millibar (mb) pressure level
V_{850mb}	V component of the wind at 850 millibar (mb) pressure level
RH_{2m}	Relative Humidity at 2 meters AGL
$SH_{surface}$	Sensible Heat Flux at the surface

In order to maintain equal weighting during the training of the SOM, the meteorological variables, above, were each normalized to have zero mean and unit standard deviation. The SOM was trained by taking each 24-hour period of data from the training data set and finding which SOM node it best matches. Each input vector was presented to the SOM and the best Matching Unit (BMU) was determined by finding the smallest Euclidian distance between the input vector and each map node. The BMU and its neighboring nodes were adjusted by the weighted difference between the node and the input vector. For this study, a “bubble” neighborhood function was used, which weights all neighboring nodes, within the neighborhood radius, equally.

The training process was repeated for each input vector in the data set. After cycling through the data set, the neighborhood radius and training weight were recomputed and the process repeated. For the NBAF SSRA SOM analysis, the training was conducted in two stages. The first stage was a coarse training of the SOM for 1000 iterations using an initial neighborhood radius of 10 units and an initial training weight of 0.05. The second refining stage of SOM training was for 10,000 iterations using an initial neighborhood radius of 3 units and an initial training weight of 0.03.

After the SOM was successfully trained, the original meteorological input data were presented to the map a final time to determine node membership for each meteorological input vector. This was used to determine the frequency of occurrence of each SOM node. The best match between the training samples and the SOM patterns was then used to define a typical day (24-hour period) for each pattern, which was defined as the input vector with the closest Euclidian distance to the SOM node vector. It was this typical 24-hour period that was then used to drive the resulting aerosol transport simulations, associated with each SOM pattern.

2.1.2.3. Results

Figure 4 - Figure 12 summarize the results of the NBAF SSRA SOM analysis. The 10x20 SOM lattice node identifiers, their associated frequency of occurrence, and typical day date/times are shown in Figure 6. As shown, the node frequencies range from a maximum of ~ 1.7 % for Node 0 (July 7, 1999 0200 UTC) to a minimum of ~ 0.1 % for Node 112 (September 20, 2001 2000 UTC).

0	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18	19
20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47	48	49
50	51	52	53	54	55	56	57	58	59
60	61	62	63	64	65	66	67	68	69
70	71	72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87	88	89
90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109
110	111	112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127	128	129
130	131	132	133	134	135	136	137	138	139
140	141	142	143	144	145	146	147	148	149
150	151	152	153	154	155	156	157	158	159
160	161	162	163	164	165	166	167	168	169
170	171	172	173	174	175	176	177	178	179
180	181	182	183	184	185	186	187	188	189
190	191	192	193	194	195	196	197	198	199

Figure 4. 10x20 NBAF SSRA SOM Lattice Node Identifiers.

7/7/95 2:00	7/7/99 3:00	7/23/93 4:00	8/24/90 5:00	7/23/99 6:00	7/28/90 6:00	10/24/98 6:00	10/15/93 6:00	12/28/04 2:00	12/18/92 14:00
8/22/93 3:00	8/22/90 4:00	8/21/85 5:00	8/24/90 6:00	7/27/90 7:00	8/18/90 7:00	10/15/93 8:00	12/11/90 7:00	12/27/04 23:00	12/2/94 13:00
8/30/08 2:00	9/2/94 4:00	8/22/90 6:00	8/21/85 7:00	8/24/90 8:00	7/27/90 9:00	8/18/90 10:00	12/29/95 11:00	12/7/99 14:00	12/2/94 14:00
12/1/97 2:00	12/1/97 6:00	8/22/90 8:00	8/7/93 9:00	8/24/90 10:00	7/27/90 11:00	8/9/93 12:00	11/27/98 14:00	10/24/98 15:00	8/15/87 16:00
11/12/04 2:00	11/12/04 7:00	9/17/98 9:00	8/31/02 9:00	8/7/93 11:00	8/24/90 12:00	10/25/98 13:00	8/9/93 14:00	8/18/90 16:00	10/24/98 17:00
10/30/85 16:00	12/27/91 10:00	8/16/89 10:00	8/22/90 11:00	8/7/93 13:00	8/7/93 14:00	10/25/98 15:00	7/27/90 16:00	7/27/90 18:00	8/24/90 18:00
12/28/94 17:00	10/5/89 14:00	8/24/89 11:00	8/31/97 11:00	2/8/95 13:00	12/15/94 15:00	10/21/85 16:00	10/25/98 18:00	8/28/90 19:00	8/24/90 19:00
9/22/98 17:00	9/6/93 15:00	9/29/90 11:00	2/8/05 8:00	1/5/98 11:00	11/24/85 14:00	8/31/92 18:00	8/20/85 20:00	8/23/90 20:00	8/24/90 20:00
7/6/99 17:00	7/6/99 15:00	9/29/90 13:00	10/13/85 11:00	11/13/85 9:00	11/13/85 1:00	1/6/93 21:00	9/13/97 22:00	8/23/90 21:00	8/24/90 21:00
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8/2/92 17:00	7/29/90 17:00	10/13/85 18:00	12/16/92 16:00	12/7/85 23:00	10/13/85 1:00	9/17/01 0:00	7/27/90 23:00	8/25/90 1:00	10/24/98 0:00
7/2/85 17:00	8/30/87 18:00	9/20/01 20:00	8/27/04 22:00	9/8/97 0:00	7/16/95 0:00	8/19/93 0:00	7/23/99 0:00	11/27/98 1:00	11/26/98 23:00
7/21/94 17:00	7/21/94 18:00	8/7/86 19:00	9/12/95 21:00	9/12/95 23:00	7/29/90 0:00	7/16/95 1:00	7/23/99 1:00	11/27/98 2:00	12/8/90 23:00
2/6/00 17:00	2/6/00 18:00	10/6/98 21:00	10/6/98 23:00	7/22/94 0:00	9/13/95 2:00	7/16/95 3:00	8/5/85 3:00	11/26/98 6:00	10/19/94 10:00
11/29/88 15:00	11/29/88 17:00	2/6/00 20:00	10/14/86 23:00	10/15/86 1:00	10/7/98 3:00	7/22/94 3:00	6/23/92 4:00	7/21/94 5:00	11/29/94 7:00
1/23/85 18:00	12/28/85 20:00	12/29/01 22:00	11/11/02 1:00	10/15/86 4:00	10/7/98 4:00	7/22/94 5:00	10/19/99 6:00	12/20/93 7:00	12/24/01 9:00
1/23/85 13:00	1/21/90 17:00	12/29/01 19:00	12/5/97 23:00	11/5/92 5:00	9/22/87 5:00	7/22/94 6:00	10/7/98 6:00	12/22/93 6:00	12/17/88 6:00
12/16/94 19:00	12/18/93 10:00	12/16/87 8:00	10/7/98 9:00	7/22/94 8:00	7/5/85 9:00	9/21/87 9:00	10/15/86 8:00	12/22/93 10:00	12/17/88 9:00
1/22/85 20:00	12/18/93 16:00	11/27/00 11:00	12/28/88 10:00	10/7/98 10:00	7/22/94 9:00	7/5/85 10:00	8/24/85 11:00	12/23/03 12:00	12/24/01 15:00
1/22/85 10:00	1/29/98 14:00	1/29/98 11:00	10/7/98 11:00	7/22/94 11:00	7/5/85 11:00	9/21/87 12:00	9/21/87 13:00	12/23/03 14:00	12/23/03 16:00

Figure 5. NBAF SSRA SOM Lattice Typical Day Date/Times (UTC)

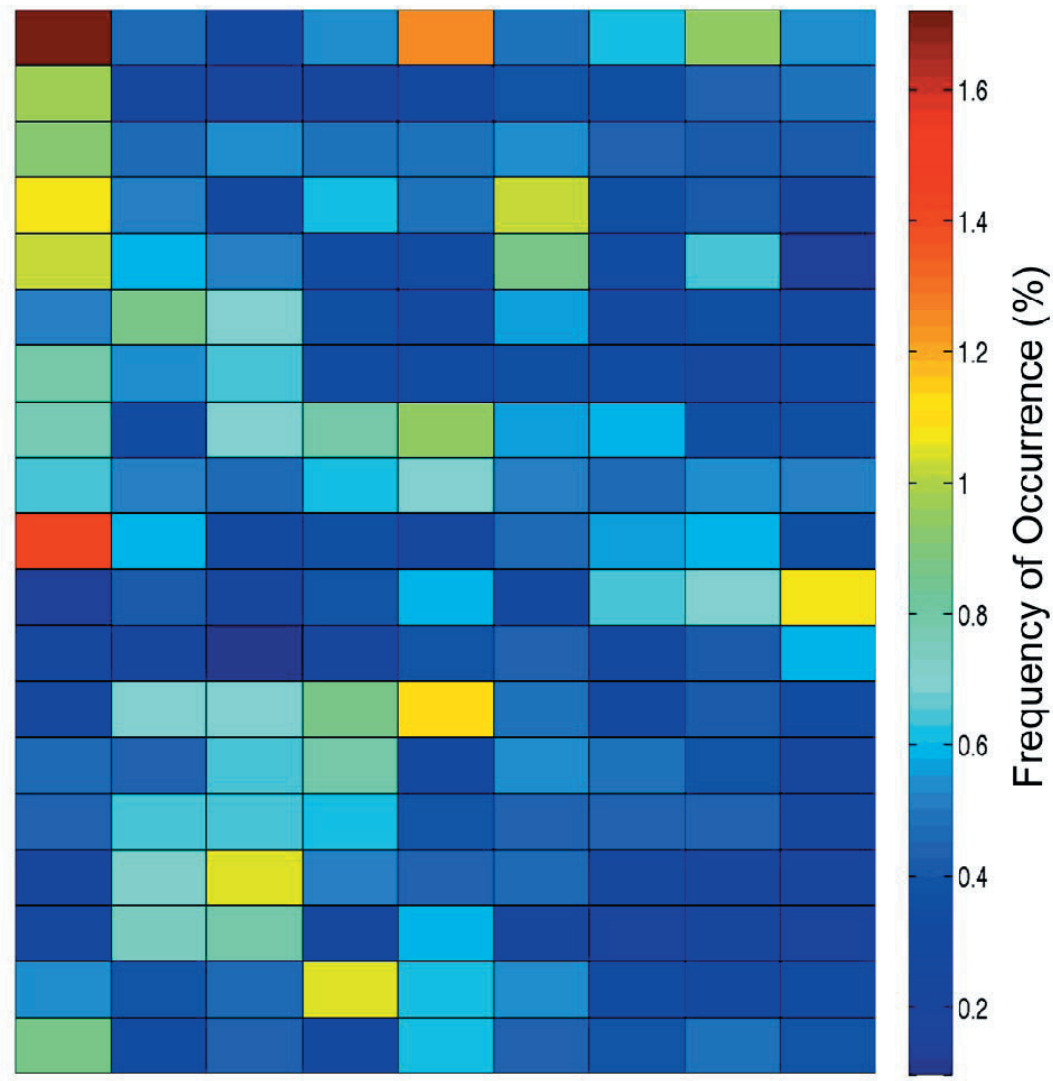

Figure 6. NBAF SSRA SOM Lattice Node Frequencies of Occurrence (%).

The resulting SOM 24-hour average values, for each meteorological variable contained in Table 2 (except the 850mb winds), are illustrated in Figure 7 -9. While the details in the lattice map images are difficult to see for any individual node, the images illustrates the wide range of patterns associated with each variable, and how similar patterns tend to localize in various areas of the map. For example, in Figure 7, the 10 meter wind speed lattice shows separate areas of higher and lower wind speed (represented by different colors) generally clustered at the bottom and top of the SOM lattice, respectively. Similarly, for relative humidity (Figure 8) and surface heat flux (Figure 9), higher humidity values (lower heat flux values) are clustered in the center of the lattice, while lower humidities (higher heat flux values) are clustered at the bottom of the map.

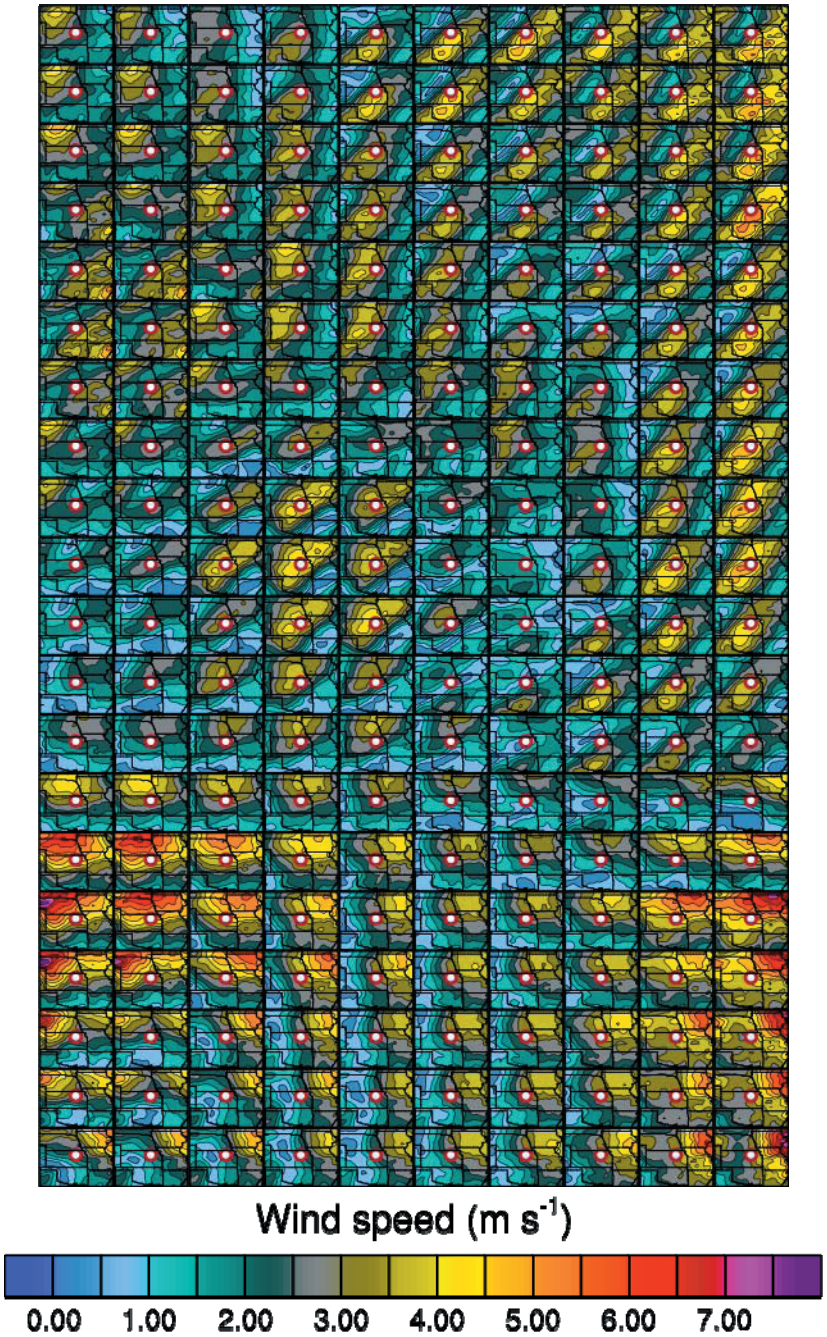

Figure 7. 10-meter 24-hour average wind speed (m/s) SOM matrix. The red circle designates the location of Manhattan, Kansas.

Each square panel represents the 1000 x 1000 km spatial domain shown in Figure 3

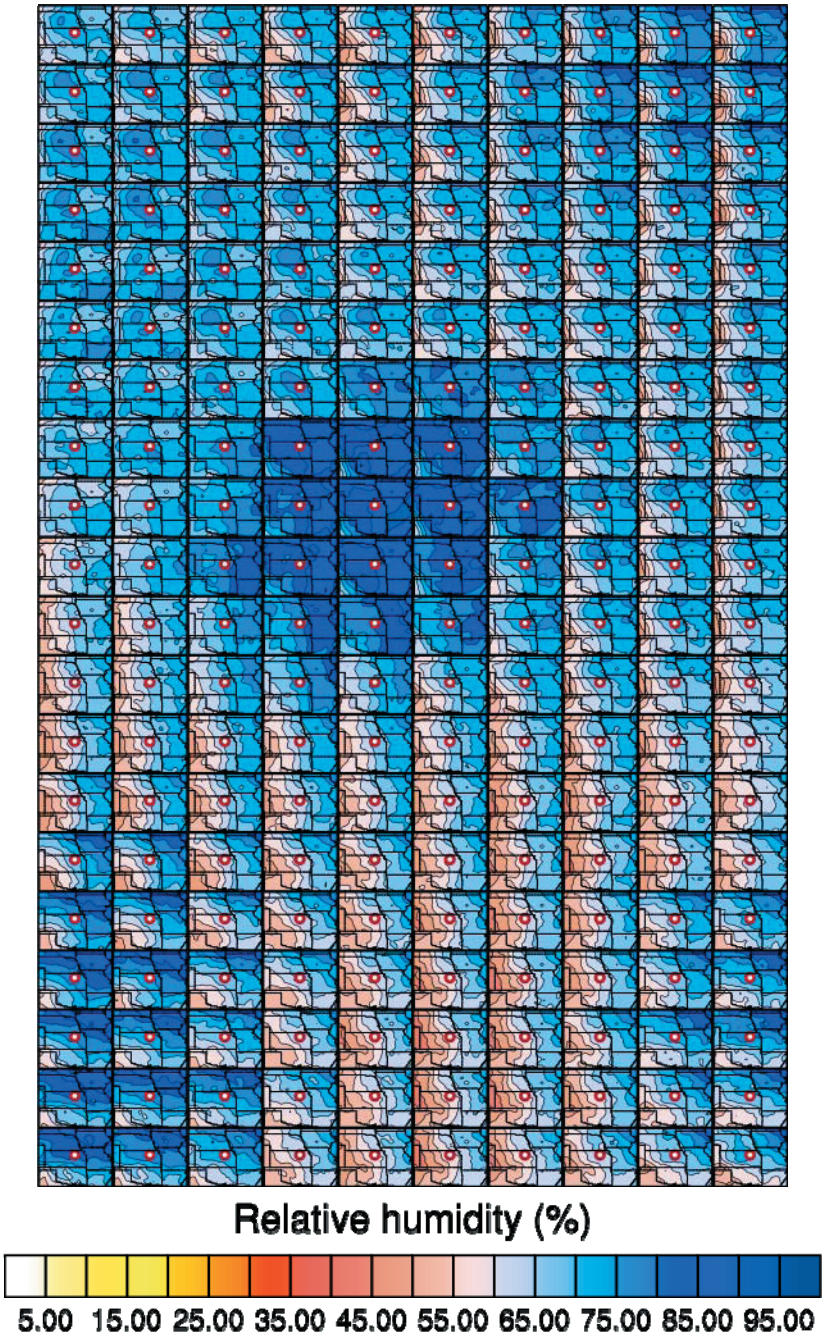

Figure 8. As in Figure 7. 2-meter Relative Humidity (%).

Each square panel represents the 1000 x 1000 km spatial domain shown in Figure 3

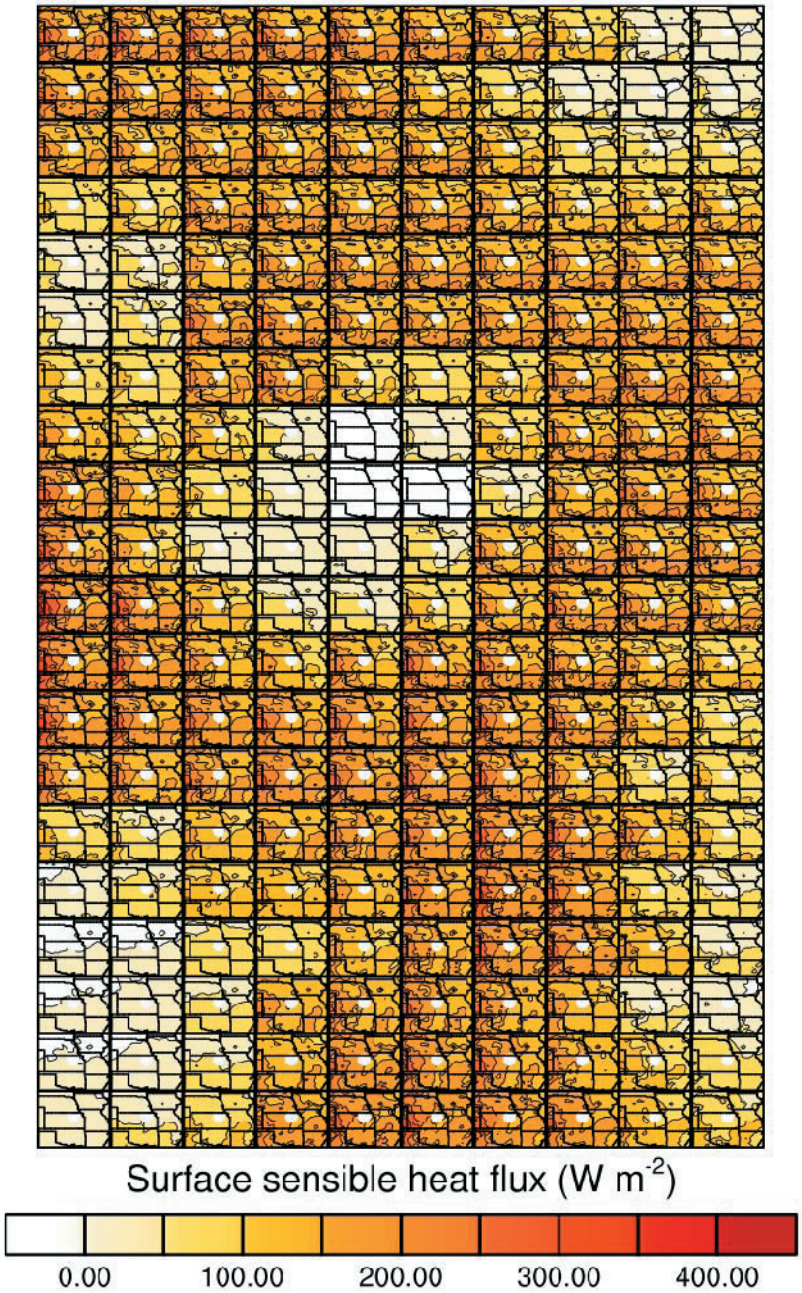

Figure 9. As in Figure 7, surface sensible heat flux (W/m²)

Each square panel represents the 1000 x 1000 km spatial domain shown in Figure 3

In addition to reviewing the 24-hour average values of each SOM node, it is also illustrative to review the 24-hour evolution of each variable, for a particular SOM node of interest.

Figure 10 - Figure 12 illustrate the time evolution of these variables for the most frequently occurring SOM pattern, Node 0. As shown in Figure 10, the 10-meter winds over the Manhattan, Kansas region (denoted by the white circle) slowly increase from ~ 2 m/s out of the East at the beginning of the 24-hour period (0200 UTC, 2000 Local) to ~ 3 m/s out of the South-East at the end of the period (2400 UTC, 1800 Local), with the approach of a wind speed maximum (~ 5m/s) out of the northwest. Similarly,

relative humidity (Figure 11) and surface sensible heat (Figure 12) levels vary over the period, with humidity and heat flux levels reaching peak values (95% and 200 W/m^2) at 1000 (0400 Local) and 1800 UTC (1200 Local), respectively. Based on these conditions, one can anticipate that an aerosol release of FMDv, would remain very stable during the first 16-hours of transport, due to the high humidity levels, while being transported to the west and northwest, at a speed of ~ 2.5 m/s (~ 5.6 mph). Conversely, RVFv, released into this same environment, would quickly decay due to the high relative humidity conditions, before being transported an appreciable downwind distance.

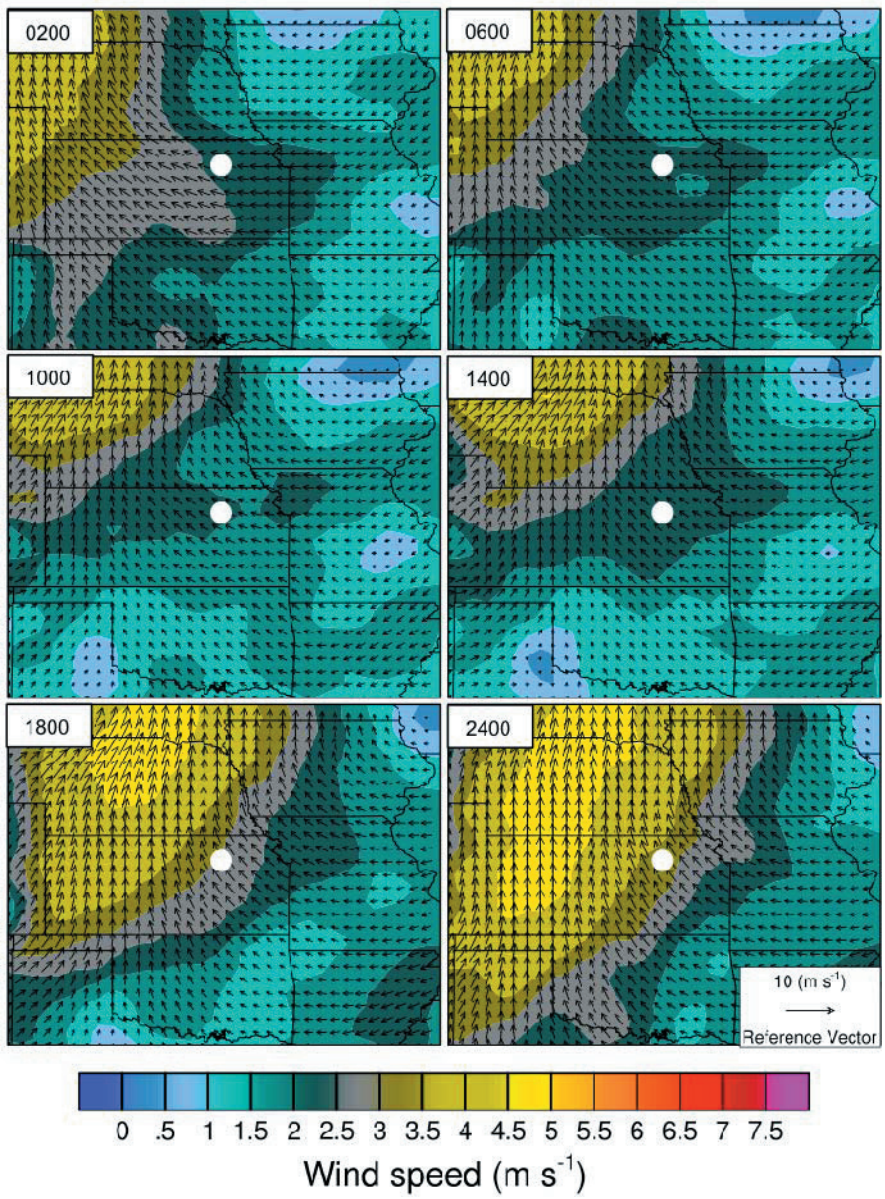

Figure 10. 24-hour evolution of 10-meter winds for SOM Node 0 (July 7, 1999)

Valid UTC time is listed in the top left corner of each panel (Local Time = UTC Time – 6 hours). The white circle designates the location of Manhattan, Kansas. Each square panel represents the 1000 x 1000 km spatial domain shown in Figure 3

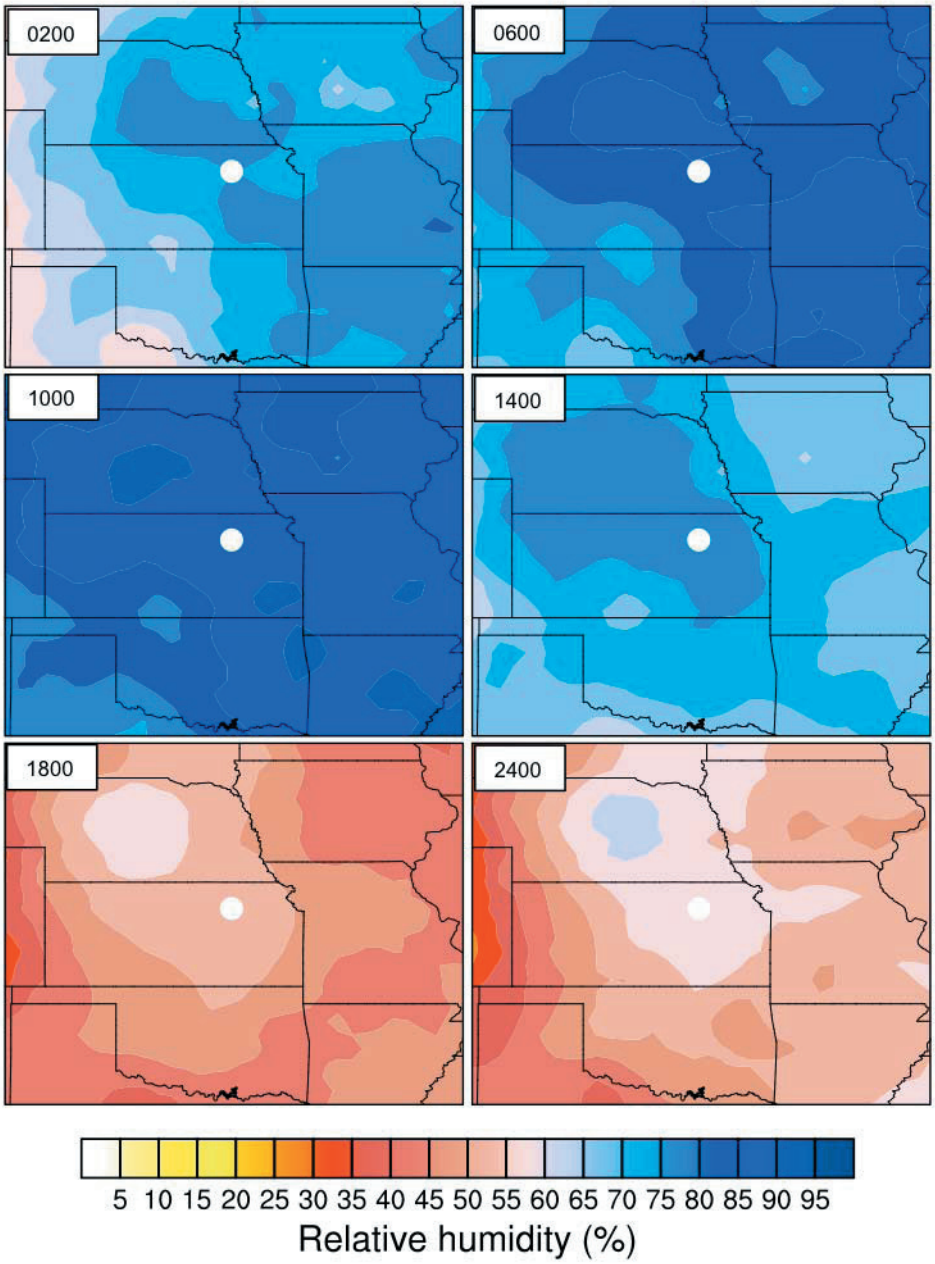

Figure 11. As in Figure 10, 2-meter Relative Humidity (%)

Each square panel represents the 1000 x 1000 km spatial domain shown in Figure 3

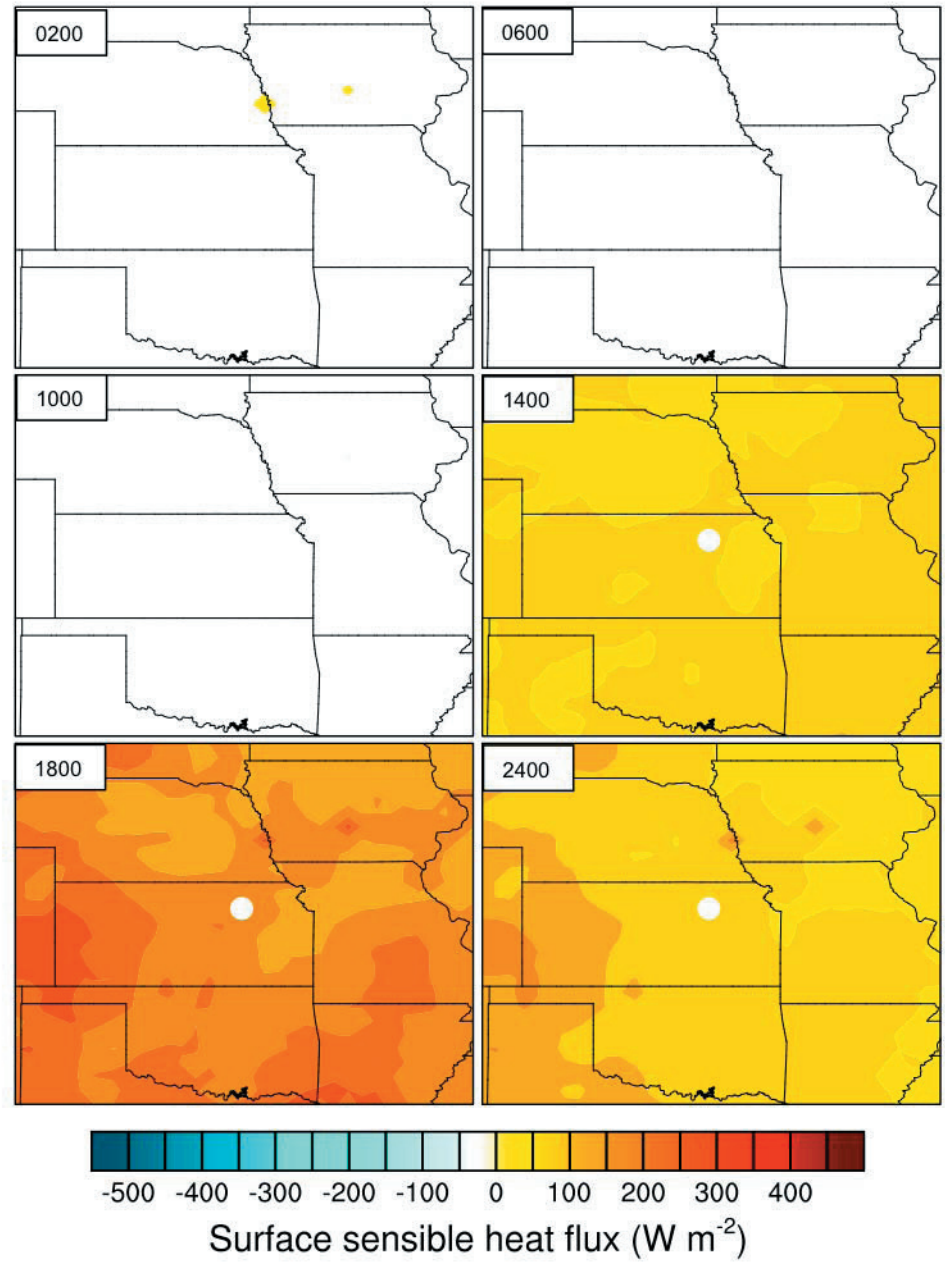

Figure 12. As in Figure 10, surface sensible heat flux (W/m²)

Each square panel represents the 1000 x 1000 km spatial domain shown in Figure 3

2.1.3. Scenario Specific Climate Data Classification

As noted above, the original NBAF SSRA SOM analysis was performed against the full 21-year historical record, contained in the NCAR climatological database. The results of this analysis represent conditions covering a wide spectrum of atmospheric phenomenon. For release scenarios that are likely to occur at any time of the day, and under any type of atmospheric condition, these patterns can be used to drive the resulting aerosol transport, dispersion, and decay. For scenarios that involve releases, which are

likely to occur at specific times or under specific conditions, the original 200 meteorological patterns must be further reduced, based on these additional criteria.

The scenario specific criteria, summarized in Table 3, included time of release, wind speed, and conditions associated with tornado events. For each release scenario, the likely time of release could either occur during work hours (0700-1800 Local) or occur at anytime over the course of a 24-hour day. In addition to the time of release, release scenarios 7 (High Winds) and 11 (Tornado) required additional climate classification, since these events represented very specific meteorological conditions. The high wind speed criteria constituted conditions with winds greater than 70 knots (~81 mph), while tornadic conditions represented larger scale weather patterns, which occurred during recorded tornadic events. The tornado and high wind analysis are further detailed in the following sections.

For each release scenario/event pathway, the combination of these three criteria dictated which matrix of meteorological conditions was to be used for the subsequent aerosol fate and transport calculations. As noted, the final meteorological pattern matrices were reduced from 200 to 153, 73, and 72 for the work hours, high wind, and tornado criterion, respectively.

Table 3. Meteorological Condition Matrix Criteria

Time of Release	Wind Speed	Tornado	Met Matrix	Met Patterns
Anytime	All	NA	allHours	200
0700-1800	All	NA	workHours	153
Anytime	> 70knots	NA	highWind	73
Anytime	All	Tornado Occurred	tornado	72

2.1.4. Tornado Analysis

Since 1994, there have been on average approximately 1250 confirmed tornadoes per year in the United States (US). Many of these tornados occur in the US central plains, including Kansas. During this same period, within approximately 120 nautical miles of Manhattan, KS, there was on average approximately 58 tornados per year, and as recently as June 11th, 2008 a tornado hit the Kansas State University campus in Manhattan. Due to the plausibility of a tornado impacting the proposed NBAF facility, and the corresponding possibility of subsequent pathogen containment loss, a detailed examination of the risks associated with this natural hazard was performed. In particularly, the climatological record was examined to characterize the frequencies that tornadoes occur in this region by intensity level. This information was then combined with information from peer-reviewed scientific literature to ascertain how often tornados occur as a function of their intensity so that a risk of pathogen containment loss could be estimated and used in the overall SSRA findings. Lastly, characteristic weather patterns, associated with these tornado events, were extracted from the SOM analysis (described previously) to determine the likely plume dispersion patterns from a tornado impact event.

2.1.4.1. F-Scale Based Tornado Frequency Analysis

Due to limited size and the relatively small area affected by any single tornado, its existence is one of the most difficult natural weather phenomena to document. The National Oceanic and Atmospheric Administration (NOAA) Storm Prediction Center (SPC) maintains an archive of all the reported tornados since January 1, 1950 [available online at: http://www.spc.noaa.gov/wcm/]. This data set represents the most reliable accounting of tornado events, and is the "official" record of confirmed tornados in the US. The archive contains information on the intensity, touchdown time, initial touchdown location, tornado path, injuries, fatalities, and numerous other factors related to the tornado event.

In spite of the extensive effort that has gone into the collection of the information contained in the tornado event database, numerous studies have characterized its shortcomings. Studies by (Galaway, 1977), (Kelly et al., 1978), (Tecson and Fujita, 1982), (Doswell and Burgess, 1988), and (Ray et al., 2003) have identified and documented significant biases in the temporal record. Between 1950 and 1992 the number of confirmed tornados increased from approximately 200 per year to over 1000 per year. This increase in the number of tornadoes is widely attributed to an increase in population, improved awareness of tornados by the public, and improved detection and identification of tornados following the deployment of weather radars. Spatial biases, associated with population, have also been identified to be present in this data set (Schaefer and Galaway, 1982; Grazulis and Abby, 1983). While clear evidence of a positive bias in tornado frequency associated with population is present in the SPC tornado data base, (McNulty et al., 1979), (Grazulis and Abby, 1983), (King, 1997), and (Ray et al., 2003), all note that population centers are not consistently associated with higher tornado frequency. In particular Ray et al. (2003) found that in the US central plains, National Weather Service (NWS) Offices and NWS weather radar sites exhibited a strong correlation with the number of confirmed tornados in the SPC data set. These findings indicate that some tornados in regions with low population density far from NWS facilities go un-reported, and that in general, the SPC tornado database under-represents the total number of tornados. In their study, the correlation between NWS facilities and the tornado reports was used to remove the apparent spatial bias, and improve the estimate of total tornado occurrence as a function of location. Their results indicate that the true total number of tornadoes is likely to be about 60% higher than the number of confirmed tornadoes that occurred between 1978 and 1992.

The NBAF SSRA leveraged the work of (Ray et al., 2003) described above to estimate the risk of pathogen containment loss associated with a tornado. Containment loss is likely to be associated with the intensity of the tornado and associated building damage. The risk of containment loss increases due to the increased likelihood of substantial damage to the facility, which is directly correlated with tornado intensity. The Fujita scale (F-Scale) is a widely-used community accepted tornado classification and damage definition metric (Table 4). The F-Scale was recently updated (January 2007) to the Enhanced Fujita Scale (EF-Scale). Since the majority of the database and reference materials use the original F-Scale, this study also used the F-Scale wind and damage definitions instead of the newer metric.

Table 4. F-Scale Description			
F-Scale	Highest 1/4-mile Wind Speed	3-Second Gust (mph)	Damage Description
F0	40-72 mph	45-78 mph	Minor damage
F1	73-112 mph	79-117 mph	Moderate damage
F2	113-157 mph	118-161 mph	Considerable damage
F3	158-207 mph	162-209 mph	Critical damage
F4	208-260 mph	210-261 mph	Severe damage
F5	261-318 mph	262-317 mph	Devastating damage

The original (Ray et al., 2003) study computed tornado climatologies for all tornados and did not attempt to correct the spatial biases for each of the F-Scale tornado intensities. Therefore, an additional analysis was performed, extending the original work, to account for tornado intensity levels. One of the challenges of characterizing tornado occurrence as a function of F-Scale is that in addition to the documented biases in the climatological record discussed above, the more intense tornados F3-F5 are extremely rare events. For example, during the entire period of record (59 years), over the entire continental US, there were only 496 F4 and F5 tornado events (Table 5). The relative rarity of these strong tornado events is also illustrated in Figure 13. Here the tracks of all the confirmed tornados between 1950 and 2009 are depicted over the central Great Plains region. As shown, black tracks represent F0-F1 tornados, blue tracks represent F2-F3 tornados, and the red tracks illustrate the F4-F5 tornado events. For reference purposes, the red dot represents the NBAF location. Because tornados are rare events, and this is particularly true for intense tornados, it is difficult to produce a statistically relevant occurrence frequency for the immediate vicinity of Manhattan, KS. This point is illustrated in Table 6, which contains a summary of the confirmed tornados that occurred within approximately 10 nautical miles (nmi) of Manhattan, KS, and in Figure 14, which depicts the paths of these tornados. As noted, over the entire 59-year record, there have been only 14 confirmed tornadoes of any intensity documented in this area.

Since the climatological record is not long enough to capture a statistically relevant number of tornadoes at all of the intensity levels in the immediate vicinity of the NBAF, it is necessary to identify an area (as large as possible) where the overall tornado occurrence statistics are relatively uniform and representative of tornado frequencies for Manhattan, KS. To accomplish this, the tornado occurrence statistics were examined in 1° longitude bands from west to east and 1° latitude bands from north to south, to identify regions of uniform tornado occurrence and/or trends in the SPC database (Figure 15 and Figure 16). The results illustrate that a region of higher tornado occurrence is present over southern Nebraska, most of Kansas and Oklahoma, and northern Texas between longitudes of 102° and 95° W and latitudes of 32° to 41° N. This area constitutes what is often referred to as a portion of “Tornado Alley”. The local maximums in tornado frequency at 98° west and at 32°, 35°, and 39° north roughly correspond with localized regions of higher population associated with the cities of Dallas - Ft. Worth, TX, Oklahoma City, OK, Kansas City, MO, and smaller towns along the transportation corridors of US interstate highways 20, 40, and 70. Outside of the 32° to 41° N latitude and 102° and 95° W longitude band, the number of tornados markedly decreases. Based on these findings, the area illustrated by the

dashed red box in Figure 13 was chosen, to provide tornado climatology statistics used in this study. Using an area of this size significantly increases the total number of tornados in each of the F-Scale categories and provides tornado occurrence statistics that are both statistically relevant and representative of the conditions that can be expected at the NBAF facility. Table 7 contains a listing of the tornado occurrences by F-Scale for the area illustrated in Figure 13

Table 5. US Total Confirmed Tornados (1950-2009)

F-Scale	Tornado Count	Percentage of Total
F0	23054	45.20 %
F1	17188	33.70 %
F2	8169	16.01 %
F3	2095	4.11 %
F4	454	0.89 %
F5	42	0.08 %

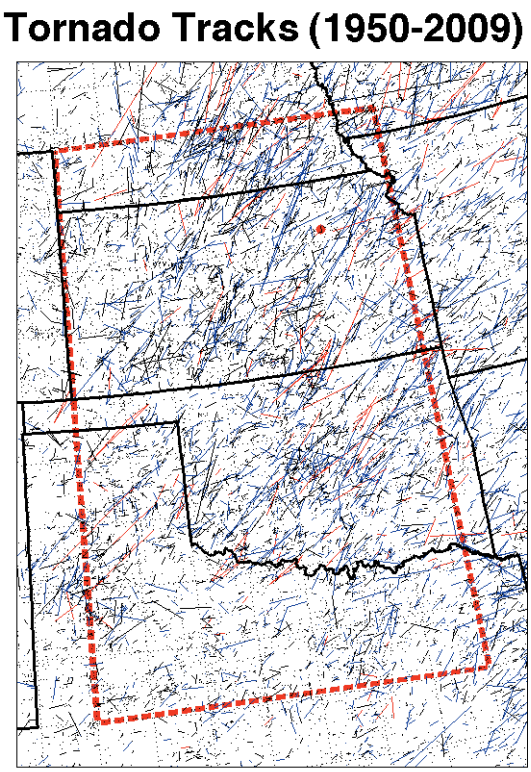

Figure 13. The tracks for all of the confirmed tornados from 1950-2009

Black is used to depict the F0-F1 intensity tornados, blue is used to depict the F2-F3 intensity tornados, and red is used to denote the F4-F5 intensity tornados. The red dot in north-eastern Kansas is the location of the NBAF in Manhattan, KS. The box denoted by the dashed red line is the region from which the tornado climatological statistics were determined.

Table 6. Confirmed Tornados Within 10 nmi of the NBAF (1950-2009)		
F-Scale	Tornado Count	Percentage of Total
F0	7	50.00 %
F1	5	35.71 %
F2	1	7.14 %
F3	0	0.00 %
F4	1	7.14 %
F5	0	0.00 %

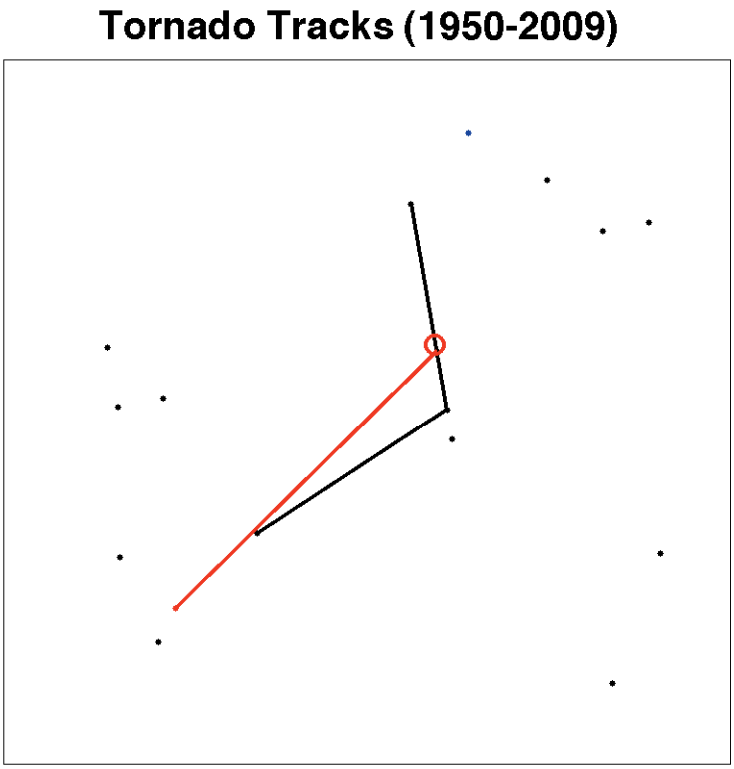

Figure 14. The touchdown location and/or tracks for all of the confirmed tornados from 1950-2009 within 10 nmi of the NBAF

Black is used to depict the F0-F1 intensity tornados, blue is used to depict the F2-F3 intensity tornados, and red is used to denote the F4-F5 intensity tornados. The red circle denotes the NBAF location.

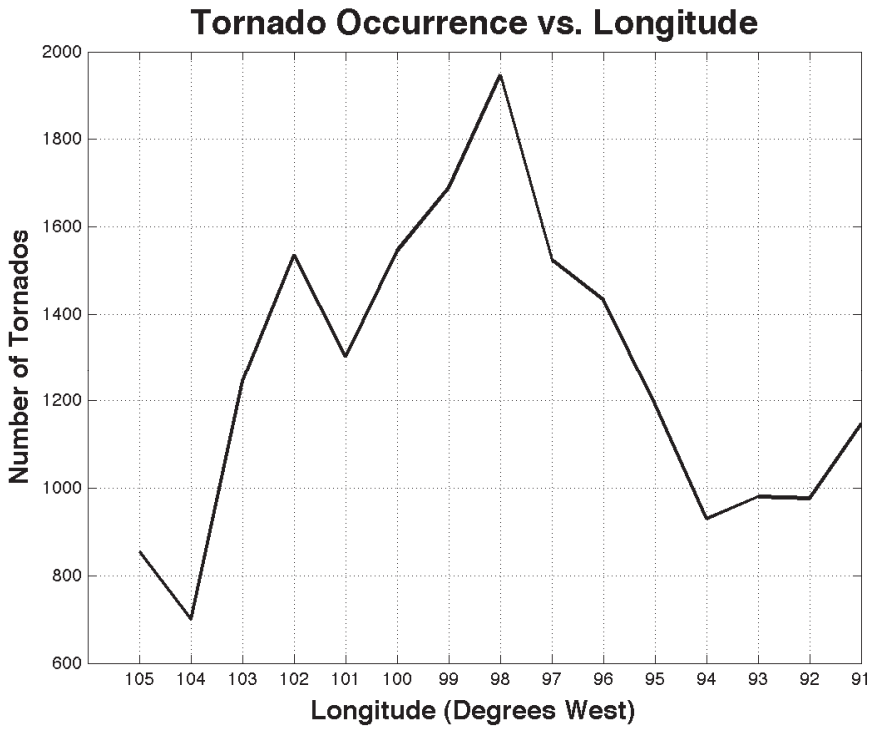

Figure 15. The number of tornados as a function of longitude inside a 1° longitude by 14° latitude region (29° to 43° N)

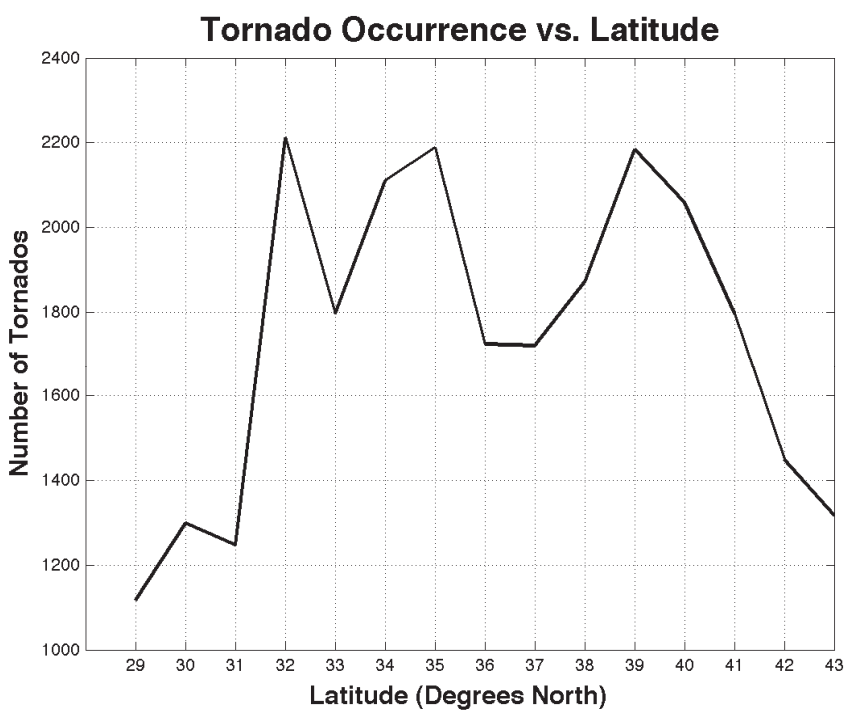

Figure 16. The number of tornados as a function of latitude inside a 1° latitude by 14° longitude region (105° to 91° W)

Table 7. Statistically Relevant Tornado Occurrences (1950-2009)		
F-Scale	Tornado Count	Percentage of Total
F0	5429	50.80 %
F1	2932	28.38 %
F2	1601	15.49 %
F3	453	4.38 %
F4	89	0.86 %
F5	9	0.09 %

Ray et al. (2003) found that the adjusted true number of tornados is about 60% higher than those reported between 1978 and 1992 in the SPC tornado occurrence record. In particular, over Manhattan, KS, it was found that the average number of tornados (for all F-Scale intensities) was 0.0625 tornados per year per 100 square kilometers (y^{-1} (100 $km^2)^{-1}$). Assuming that all locations inside the 100 km^2 are equally likely to be struck by the tornado, this corresponds to a return period of approximately 16 years. This original analysis was extended by computing the mean return period for tornados of a given intensity or higher. The mean return periods were determined by combining the probabilities of the tornado intensities with the adjusted probable number of tornados from (Ray et al., 2003), using the formulation of (Wilks, 2006) (Equation 1). Table 8 lists the results of this computation and provides the average return period for a given tornado F-Scale intensity or greater event. It is important to note that this measure does not guarantee that an event will occur within a particular return period. This measure is simply the average time between these events, assuming a very long sampling period (Wilks, 2006). It is these return periods, which were then used to characterize the corresponding pathogen containment loss risk associated with tornados across the full spectrum of tornado intensities.

Equation 1:

$$R(x) = \frac{1}{w\left[1 - F(x)\right]}$$

$$R(x) = \text{Mean Return Period}$$

$$w = \text{Annual Occurrence} \left({}^{1}\!/_{yr} \right)$$

$$F(x) = \text{Cumulative Probability}$$

Table 8. Statistically Relevant Tornado Occurrence and Average Return Period			
F-Scale	Tornado Count	Percentage of Total	Mean Return Period
F0 or Greater	5429	50.80 %	16 Years
F1 or Greater	2932	28.38 %	33 Years
F2 or Greater	1601	15.49 %	77 Years
F3 or Greater	453	4.38 %	300 Years
F4 or Greater	89	0.86 %	1687 Years
F5 or Greater	9	0.09 %	18370 Years

2.1.4.2 Tornado Meteorological Condition Mapping

It is well known that tornados preferentially form under certain atmospheric conditions. While we intuitively know that these conditions occur in the spring and early summer months, the corresponding atmospheric conditions that impact the subsequent transport and dispersion of any released pathogen are not necessarily intuitive. In order to determine the appropriate atmospheric conditions required to drive the aerosol transport analysis, the original SOM analysis was combined with the SPC derived tornado climatological record, to determine which SOM patterns were associated with documented tornado events (within approximately 100 nmi of Manhattan). Within the 100 nmi range, 763 confirmed tornadoes were identified in the climatological record, and provided an adequate number to diagnose clear patterns in the SOM weather pattern analysis. The SOM weather pattern for each tornado event was determined by matching each tornado event with the date and time from the SOM map node members. Figure 4 depicts a histogram of the number of times that a given event fell into a particular SOM node. This frequency distribution was then mapped to the same SOM node configuration for Manhattan, KS to characterize the series of SOM weather patterns that should be used to represent the dispersion patterns following a tornado impact on the facility (Figure 1.3.5). The results of this analysis indicated the specific SOM nodes, which represent the larger scale atmospheric conditions, prevalent during these documented tornadic events. It was these nodes, and their corresponding weather conditions, which were then used as inputs for the subsequent aerosol fate and transport calculations associated with the tornado release scenario event (Scenario 11).

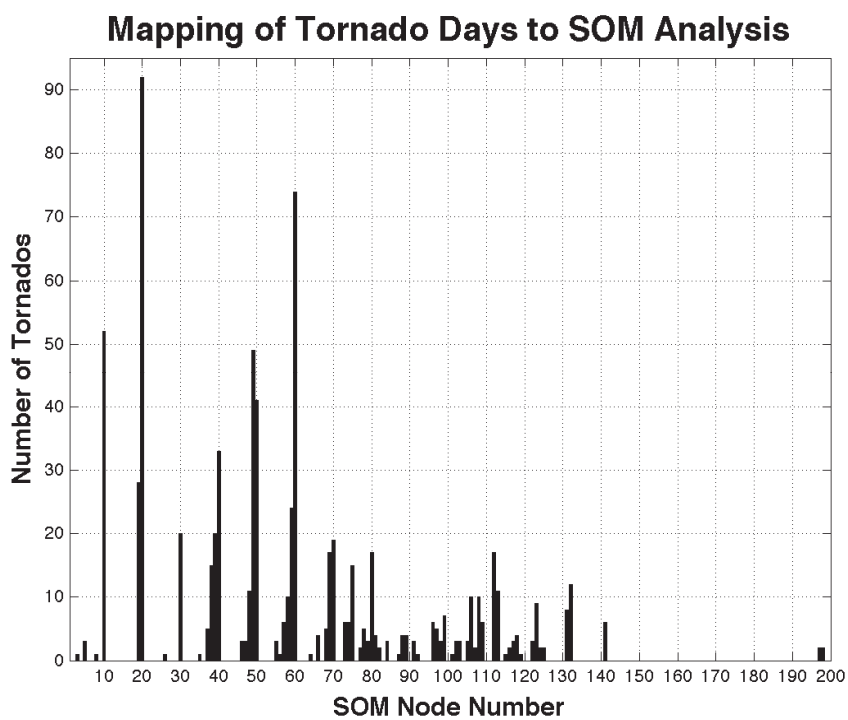

Figure 17. A frequency distribution depicting the number of tornado events that correspond to a given SOM weather pattern

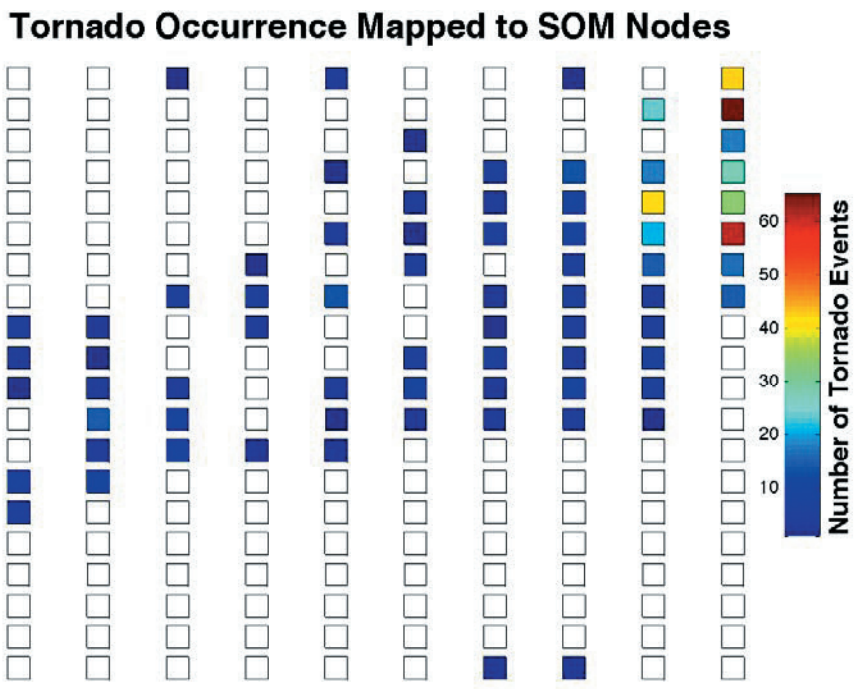

Figure 18. The tornado frequency distribution from Figure 17 mapped to the SOM "postage stamp-map"

2.1.5 High Wind Speed Analysis

In addition to tornado records, the NOAA SPC also maintains an archive of all hail and damaging wind reports, within the continental United States, recorded since January 1, 1950 [available online at: http://www.spc.noaa.gov/wcm/]. The archive contains information on the wind intensity, event date/time, and event location. Like tornados, high winds tend to be associated with severe thunderstorms, either from a short lived thunderstorm downburst or sustained straight line wind event, also known as a derecho, and therefore most commonly occur during the spring and early summer.

As defined in the NBAF SSRA high wind release scenario (Scenario 7), a high wind event is classified as any event having winds, which exceed 119 mph (~ 103 knots). These events are incredibly rare, as evidenced in the SPC database, with only 57 recorded events over the entire continental United States, and only 2 events ever recorded within the state of Kansas. Due to the rarity of these events, a lower high wind threshold was required to compile a larger event sample size from which occurrence statistics could be produced that are both statistically relevant and representative of the conditions that can be expected at the NBAF facility. Therefore, for the NBAF SSRA analysis, a high wind event was classified as any event with winds greater than 70 knots (~ 81 mph). The justification for choosing a threshold of 70 knots included the following:

1) The 70 knot threshold provided a sufficient number of events to be statistically relevant number of events.

2) The 70 knot threshold constitutes a severe wind event. Therefore the larger scale weather conditions associated with a 70 knot wind event will likely be the same conditions, which would result in 103 knot wind event.

2.1.6. High Wind Meteorological Condition Mapping

Using the high wind threshold of 70 knots, the number and dates of all high wind events, which occurred within a 100 nmi radius of Manhattan, was compiled. Within this range, 319 confirmed high wind events were identified in the climatological record and subsequently matched with the representative SOM weather pattern by matching the event with the date and time from the SOM map node members. The results of this analysis (Figures 19 and 20) identified the specific SOM nodes, which represent the larger scale atmospheric conditions, prevalent during these smaller scale high wind events. It was these nodes, and their corresponding weather conditions, which were then used as inputs for the subsequent aerosol fate and transport calculations associated with the high wind release scenario event (Scenario 7).

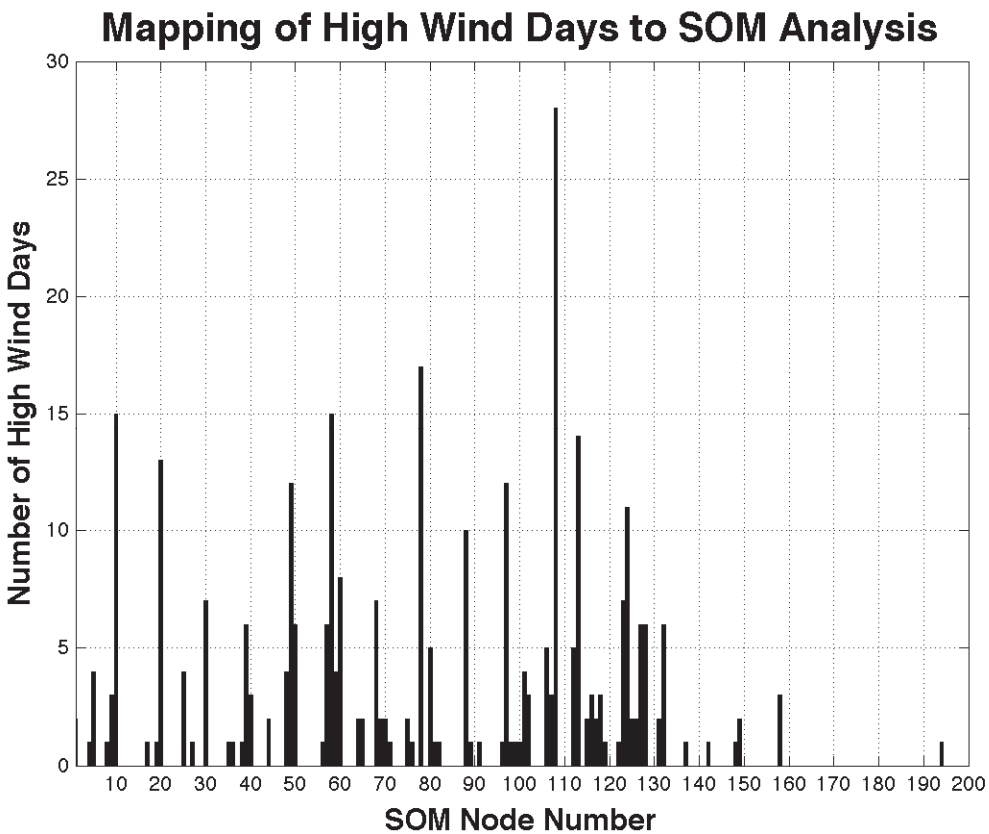

Figure 19. A frequency distribution depicting the number of high wind events that correspond to a given SOM weather pattern

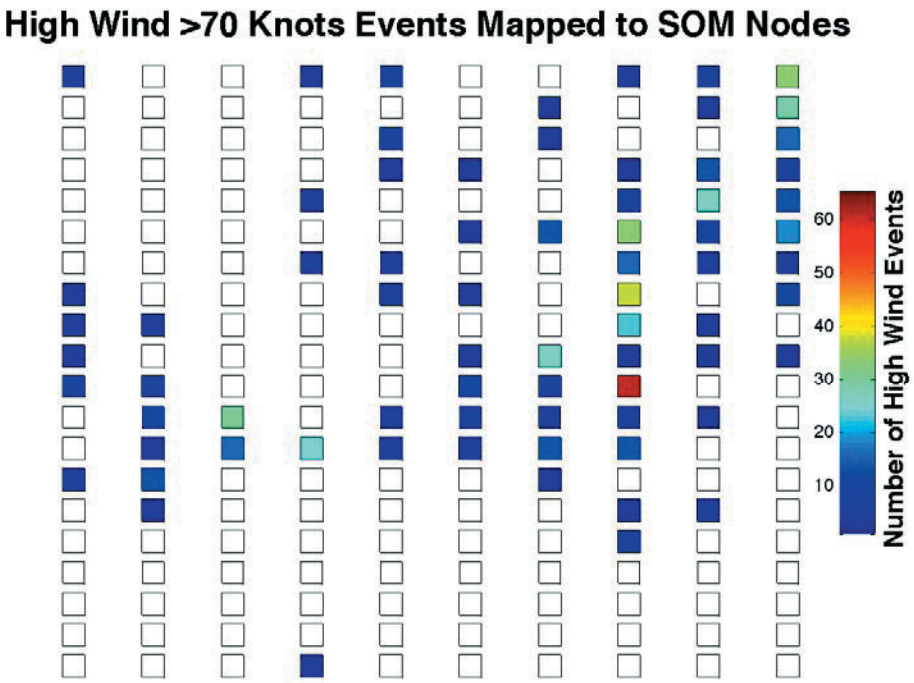

Figure 20. The high wind frequency distribution from Figure 19 mapped to the SOM "postage stamp-map"

2.2 Aerosol Transport Modeling

2.2.1. Overview

Using the meteorological conditions, described above, FMDv and RVFv aerosol transport simulations were performed for six of the thirteen scenarios (Table 9), described in Section 2.3, using the Second-order Closure Integrated PUFF model (SCIPUFF) of Sykes et al. (2008). SCIPUFF is a Lagrangian puff model, which uses a collection of three-dimensional Gaussian puffs to represent an arbitrary time varying concentration field. Turbulent diffusion is parameterized using second-order turbulence closure techniques devised by Donaldson (1973) and Lewellen (1977), which utilizes available velocity statistics to predict the associated dispersion rates. SCIPUFF supports the modeling of various material types, including gases, particles, and liquid droplets and their associated size distributions. Particle and droplet dynamic effects are included, particularly dry/wet deposition and material decay. Urban building effects are modeled using an urban canopy model, which estimates the bulk impacts of the buildings on the wind and turbulent dispersion profiles.

The SCIPUFF model was chosen for this study, over other readily available aerosol transport models, based on a variety of factors, which are listed and expanded upon, below:

- Execution Speed: SCIPUFF is very computationally efficient, as compared to other more sophisticated Lagrangian particle or Computational Fluid Dynamic (CFD) models. Due to the large number of aerosol simulations required for this risk assessment, a relatively fast running model was required to complete the simulations within a reasonable timeframe.

- Applicable Downwind Range: SCIPUFF is applicable for a much wider range of downwind ranges, compared to standard Gaussian Plume models and Lagrangian particle models. Since it was anticipated that the downwind infective range of FMDv could extend up to 100s of kilometers downwind from the NBAF, a model that is applicable for these larger downwind ranges was required.

- Building effects: SCIPUFF utilizes a simple urban/vegetative canopy model to modify the mean and turbulent velocity profiles, below a defined canopy height (Sykes et al., 2008). Due to the low building density of the Manhattan, KS area, it was believed that SCIPUFF's urban parameterization was suitable for this study.

- Terrain effects: SCIPUFF supports the modeling of terrain effects on the atmospheric flow and dispersion, through the use of a mass consistent diagnostic wind model (Sykes et al., 2010). This allowed for the effects of the local small scale topography, surrounding the NBAF, which were not included in the larger scale NCAR gridded weather database, to be properly accounted for in the model simulations.

- Aerosol Particle Size Distributions: SCIPUFF can model aerosol sources with various particle size distributions. Aerosol particle size has a direct impact on dry/wet deposition efficiency, and subsequently, the amount of aerosol material available for ingestion and inhalation.

- Material Decay: SCIPUFF can utilize user specified, material decay rates in its agent fate calculations. The stabilities of both FMDv and RVFv are highly sensitive to atmospheric relative humidity levels, therefore material decay must be accounted for when modeling the subsequent fate of these pathogens

- Time/Space Variable Meteorology: SCIPUFF supports the input of time and space varying meteorological information, as compared to Gaussian Plume models which only allow for a the prescription of a fixed (in space and time) meteorological input.

- Dry/Wet Deposition: SCIPUFF can model both dry deposition (gravitational and turbulent impaction induced) and wet deposition/scavenging (precipitation induced).

- Batch processing capability: A large codebase of processing software has been developed which allows for automated execution and processing of SCIPUFF model results.

- Validation: The SCIPUFF model has been officially validated for use within the Department of Defense (DoD) to simulate the aerosol transport of Chemical, Biological, and Radiological (CBR) materials and is currently the core dispersion engine of the DoD Joint Effects Model (JEM) system and Defense Threat Reduction Agency's (DTRA's) Hazard Prediction and Assessment Capability (HPAC). Additionally, the Environmental Protection Agency (EPA) has accepted the use of the SCIPUFF model for regulatory applications on a case-by-case basis (EPA 2010). Lastly, the modeling system has been extensively validated against a variety of short-range and long-range diffusion experiments (Sykes et al 2008).

2.2.2. Methodology/Configuration

The SCIPUFF model was configured to capture a variety of scenario and pathogen specific effects, which are listed and described below:

Local Terrain. The impact of the local small scale terrain on the local aerosol transport was included, using a 30 arc-second resolution Digital Terrain Elevation Database (DTED Level 0), developed by the National Geospatial-Intelligence Agency (NGA 2000).

Local Land-use. The effects of land-use characteristics on the plume dispersion were included using a 30 arc-second resolution data base developed by Oak Ridge National Laboratory (ORNL) and based on ORNL's Landscan 2006 product.

Aerosol Decay. FMDv and RVFv specific decay rates associated with relative humidity and ultra violet light exposures were included in the aerosol fate calculations, based on the decay curves shown in Figure 21 - Figure 23. As shown, FMDv decay was separated into primary and secondary decay phases, based on time after release, while RVFv decay only included one decay phase. In order to account for the two FMDv decay phases, the primary decay rate was first applied to the initial release amount and assumed to occur before the pathogen was released into the open atmosphere. This effectively reduced the source amount, which was then used in the subsequent aerosol transport calculations. The second decay rate was then fed to the SCIPUFF modeling system to account for the aerosol decay, during the transport simulation. For RVFv, only a single decay rate was applied during the transport calculations, using the original source amount. A unique decay rate was applied for each of the meteorological patterns, described previously, based on their corresponding relative humidity and UV exposure (incoming solar radiation) values centered at the NBAF location.

Wet Aerosols. Aerosol releases were treated as "wet particles", within the SCIPUFF model, which models the effects of wet aerosol size evolution, due to evaporation processes.

Aerosol Deposition. Aerosols were modeled using various size distributions, depending on the method of release, to properly account for aerosol deposition, due to gravitational settling and turbulent impaction processes.

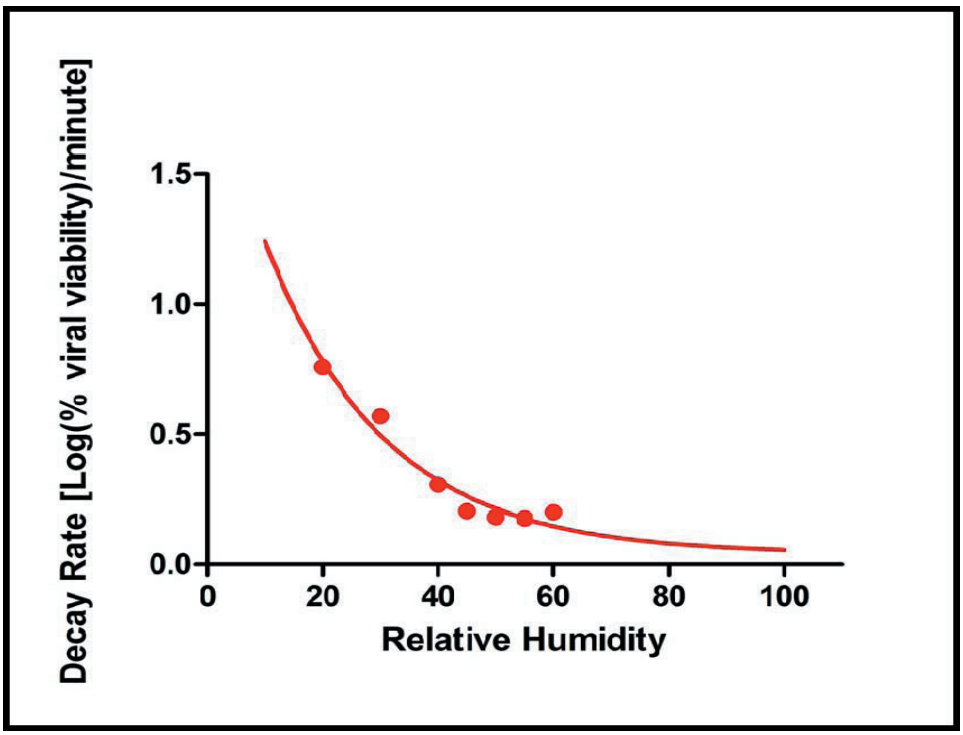

Figure 21. The effect of relative humidity on aerosolized FMDV Primary Decay Rate during the first five minutes after release

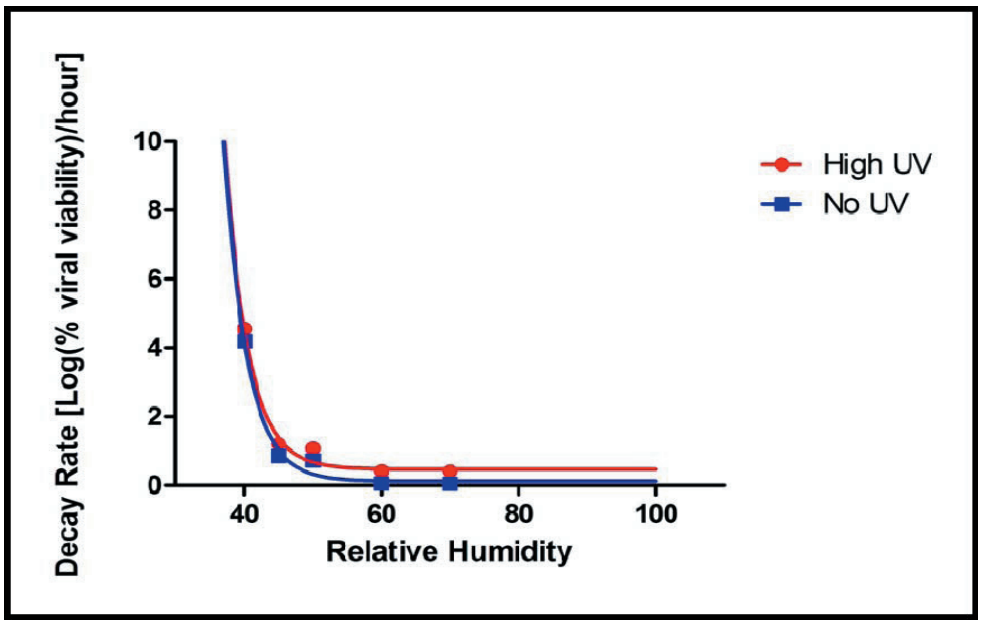

Figure 22. Aerosolized FMDV Secondary Decay Rate (5 minutes or more after release) taking into account UV and relative humidity

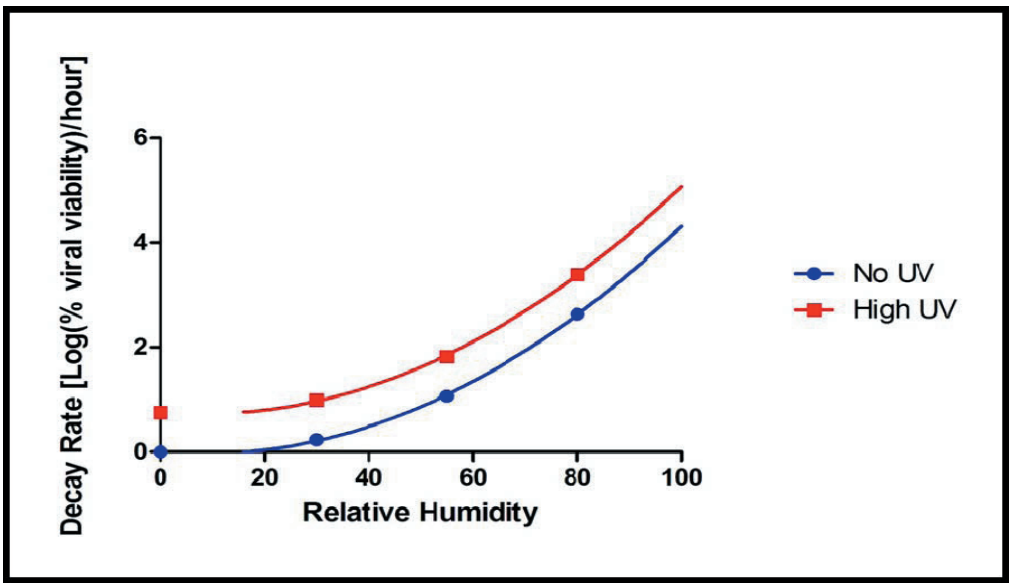

Figure 23. Aerosolized RVFv Decay Rate taking into account UV and relative humidity

Table 9. Aerosol Transport Scenario Matrix					
Scenario No.	Scenario Description	Case Identifier	Pathogen	Q (PFU)	Met Matrix
1	Small/Medium Spill	1FA	FMDv	1.00E+03	workHours
1	Small/Medium Spill	1FB	FMDv	1.00E+08	workHours
1	Small/Medium Spill	1FC	FMDv	1.00E+08	workHours
1	Small/Medium Spill	1RA	RVFv	1.00E+03	workHours
1	Small/Medium Spill	1RB	RVFv	1.00E+08	workHours
1	Small/Medium Spill	1RC	RVFv	1.00E+08	workHours
5	Single Room Fire	5FA	FMDv	3.00E+01	allHours
5	Single Room Fire	5FB	FMDv	3.00E+06	allHours
5	Single Room Fire	5RA	RVFv	3.00E+03	allHours
5	Single Room Fire	5RB	RVFv	3.00E+08	allHours
6	Overpressure	6FA	FMDv	3.00E+01	allHours
6	Overpressure	6FB	FMDv	3.00E+06	allHours
6	Overpressure	6RA	RVFv	3.00E+03	allHours
6	Overpressure	6RB	RVFv	3.00E+08	allHours
7	High Wind/Seismic Event	7FW	FMDv	1.55E+09	highWinds
7	High Wind/Seismic Event	7FSA	FMDv	1.00E+01	allHours
7	High Wind/Seismic Event	7FSB	FMDv	1.55E+09	allHours
7	High Wind/Seismic Event	7RW	RVFv	1.00E+06	highWinds
7	High Wind/Seismic Event	7RSA	RVFv	1.00E+01	allHours
7	High Wind/Seismic Event	7RSB	RVFv	1.00E+06	allHours

Table 9. Aerosol Transport Scenario Matrix					
Scenario No.	Scenario Description	Case Identifier	Pathogen	Q (PFU)	Met Matrix
8	Aircraft	8FA	FMDv	3.00E+06	workHours
8	Aircraft	8FB	FMDv	3.00E+04	workHours
8	Aircraft	8RA	RVFv	3.00E+08	workHours
8	Aircraft	8RB	RVFv	3.00E+06	workHours
11	Tornado	11FA	FMDv	5.80E+09	tornado
11	Tornado	11RA	RVFv	1.00E+06	tornado

2.2.3. Model Output Products

The raw output from each individual aerosol simulation included instantaneous airborne pathogen concentration (PFU/m^3), time-integrated airborne concentration (PFU-sec/m^3), surface deposition (PFU/m^2), and a frequency of occurrence for the specific meteorological condition, used to drive the simulation (Figure 24 - Figure 26). These products were further processed to calculate inhalation exposures based on susceptible population species, as detailed in the following sections.

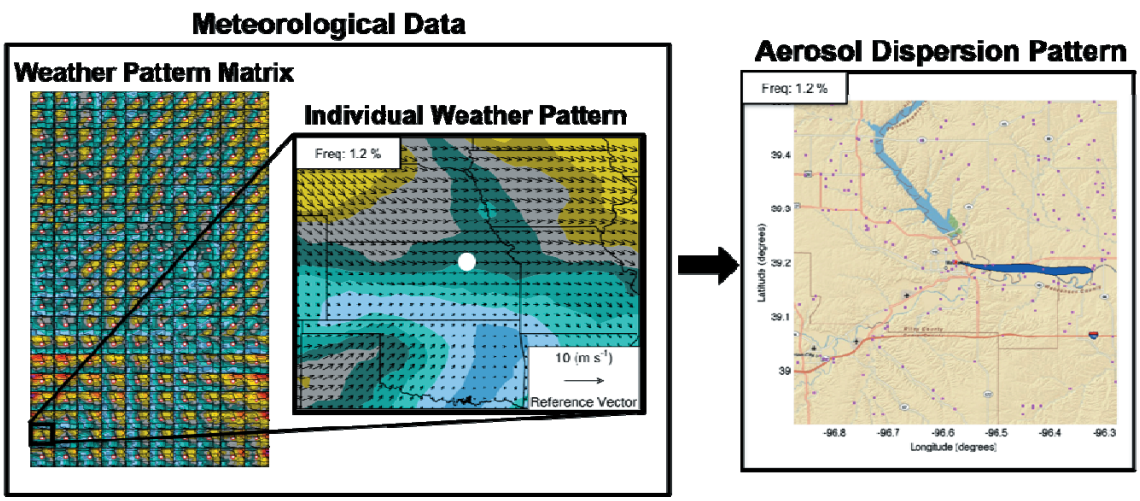

Figure 24. Conceptual diagram of aerosol transport inputs/outputs

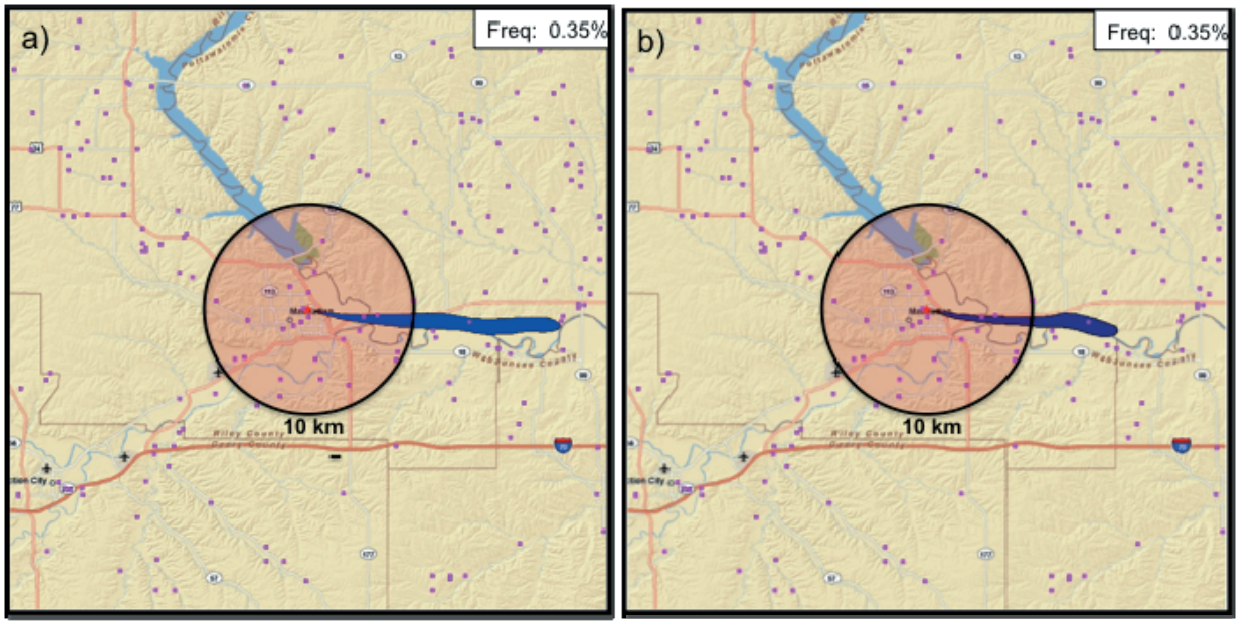

Figure 25. a) Time-integrated concentration and b) surface deposition for CaseID 1FB, MetID 159

The colored contour represents concentration and deposition values greater than or equal to 48.41 PFU-sec/m3 and 0.1 PFU/m2, respectively. Purple squares designate susceptible animal species locations, while the red star designates the release location.

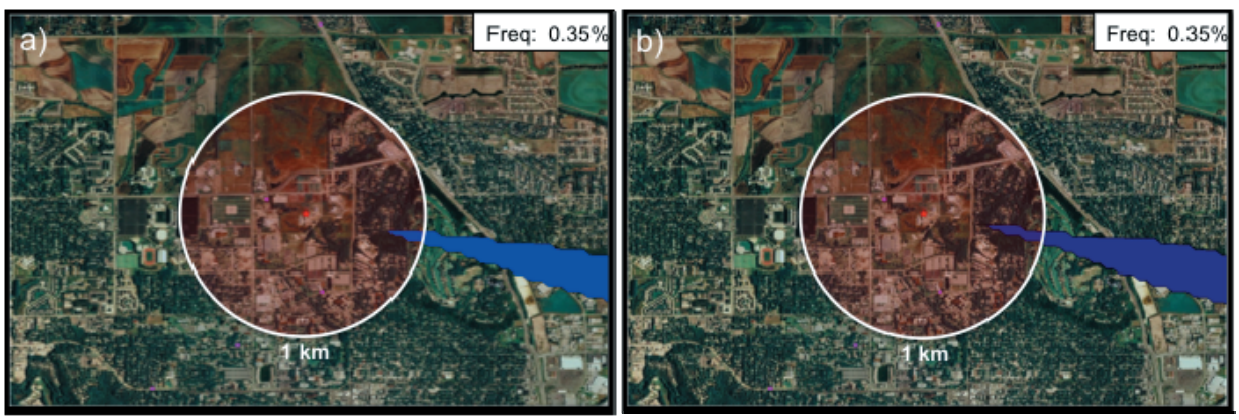

Figure 26. As in Figure 25. Zoomed-in view

2.2.4. Aerosol Inhalation Exposure Calculation

Based on the raw aerosol transport results, above, inhalation exposures levels were calculated for the range of susceptible species (cattle, swine, sheep, humans). Inhalation exposure represents the quantity of pathogen inhaled by a particular species, based on their average breathing rate and the ambient concentration of pathogen. As shown in Equation 2, inhalation exposure is simply the product of the time-integrated concentration (PFU-sec/m^3) and the breathing rate of the exposed species (m^3/sec).

Equation 2:

$$E = D \times BR,$$

E = Inhlation Exposure (PFU)

D = Time-integrated Concentration (PFU-sec/m3)

BR = Breathing Rate (m3/sec)

The list of susceptible species and their associated breathing rates are summarized in Table 10, below. As is evident, cattle breathing rates are approximately ten times larger than all other susceptible species. Due to this fact, when exposed to particular pathogen concentration level, cattle will subsequently inhale approximately ten times more pathogen. Similarly, swine will inhale more pathogen, than sheep, which will inhale more than humans. This behavior is further illustrated in Figure 27 and Figure 28, which show exposure levels, when cattle (a), swine (b), and sheep (c) breathing rates are applied to the time-integrated concentration values from Figure 25a and Figure 26a. The colored contour area represents exposure levels, which equal or exceed a minimum infective exposure level of 0.1 PFUs, and therefore denotes an area of infection risk. As expected, the downwind risk area for cattle, is substantially larger than corresponding risk areas for swine and sheep, and even less so for humans (not shown).

Table 10. Average Breathing Rates per Susceptible Species

Species	Breathing Rate (L/min)	Breathing Rate (m^3/sec)
Cattle (beef)	123.95	2.1E-03
Swine	18.28	3.0E-04
Sheep	12.77	2.1E-04
Humans	6.0	1.0E-04

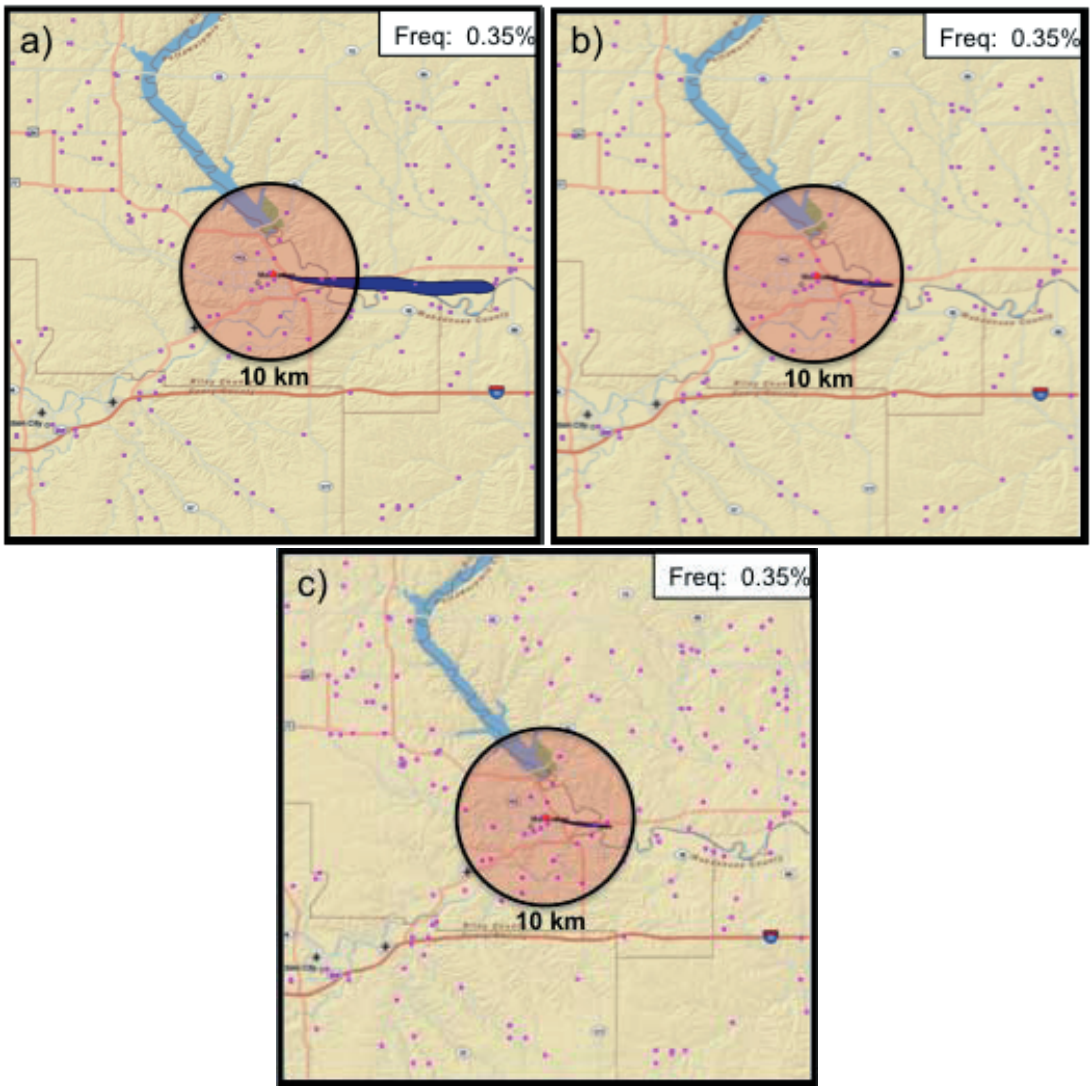

Figure 27. a) Cattle Inhalation Exposure, b) Swine Inhalation Exposure, and c) Sheep Inhalation Exposure for CaseID 1FB, MetID 159

The colored contour represents exposure levels greater than or equal to 0.1 PFU.

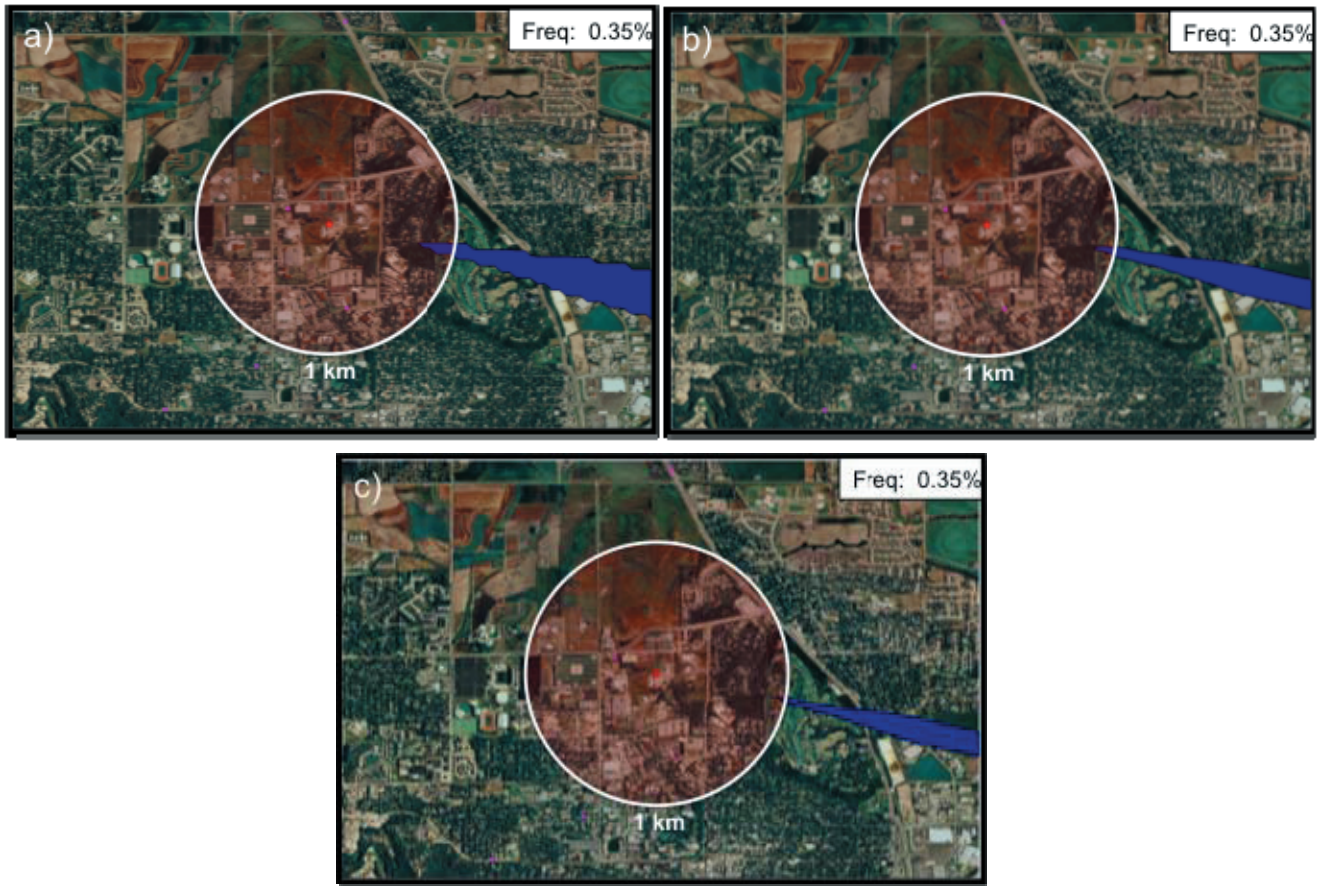

Figure 28. As in Figure 27, Zoomed-in view

Before these exposure levels can be used to estimate numbers of initial infections, they first must be correlated with known animal population locations, surrounding the release location. Utilizing the susceptible species population datasets, detailed in Section 2.2, and the exposure levels calculated above, correlated exposure values were estimated, based on location and animal species type (Figure 29). These results, combined with the meteorological condition frequencies, were subsequently provided to the epidemiological models (Section 2.5) for further processing and analysis.

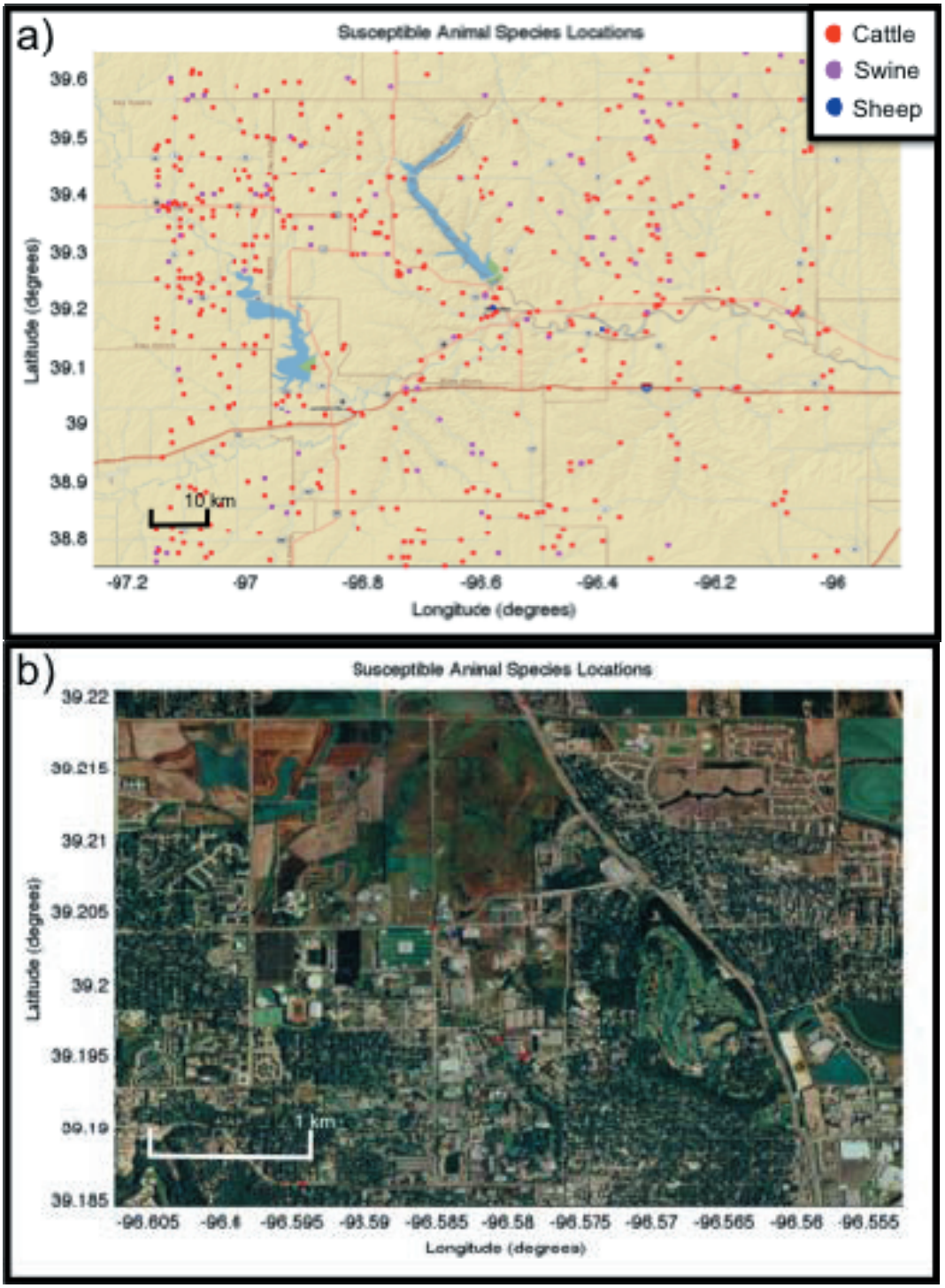

Figure 29. Susceptible animal locations and species type

For scenarios involving an aerosol release of RVFv, human exposure levels were also calculated for specific locations on the Kansas State University campus and for a grid of locations surrounding the NBAF site. The exposure grid resolution (100 meters) was based on the resolution of the underlying gridded population data (Landscan USA Gold) used for this study.

3.0 Aerosol Fate and Transport Results

3.1 Summary of Aerosol Fate and Transport Modeling Results

The following summarizes the inhalation exposure results for all the aerosol transport scenario cases and pathogens used as the basis for subsequent epidemiological modeling. A detailed and comprehensive analysis of aerosol fate and transport modeling results are contained in this Appendix. The aerosol transport simulation data described herein were consolidated according to:

- Maximum Areal Coverage
  - Defined as the maximum surface area (in square kilometers, km^2) which received a time-integrated concentration, surface deposition, and inhalation exposure value greater than or equal to a specified threshold, over all meteorological conditions.
- Maximum Downwind Range
  - Defined as the maximum downwind range (in kilometers, km) that received a time-integrated concentration, surface deposition, and inhalation exposure value greater than or equal to a specified threshold over all meteorological conditions.
- Maximum Animal Population Locations
  - Defined as the maximum number of animal population centers that received an inhalation exposure level greater than or equal to a specified threshold, over all meteorological conditions.
- Probability of Exceeding a Specified Area Size
  - Defined as the probability that the plume surface area (in square kilometers, km^2) will exceed a specified size threshold, for time-integrated concentration, surface deposition, and inhalation exposure, over all meteorological conditions. It should be noted that this probability only accounts for the meteorological condition frequencies of occurrence and does not account for the associated release event/pathway probabilities.
- Probability of Exceeding a Specified Downwind Range
  - Defined as the probability that the plume downwind range (in square kilometers, km^2) will exceed a specified threshold for time-integrated concentration, surface deposition, and inhalation exposure over all meteorological conditions. It should be noted that this probability only accounts for the meteorological condition frequencies of occurrence and does not account for the associated release event/pathway probabilities.

It should be noted that for any particular release scenario, the meteorological condition that produced the maximum areal coverage and/or maximum plume downwind range was not necessarily the same condition that also resulted in the maximum number of animal location exposures. This was due to the orientation of the resulting aerosol plume and location of surrounding susceptible animal populations.

For example, in release scenario 1FB, the aerosol plume with the largest areal extent (Figure 30a) covered fewer animal population centers (magenta squares) as compared to the plume that encompassed the largest number of population locations (Figure 30b). This was due to its (Figure 30a) northern orientation and the distribution of animal population centers north of the NBAF. Note that the scale of Figure 30b was enlarged relative to Figure30a to allow the reader to visualize the increased number of animal population centers within that plume.

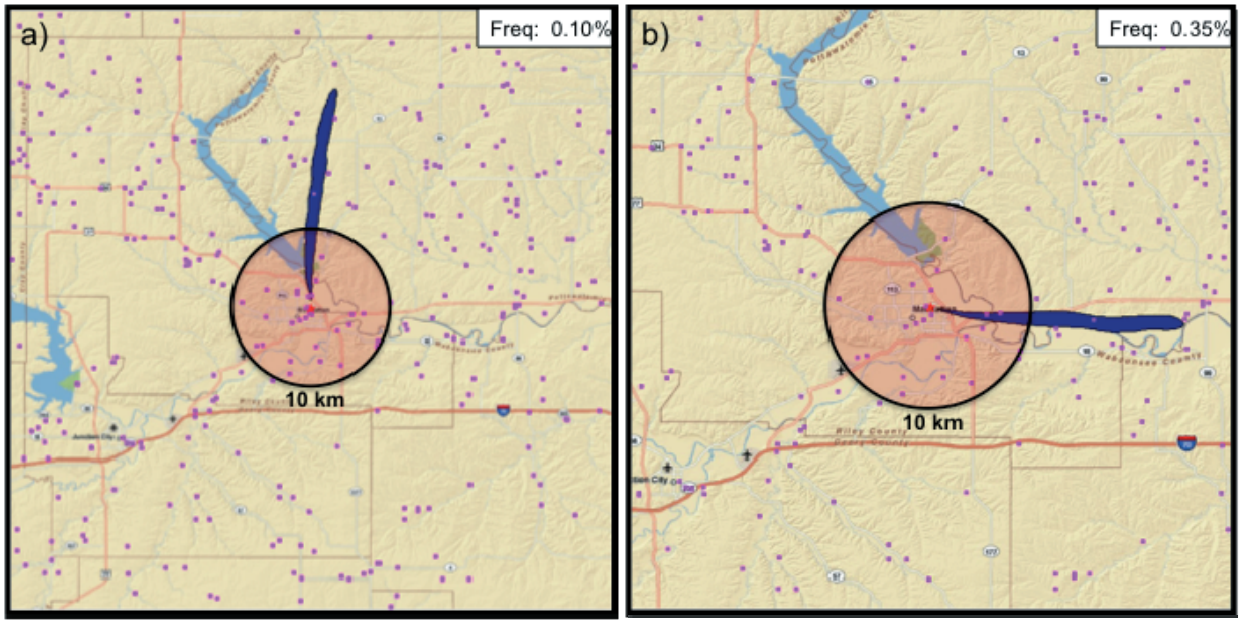

Figure 30: Cattle Inhalation Exposure Footprints from Case 1FB

(Biocontainment spill with nonfunctional HEPA) for a) The Maximum Exposure Area Meteorological Condition 17 (MET ID 17) and b) The Largest Number of Animal Location Exposures Meteorological Condition 159 (MET ID 159)

The maximum aerosol area coverage (km^2) of each case modeled by output product (cattle, swine, sheep or human) is presented in Table 11. Here, a threshold value of 48.4066 pfu-sec/m^3 was used to define the time-integrated concentration area coverage, while 0.1 pfu/m^2 and 0.1 pfu were used to define the surface deposition and inhalation exposure areas, respectively. Also shown is the associated meteorological pattern frequency of occurrence (%) that resulted in the maximum area coverage. In every case, the frequency of the corresponding meteorological pattern was less than ~1 %.

Table 11: Maximum Aerosol Area Coverage (km^2) for each Release Scenario							
Case ID	Met Frequency (%)	Time-integrated Concentration Area (km^2)	Surface Deposition Area (km^2)	Cattle Exposure Area (km^2)	Swine Exposure Area (km^2)	Sheep Exposure Area (km^2)	Human Exposure Area (km^2)
1FA	NA	0	0	0	0	0	NA
1FB	0.104316	38.374141	92.741785	38.374141	2.577666	1.58823	NA
1FC	0.104316	35.197682	77.997196	35.197682	3.658346	2.509232	NA
1RA	NA	0	0	0	0	0	0
1RB	0.002371	0.111205	0	0.111205	0.01996	0	0
1RC	1.032492	0.199598	0	0.199598	0.082691	0.062731	0.034217
5FA	NA	0	0	0	0	0	NA
5FB	0.550376	1.602487	3.222082	1.602487	0.025663	0	NA
5RA	NA	0	0	0	0	0	0
5RB	0.862781	0.222409	0	0.222409	0.037068	0.014257	0
6FA	NA	0	0	0	0	0	NA
6FB	0.550376	2.232646	0.553172	2.232646	0.031365	0	NA
6RA	NA	0	0	0	0	0	0
6RB	0.862781	0.225261	0	0.225261	0.037068	0.014257	0
7FW	0.31	1057.515826	425.597113	1057.515826	294.12191	212.186931	NA
7FSA	NA	0	0	0	0	0	NA
7FSB	0.444973	1040.367507	642.782548	1040.367507	272.251672	201.642454	NA
7RW	NA	0	0	0	0	0	0
7RSA	NA	0	0	0	0	0	0
7RSB	0.448776	0.01996	0	0.01996	0.005703	0.002851	0.002851
8FA	0.104316	0.573131	2.17847	0.573131	0.085542	0.057028	NA
8FB	NA	0	0	0	0	0	NA
8RA	1.032492	0.316505	0	0.316505	0.134016	0.108353	0.082691
8RB	NA	0	0	0	0	0	0
11FA	0.131062	1922.673357	1013.396114	1922.673357	696.18927	613.330437	NA
11RA	NA	0	0	0	0	0	0

Figure 31 plots the maximum number of animal populations that received an inhalation exposure of 0.1 pfu or greater for each of the cases modeled across all meteorological conditions. The meteorological pattern frequencies were not included; however in every case the frequency of the corresponding meteorological pattern occurring was less than ~1%.

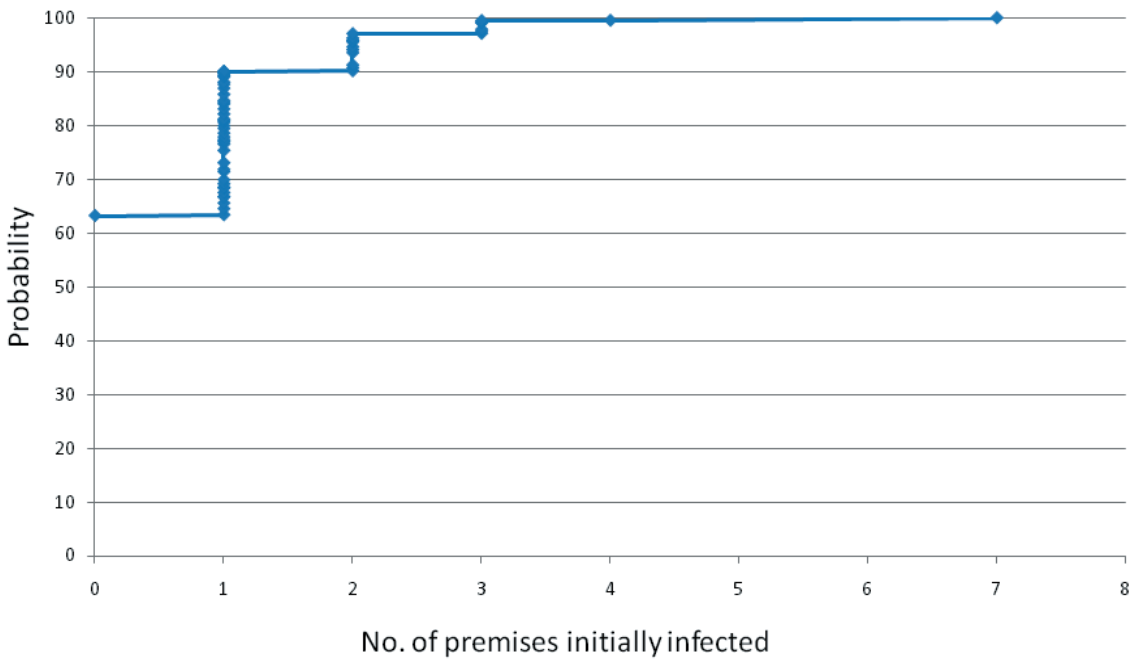

Figure 31: Number of Animal Locations that Received an Inhalation Exposure of 0.1 pfu or greater

While useful to ascertain the maximum plausible impact for each scenario, the metrics, above, don't illustrate the overall impact probabilities, associated with the underlying meteorological conditions. As noted earlier, these maximum impacts, in terms of areal coverage, downwind range, and animal locations exposed, may occur infrequently when compared to the range of aerosol plume results for any one scenario. Therefore, it is more useful to analyze the results in terms of probability of a specific impact occurring, based on the range of input meteorological conditions. Therefore, the probability of exceeding a specified set of both aerosol plume areas (1, 10, and 100 km^2) and plume downwind ranges (1, 10, 50 km) were calculated and have been summarized in Tables 12 through 14 and Figures 32 through 37.

Table 12: Probability of Exceeding an Area greater than or equal to 1km² (PoE-1km²)

Case ID	Time-Integrated Concentration Area PoE-1km² (%)	Surface Deposition Area PoE-1km² (%)	Cattle Exposure Area PoE-1km² (%)	Swine Exposure Area PoE-1km² (%)	Sheep Exposure Area PoE-1km² (%)	Human Exposure Area PoE-1km² (%)
1FA	0	0	0	0	0	NA
1FB	47.781505	72.17013	47.781505	5.294041	2.29851	NA
1FC	46.309226	69.492289	46.309226	5.400728	4.714375	NA
1RA	0	0	0	0	0	0
1RB	0	0	0	0	0	0
1RC	0	0	0	0	0	0
5FA	0	0	0	0	0	NA
5FB	0.550376	0.61177	0.550376	0	0	NA

Table 12: Probability of Exceeding an Area greater than or equal to 1km² (PoE-1km²)						
Case ID	Time-Integrated Concentration Area PoE-1km² (%)	Surface Deposition Area PoE-1km² (%)	Cattle Exposure Area PoE-1km² (%)	Swine Exposure Area PoE-1km² (%)	Sheep Exposure Area PoE-1km² (%)	Human Exposure Area PoE-1km² (%)
5RA	0	0	0	0	0	0
5RB	0	0	0	0	0	0
6FA	0	0	0	0	0	NA
6FB	0.550376	0	0.550376	0	0	NA
6RA	0	0	0	0	0	0
6RB	0	0	0	0	0	0
7FW	99.92	83	99.92	95.85	82.07	NA
7FSA	0	0	0	0	0	NA
7FSB	100	91.136937	100	96.082714	89.517864	NA
7RW	0	0	0	0	0	0
7RSA	0	0	0	0	0	0
7RSB	0	0	0	0	0	0
8FA	0	0.301094	0	0	0	NA
8FB	0	0	0	0	0	NA
8RA	0	0	0	0	0	0
8RB	0	0	0	0	0	0
11FA	100	95.01966	100	100	100	NA
11RA	0	0	0	0	0	0

Table 13: Probability of Exceeding an Area greater than or equal to 10km² (PoE-10km²)						
Case ID	Time-Integrated Concentration Area PoE-10km² (%)	Surface Deposition Area PoE-10km² (%)	Cattle Exposure Area PoE-10km² (%)	Swine Exposure Area PoE-10km² (%)	Sheep Exposure Area PoE-10km² (%)	Human Exposure Area PoE-10km² (%)
1FA	0	0	0	0	0	NA
1FB	8.960514	23.637075	8.960514	0	0	NA
1FC	8.794557	13.06796	8.794557	0	0	NA
1RA	0	0	0	0	0	0
1RB	0	0	0	0	0	0
1RC	0	0	0	0	0	0
5FA	0	0	0	0	0	NA
5FB	0	0	0	0	0	NA
5RA	0	0	0	0	0	0
5RB	0	0	0	0	0	0

Table 13: Probability of Exceeding an Area greater than or equal to 10km² (PoE-10km²)						
Case ID	Time-Integrated Concentration Area PoE-10km² (%)	Surface Deposition Area PoE-10km² (%)	Cattle Exposure Area PoE-10km² (%)	Swine Exposure Area PoE-10km² (%)	Sheep Exposure Area PoE-10km² (%)	Human Exposure Area PoE-10km² (%)
6FA	0	0	0	0	0	NA
6FB	0	0	0	0	0	NA
6RA	0	0	0	0	0	0
6RB	0	0	0	0	0	0
7FW	91.78	72.67	91.78	30.06	25.68	NA
7FSA	0	0	0	0	0	NA
7FSB	94.220237	81.169318	94.220237	53.573369	43.365063	NA
7RW	0	0	0	0	0	0
7RSA	0	0	0	0	0	0
7RSB	0	0	0	0	0	0
8FA	0	0	0	0	0	NA
8FB	0	0	0	0	0	NA
8RA	0	0	0	0	0	0
8RB	0	0	0	0	0	0
11FA	100	93.053736	100	59.239843	48.230669	NA
11RA	0	0	0	0	0	0

Table 14: Probability of Exceeding an Area greater than or equal to 100km² (PoE-100km²)						
Case ID	Time-Integrated Concentration Area PoE-100km² (%)	Surface Deposition Area PoE-100km² (%)	Cattle Exposure Area PoE-100km² (%)	Swine Exposure Area PoE-100km² (%)	Sheep Exposure Area PoE-100km² (%)	Human Exposure Area PoE-100km² (%)
1FA	0	0	0	0	0	NA
1FB	0	0	0	0	0	NA
1FC	0	0	0	0	0	NA
1RA	0	0	0	0	0	0
1RB	0	0	0	0	0	0
1RC	0	0	0	0	0	0
5FA	0	0	0	0	0	NA
5FB	0	0	0	0	0	NA

Table 14: Probability of Exceeding an Area greater than or equal to 100km² (PoE-100km²)						
Case ID	Time-Integrated Concentration Area PoE-100km² (%)	Surface Deposition Area PoE-100km² (%)	Cattle Exposure Area PoE-100km² (%)	Swine Exposure Area PoE-100km² (%)	Sheep Exposure Area PoE-100km² (%)	Human Exposure Area PoE-100km² (%)
5RA	0	0	0	0	0	0
5RB	0	0	0	0	0	0
6FA	0	0	0	0	0	NA
6FB	0	0	0	0	0	NA
6RA	0	0	0	0	0	0
6RB	0	0	0	0	0	0
7FW	30.06	18.16	30.06	4.08	2.2	NA
7FSA	0	0	0	0	0	NA
7FSB	54.916438	32.112509	54.916438	8.682684	5.139197	NA
7RW	0	0	0	0	0	0
7RSA	0	0	0	0	0	0
7RSB	0	0	0	0	0	0
8FA	0	0	0	0	0	NA
8FB	0	0	0	0	0	NA
8RA	0	0	0	0	0	0
8RB	0	0	0	0	0	0
11FA	64.482307	56.618611	64.482307	9.82962	6.290957	NA
11RA	0	0	0	0	0	0

Similarly, the maximum plume downwind ranges for each scenario are summarized in Figures 32 through 37, below.

FMDv

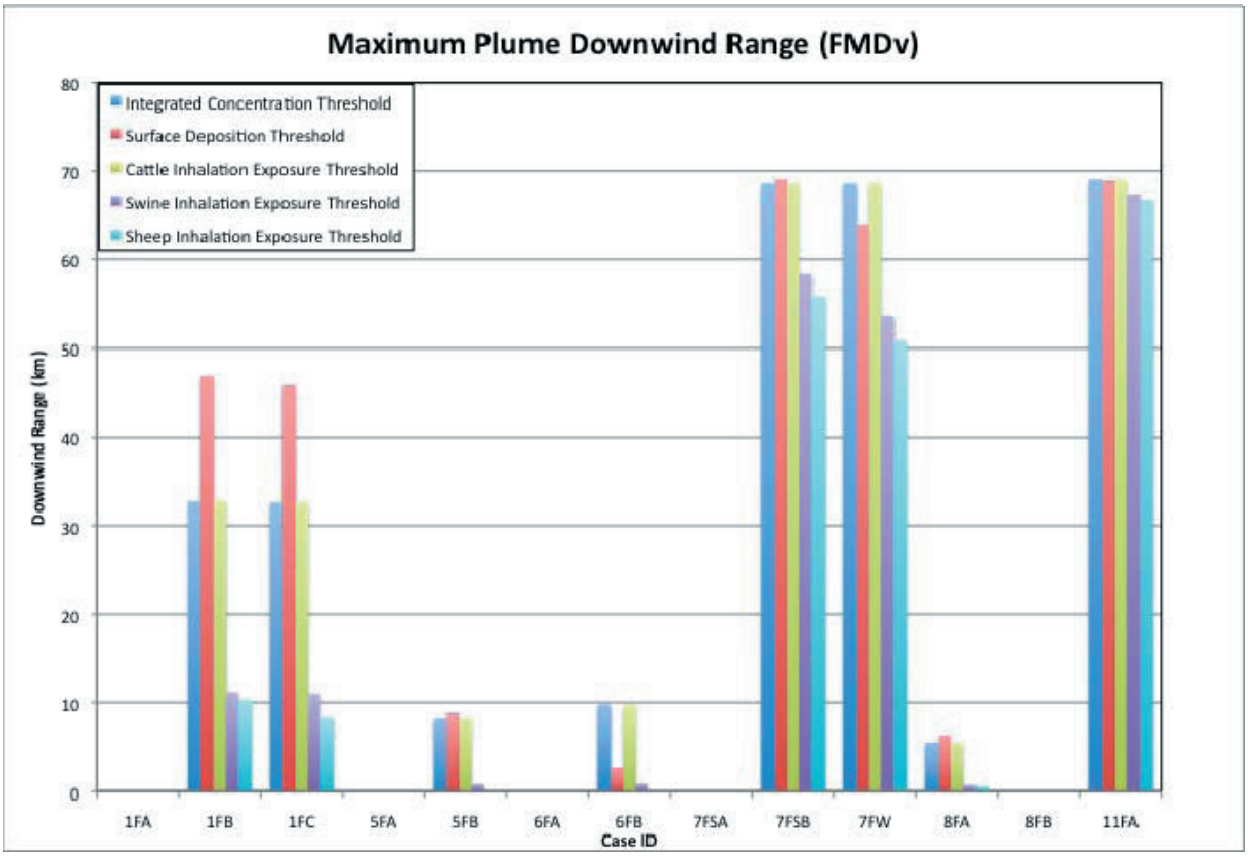

Figure 32: Maximum downwind range, which received a time-integrated concentration, surface deposition, and inhalation exposure of FMDv greater than or equal to 48.4 PFU-s/m^3, 0.1 PFU/m^2, and 0.1 PFU, respectively, over all meteorological conditions

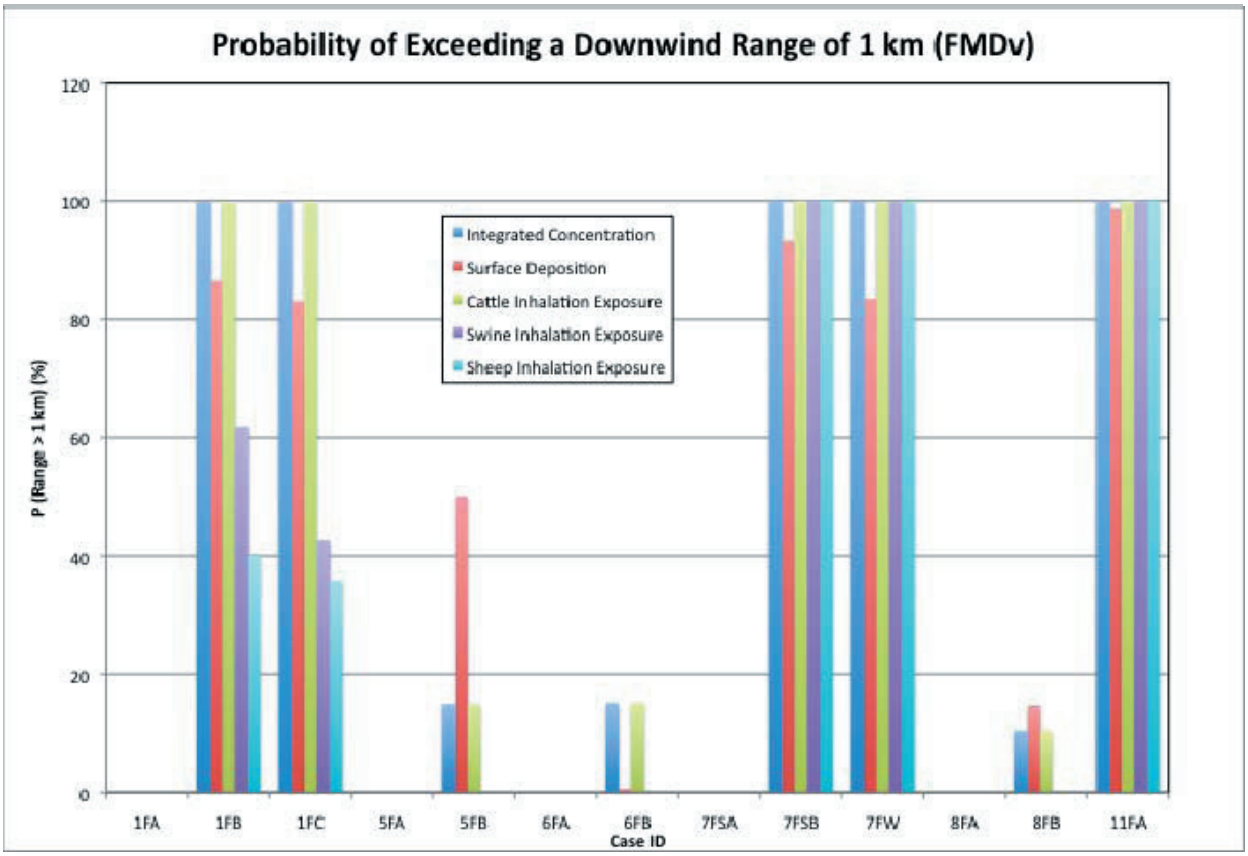

Figure 33: Probability of receiving a time-integrated concentration, surface deposition, and inhalation exposure of 48.4 PFU-s/m^3, 0.1 PFU/m^2, and 0.1 PFU greater than 1km downrange from the NBAF

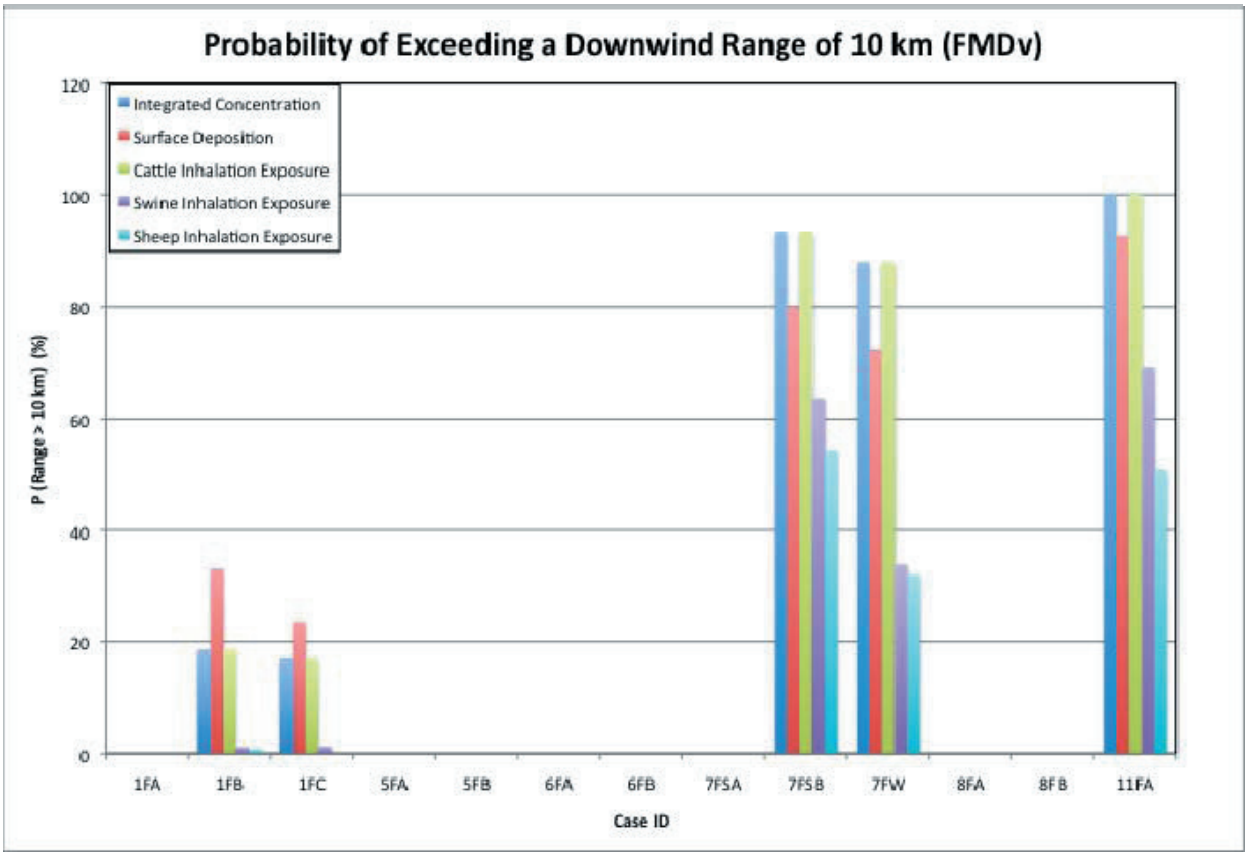

Figure 34: Probability of receiving a time-integrated concentration, surface deposition, and inhalation exposure of 48.4 PFU-s/m^3, 0.1 PFU/m^2, and 0.1 PFU greater than 10km downrange from the NBAF

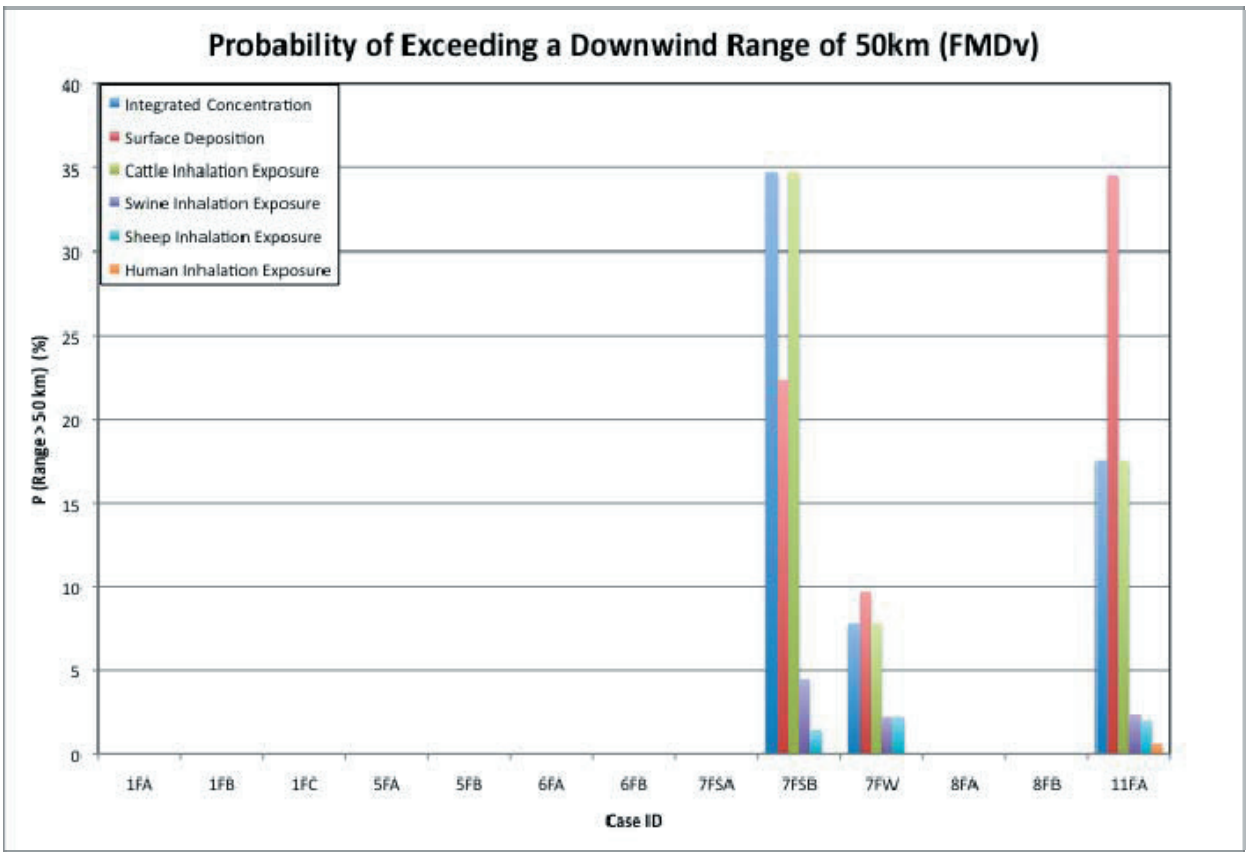

Figure 35: Probability of receiving a time-integrated concentration, surface deposition, and inhalation exposure of 48.4 PFU-s/m3, 0.1 PFU/m2, and 0.1 PFU greater than 50 km downrange from the NBAF

RVFv

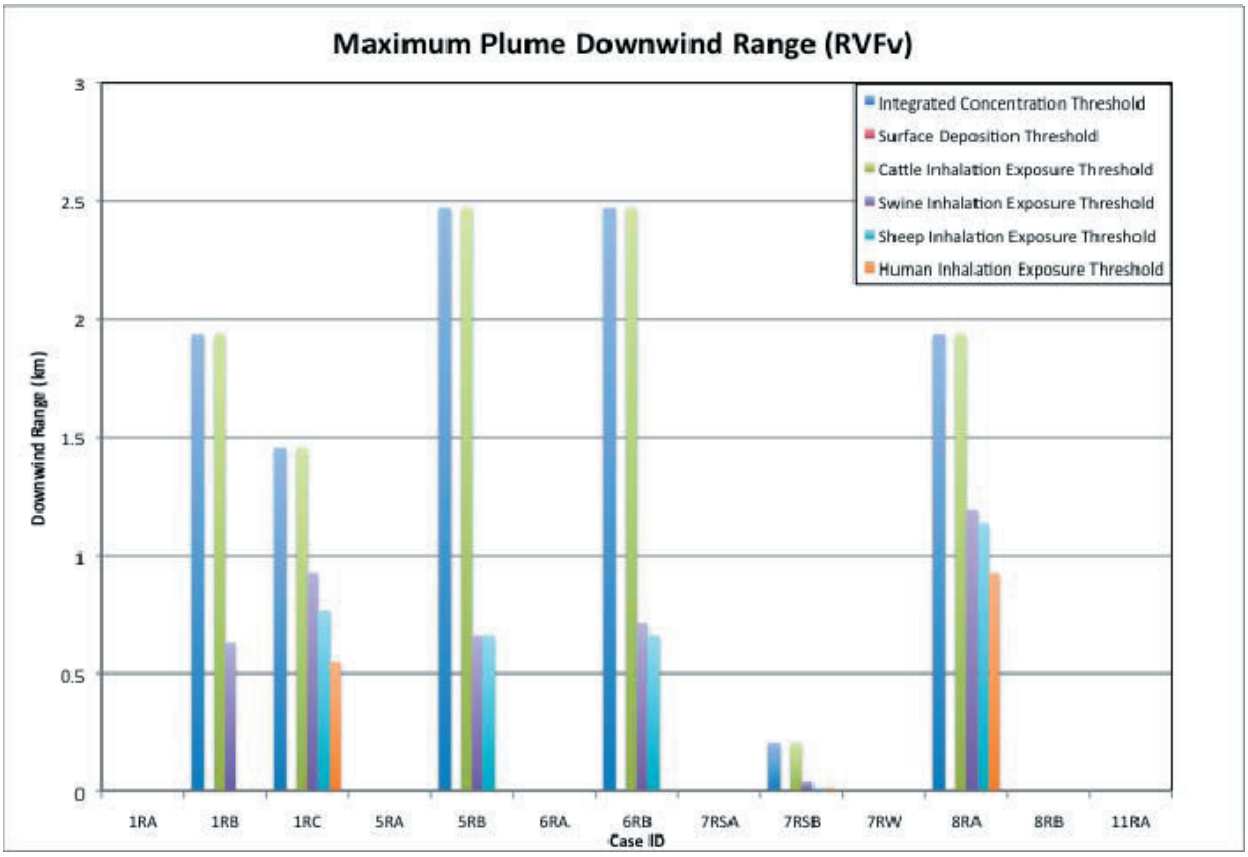

Figure 36: Maximum downwind range, which received a time-integrated concentration, surface deposition, and inhalation exposure of RVFv greater than or equal to 48.4 PFU-s/m^3, 0.1 PFU/m^2, and 0.1 PFU, respectively, over all meteorological conditions

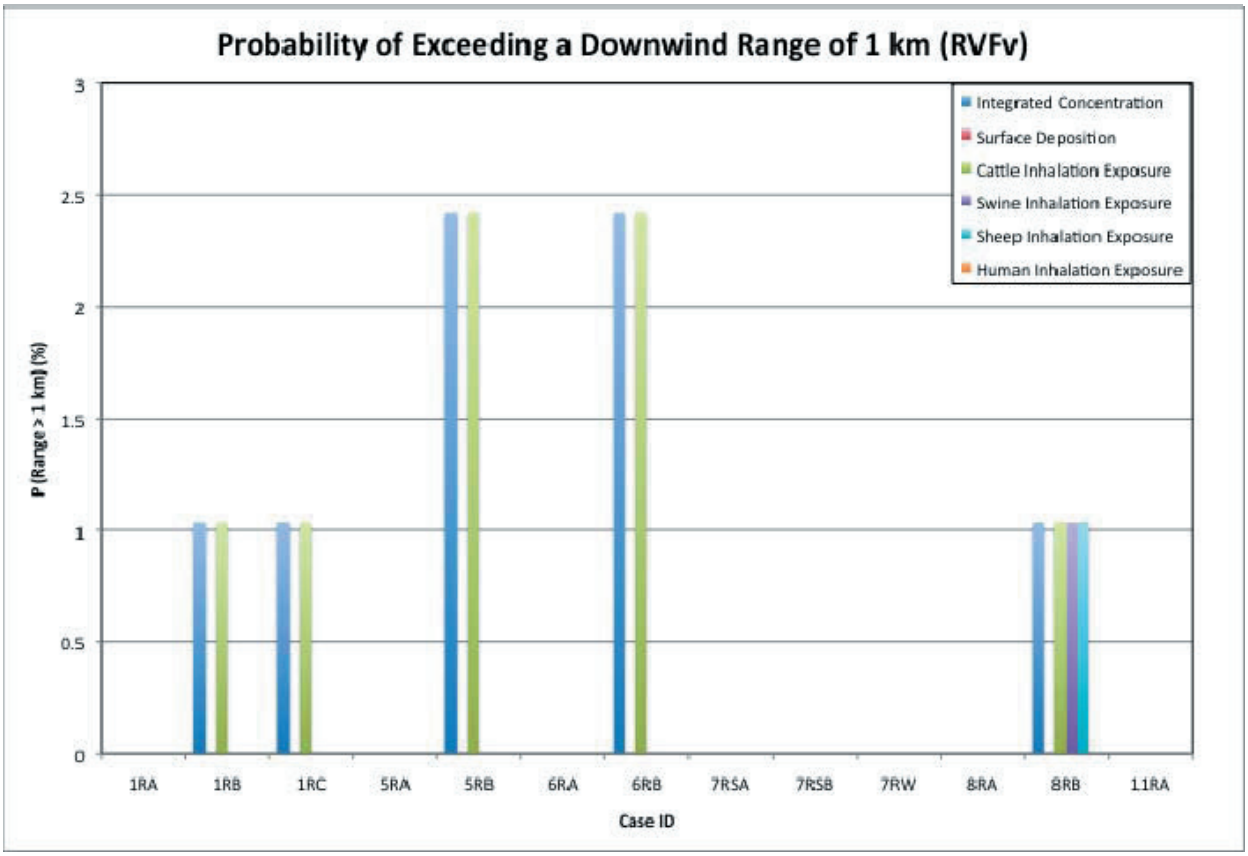

Figure 37: Probability of receiving a time-integrated concentration, surface deposition, and inhalation exposure of 48.4 PFU-s/m^3, 0.1 PFU/m^2, and 0.1 PFU greater than 1 km downrange from the NBAF

3.2 FMDv Case Observations

Upon examination of the results summarized above, it is immediately evident that the rare event FMDv release scenarios—7FSB (Seismic), 7FW (High Wind), and 11FA (Tornado)—all resulted in the largest aerosol plume area footprints, (Sheep Exposure Area > 200 km^2), plume downwind ranges (Sheep Exposure Range > 50 km), and highest number of animal location exposures (> 190). This comes as no surprise, given the large quantities of viral material released (greater than 1E+09 pfus) in these scenarios. It is important to remember, however, that these results only represent the worst case meteorological conditions in terms of aerosol transport and decay, and occur only a small percentage of the time relative to all other possible conditions. For example, the meteorological condition associated with the worst-case seismic release inhalation exposure result (1FSB), only occurred 0.64% of the time. Additionally, the probability that these rare release events will occur (such as a tornado) is also very small. Lastly, these results do not include the associated probabilities of infection, given a certain exposure level. Even though a large number of animal populations may be exposed to a certain threshold inhalation exposure level, only a percentage of the total population will become infected. Those calculations, and the resulting number of infections for each case, are presented in Section 4 of the SSRA Report.

The accidental spill scenarios, 1FB (biocontainment spill, nonfunctional HEPA) and 1FC (exterior spill), produced the next largest set of plume footprints (Sheep Exposure Area > 1 km^2), plume downwind ranges (Sheep Exposure Range > 8 km), and animal location exposures (> 70). The remaining scenarios either resulted in relatively small footprints, short downwind ranges, and few exposures (5FB, 6FB, 8FA) or approximately zero footprints, ranges, and exposures (1FA, 5FA, 6FA, 7FSA, 8FB). As expected, all scenario/event pathways that represented normally functioning HEPA filtration systems produced zero plume footprints, downwind ranges, and animal location exposures.

Upon analyzing the plume surface area and downwind range probabilities of exceedance, it is immediately apparent that the rare event FMDv release scenarios, 7FSB (Seismic), 7FW (High Wind), and 11FA (Tornado), produced the highest probabilities. This is most apparent when reviewing the probabilities of exceeding an exposure area greater than 100 km^2 and downwind range greater than 50 km. As shown, the rare event releases are the only scenarios, which have a non-zero probability of exceedance. The remaining scenarios either resulted in medium to low or zero probabilities of exceeding an area of 1 km^2 and a range of 10 km.

The probability of any scenario/event pathway, which represented normally functioning HEPA filtration systems, producing an aerosol exposure footprint of 1 km^2 and a downwind range of 1 km was 0%.

3.3 RVFv Case Observations

Generally speaking, the RVFv release scenarios resulted in smaller plume footprints, downwind ranges, and fewer animal location exposures compared to similar FMDv releases, even though many of the same RVFv scenarios contained a larger initial source amount (Q). For example, the overpressure, nonfunctioning HEPA scenario (6FB and 6RB) release quantities (Q) are 3.00E+06 and 3.00E+08 pfus for FMDv and RVFv, respectively. Given the large difference between the two source amounts, one would expect the RVFv aerosol transport simulations to result in much larger plume footprints, downwind ranges, and exposure locations. These counterintuitive findings can be directly attributed to the different decay behavior of each pathogen under the same meteorological conditions. RVFv decay rates are directly proportional to relative humidity levels (e.g. higher humidity equates to faster decay), while FMDv decay rates are inversely proportional to humidity levels (e.g. higher humidity equates to slower decay). As noted previously, Manhattan, KS, frequently experiences high relative humidities. Given these conditions, RVFv will rapidly decay upon release, while FMDv will remain viable over longer periods of time. This behavior is not only evident when comparing the RVFv results to the corresponding FMDv results, but is also evident when analyzing the RVFv results in isolation. As shown, all the RVFv scenarios resulted in aerosol plume footprints of less than 0.5 km^2, with many equal to 0 km^2 (1RA, 5RA, 6RA, 7RW, 7RSA, 8RB, 11RA). Additionally, the maximum plume downwind range over all scenarios was less than 2.5 km, with many equal to 0 km (1RA, 5RA, 6RA, 7RW, 7RSA, 8RB, 11RA). Consequently, due to the small RVFv aerosol footprints and downwind ranges, only a few nearby animal population centers received inhalation exposures above the defined minimum threshold of 0.1 pfus. With respect to human inhalation exposures, these areas were also restricted to the immediate vicinity of the NBAF, with the vast majority of scenarios producing exposure areas of approximately 0 km^2 and exposure downwind ranges of 0 km. The largest human exposure area (8RA) covered an area less than 0.1 km^2 and

downwind range less than 1 km. This is consistent with expectations, given the small average breathing rates of humans; a much larger quantity of material would be required to exceed the inhalation exposure threshold of 0.1 pfu.

These findings are also evident, when analyzing the associated probabilities of exceedance. As expected, based on the small size of the maximum areal footprint sizes (all less than 1 km^2), the probability of exceeding a minimum exposure area of 1 km^2 is 0% for all the RVFv scenario/event pathways. Similarly, the probability of exceeding a plume downwind range of 10 km is 0% for all scenarios, with only a few scenarios resulting in non-zero probabilities (< 2.5%) of exceeding a range of 1 km.

3.4 Detailed Release Scenario Results

Simulation Results are summarized below for each release scenario, using the following metrics:

- Areal Coverage per Meteorological Condition: Defines the surface area (in square kilometers, km^2), which receives a time-integrated concentration and surface deposition value greater than or equal to 48.4066 PFU-sec/m^3 and 0.1 PFU/m^2, respectively, for each meteorological input condition.
- Areal Coverage Frequency: As above, but showing associated frequencies of occurrence.

It should be noted that only those scenarios, which resulted in plumes greater than the specified thresholds, are summarized here.

3.4.1. Scenario 1

3.4.1.1. CaseID 1FB

As illustrated in 38, the most frequently occurring surface dosage footprint (90%) was less than 10km^2 in size, with 10% between 10 and 40 km^2. Similarly, most (80%) of the resulting surface deposition footprints were less than 10 km^2.

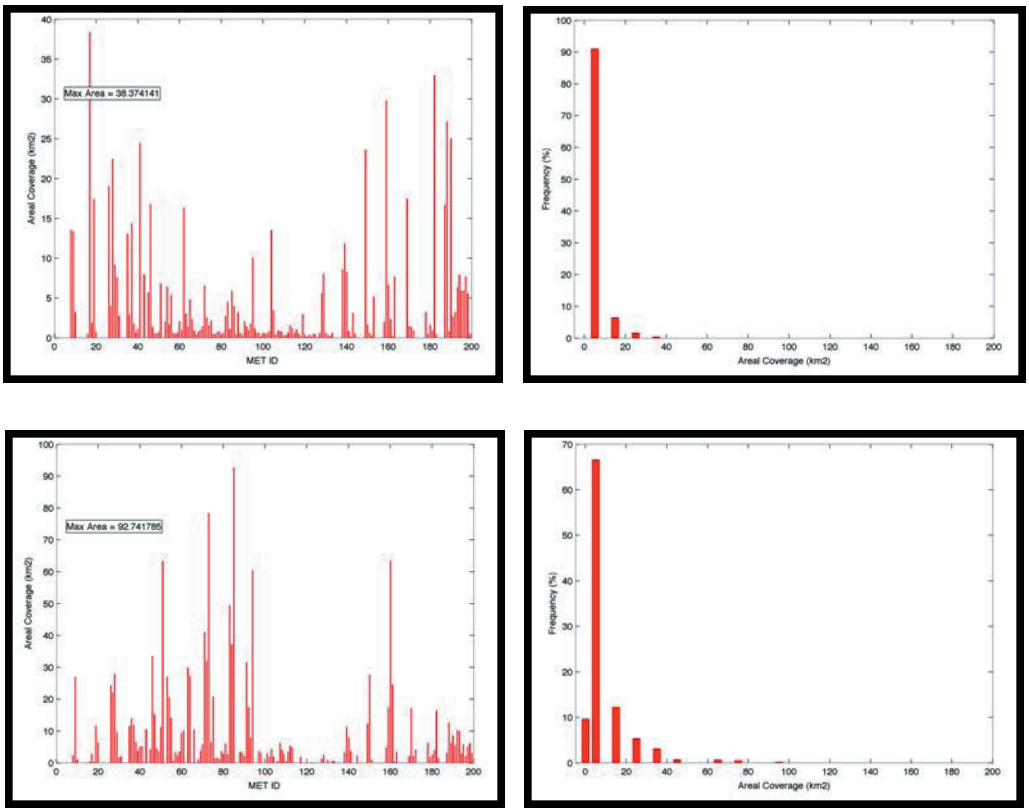

Figure 38. CaseID 1FB time-integrated concentration (PFU-sec/m^3) [TOP ROW] and surface deposition [BOTTOM ROW] areal coverage (km^2), using threshold values of 48.4066 PFU-sec/m^3 and 0.1 PFU/m^2, respectively. Areal coverage vs. each meteorological condition [LEFT COLUMN] and areal coverage frequency histograms [RIGHT COLUMN].

3.4.1.2. CaseID 1FC

As illustrated in Figure 39, and similar to CaseID 1FB, a majority of surface dosage footprints were less than 10 km^2 in size (90%), with a small percentage (10%) between 10 and 40 km^2. Similarly, most of the resulting surface deposition footprints (85%) were less than 10 km^2.

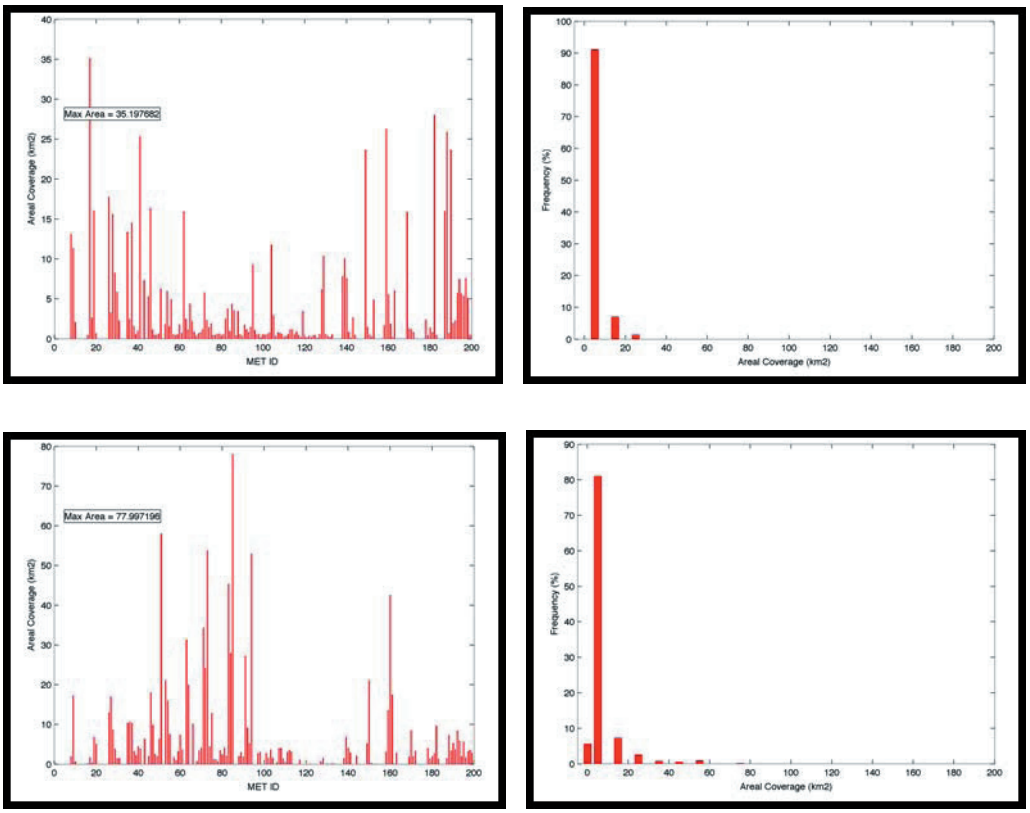

Figure 39. As in Figure 38 for CaseID 1FC

3.4.1.3. CaseID 1RB

As illustrated below, only 38% of the surface dosage footprints were greater than 0 km^2 and less than 1km^2, with the remaining 62% equal to 0 km^2. 100% of the surface deposition patterns were less than the defined threshold value of 0.1 PFU/m^2.

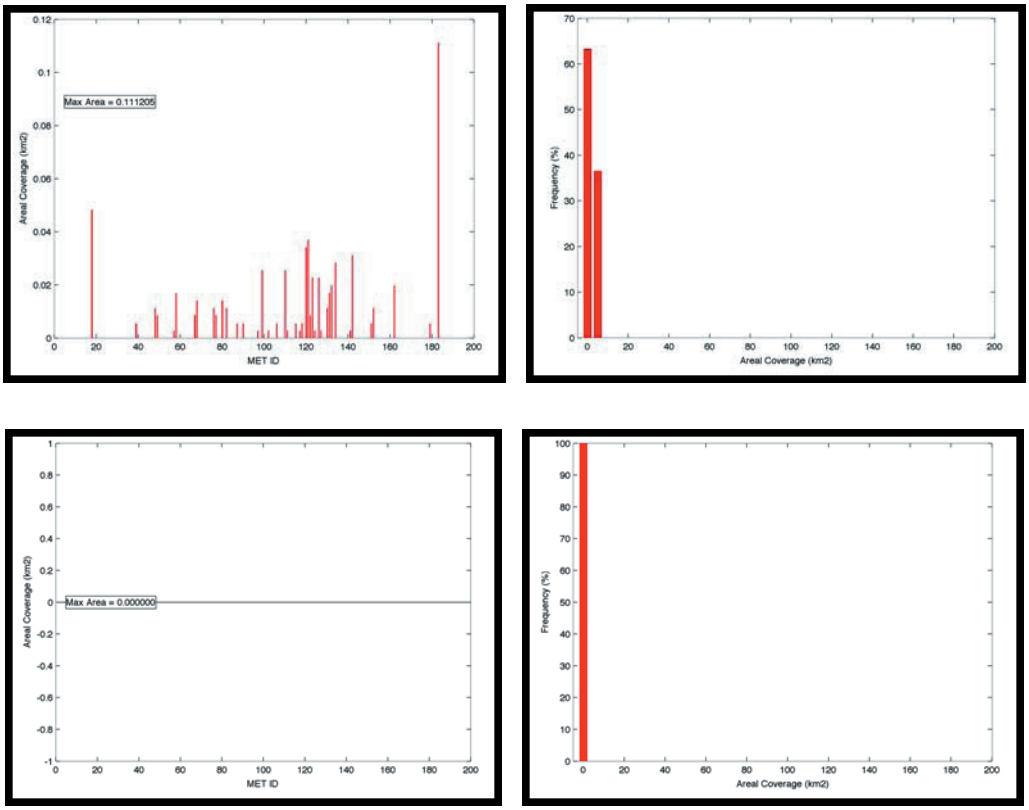

Figure 40. As in Figure 38 for CaseID 1RB

3.4.1.4. CaseID 1RC

Although 100% of the 1RC simulations produced surface dosage footprint less than 1km2, only a tiny percentage (1%) were less than the threshold value. As in CaseID 1RB, 100% of the surface deposition patterns were less than the defined threshold value of 0.1 PFU/m^2.

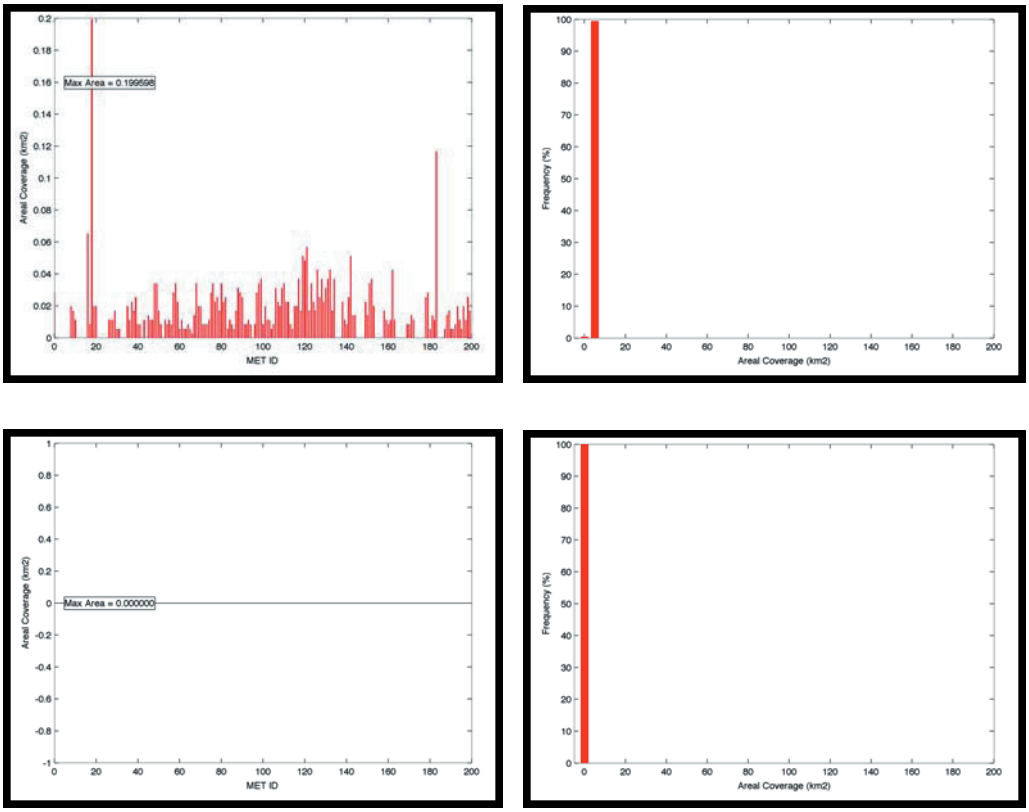

Figure 41. As in Figure 38 for CaseID 1RC

3.4.2. Scenario 5

3.4.2.1. CaseID 5FB

As shown, the majority of simulations produced surface dosage areas less than the dosage threshold (65%), while the remaining 35% only produced areas less than 2 km^2. Surface deposition area sizes ranged from 0 (35%) to ~ 3 km^2 (65%).

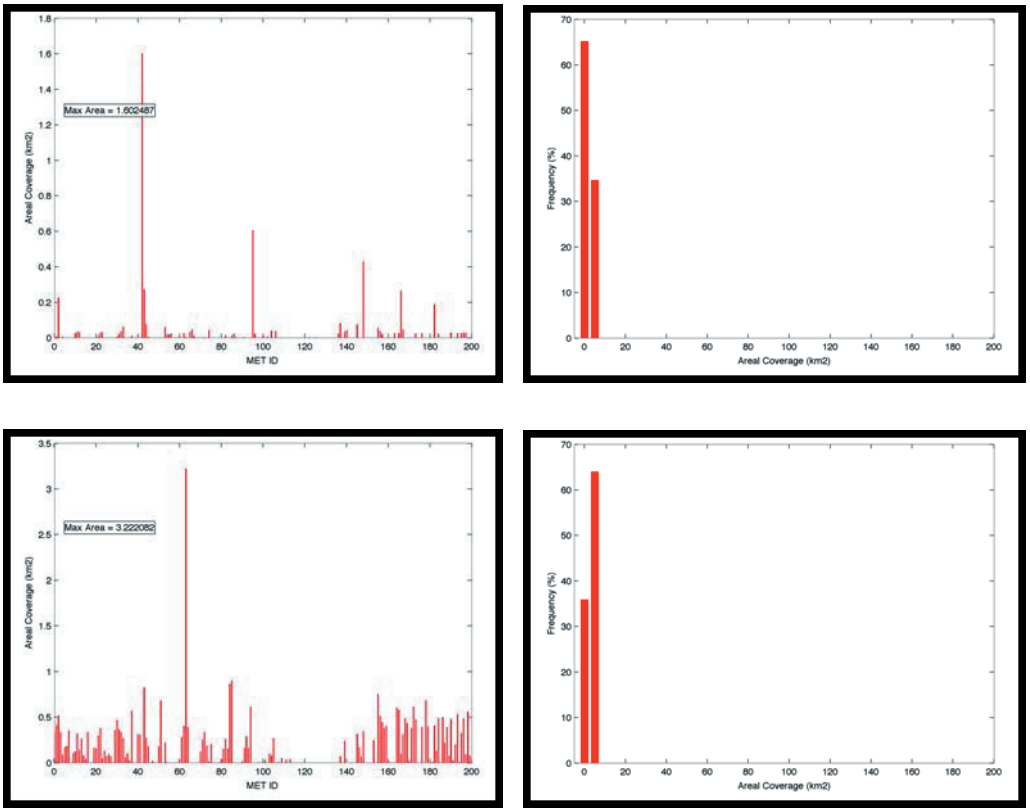

Figure 42. As in Figure 38 for CaseID 5FB

3.4.2.2. CaseID 5RB

Similar to 5FB, the majority of simulations produced surface dosage areas less than the dosage threshold (59%), while the remaining 41% produced areas less than 1 km^2. 100% of the surface deposition patterns were less than the defined threshold value of 0.1 PFU/m^2.

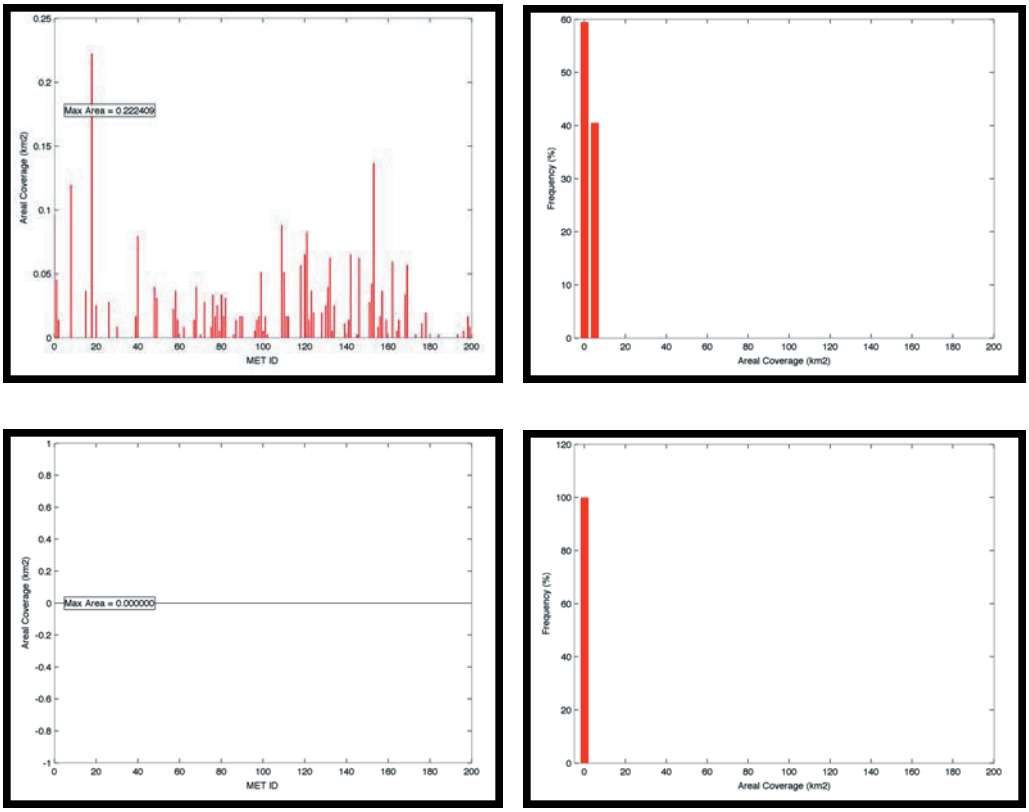

Figure 43. As in Figure 38 for CaseID 5RB

3.4.3. Scenario 6

3.4.3.1. CaseID 6FB

As shown, the majority of simulations produced surface dosage areas less than the dosage threshold (65%), while the remaining 35% produced areas less than 3 km^2. Close to 100% of the surface deposition patterns were less than the defined threshold value of 0.1 PFU/m^2.

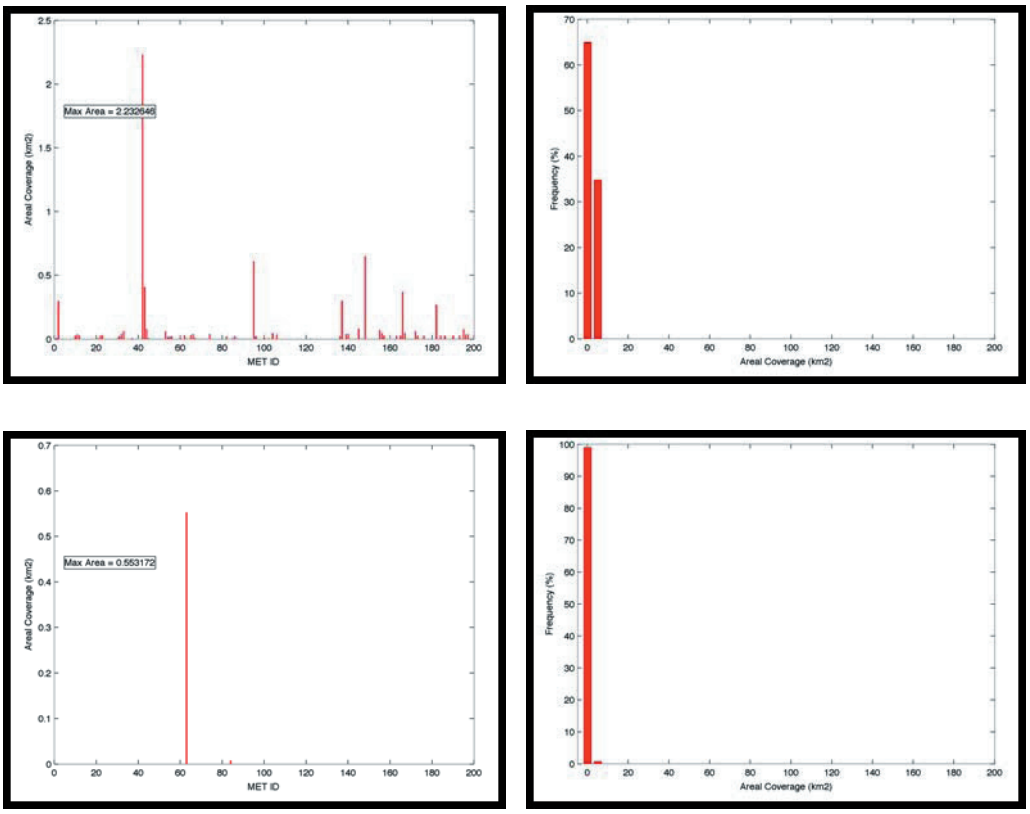

Figure 44. As in Figure 38 for CaseID 6FB

3.4.3.2. CaseID 6RB

As shown, the majority of simulations produced surface dosage areas less than the dosage threshold (59%), while the remaining 41% produced areas less than 1 km^2. 100% of the surface deposition patterns were less than the defined threshold value of 0.1 PFU/m^2.

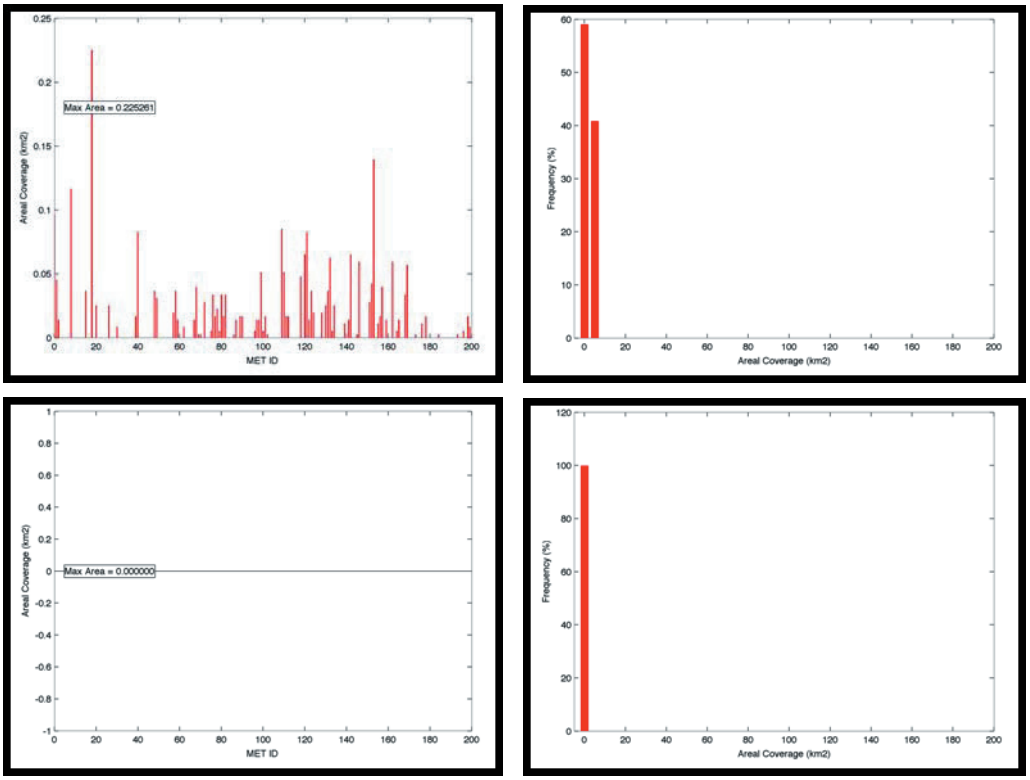

Figure 45. As in Figure 38 for CaseID 6RB

3.4.4. Scenario 7

3.4.4.1. CaseID 7FW

As shown, approximately 93% of the simulations resulted in dosage footprints less than 200 km^2, with the remaining small percentage ranging from 200 to 1000 km^2. Similarly, a majority of the surface deposition footprints were less than 200 km^2 (~90%).

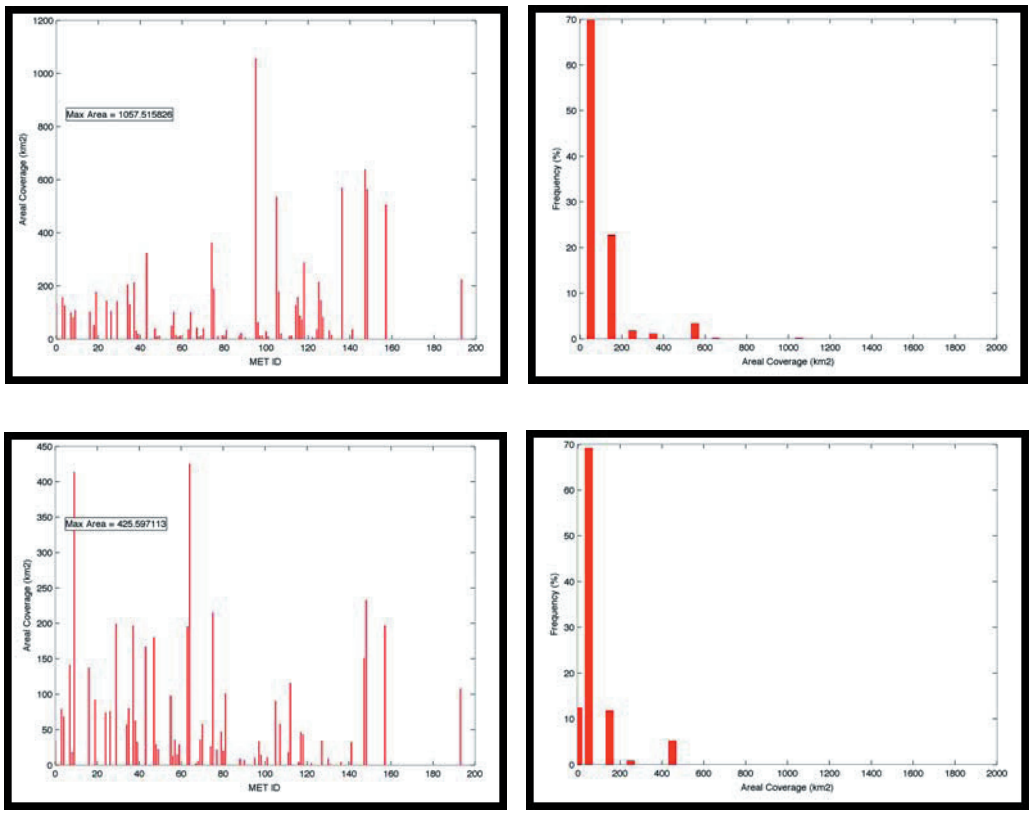

Figure 46. As in Figure 38 for CaseID 7FW

3.4.4.2. CaseID 7FSB

As shown, approximately 70% of the simulations resulted in dosage footprints less than 200 km^2, with the remaining percentage (30%) ranging from 200 to 1000 km^2. Similarly, a majority of the surface deposition footprints were less than 200 km^2 (~90%).

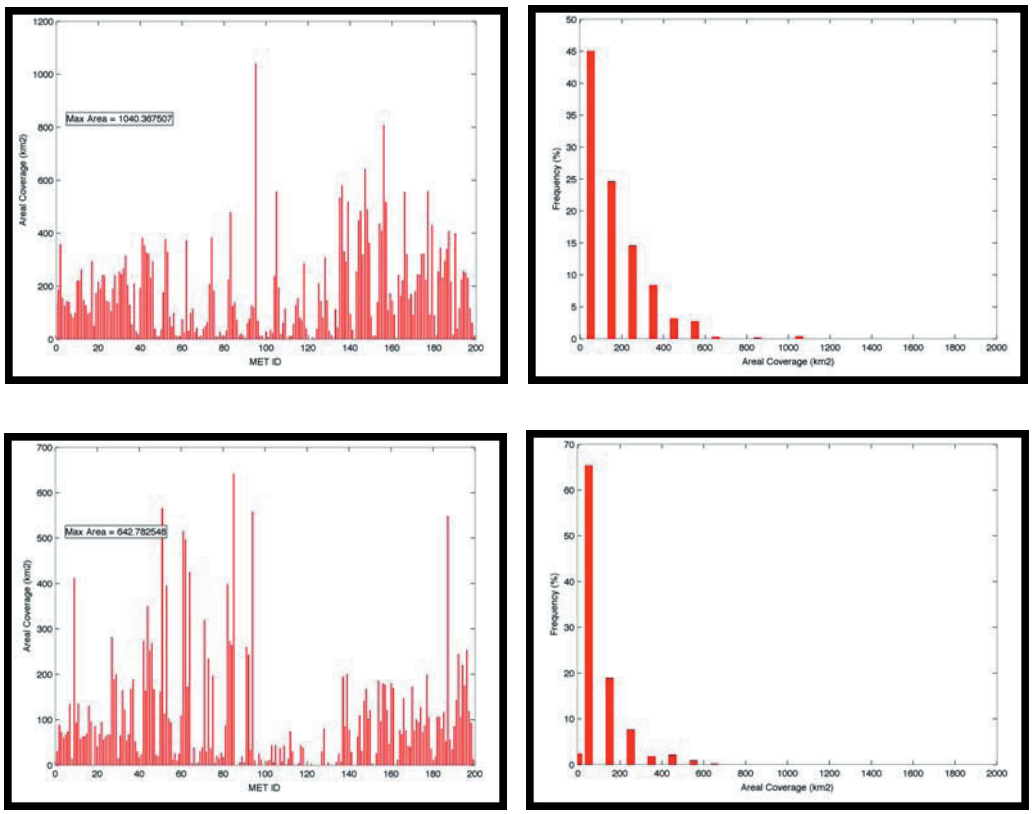

Figure 47. As in Figure 38 for CaseID 7FSB

3.4.4.3. CaseID 7RSB

As illustrated below, 100% of the resulting dosage footprints were less than 1 km^2, while 100% of the surface deposition results were less than the deposition threshold.

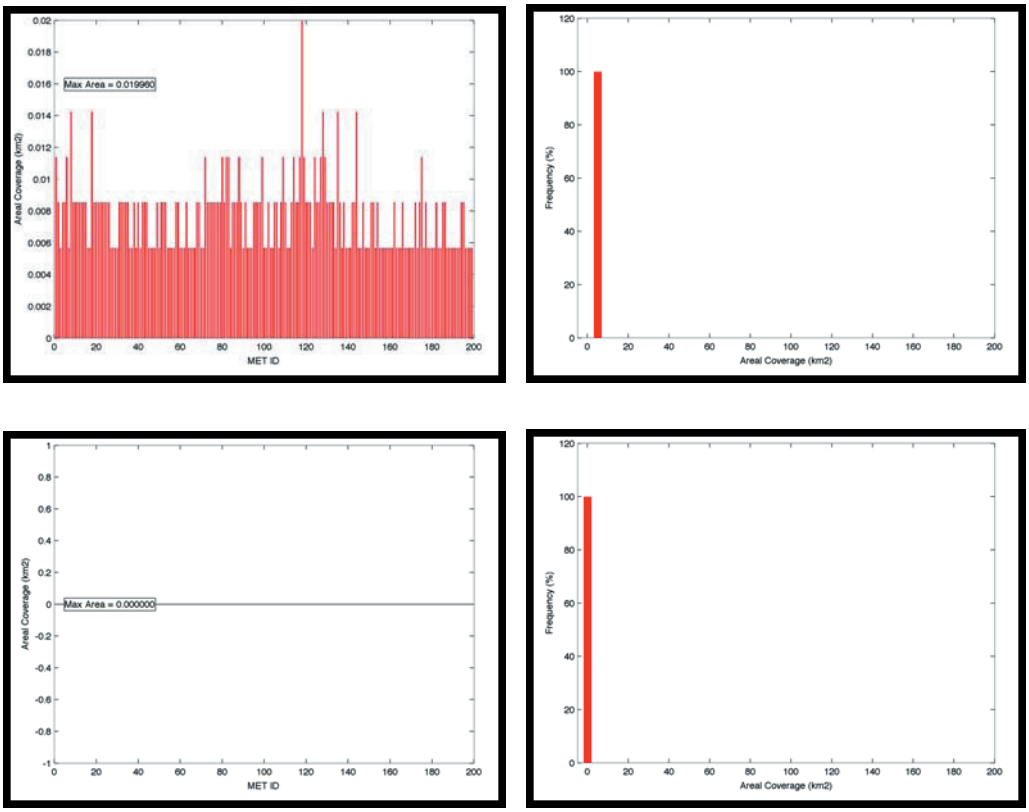

Figure 48. As in Figure 38 for CaseID 7RSB

3.4.5. Scenario 8

3.4.5.1. CaseID 8FA

As illustrated below, 100% of the resulting dosage footprints were less than 1 km^2, while 90% of the surface deposition results were less than 2 km^2.

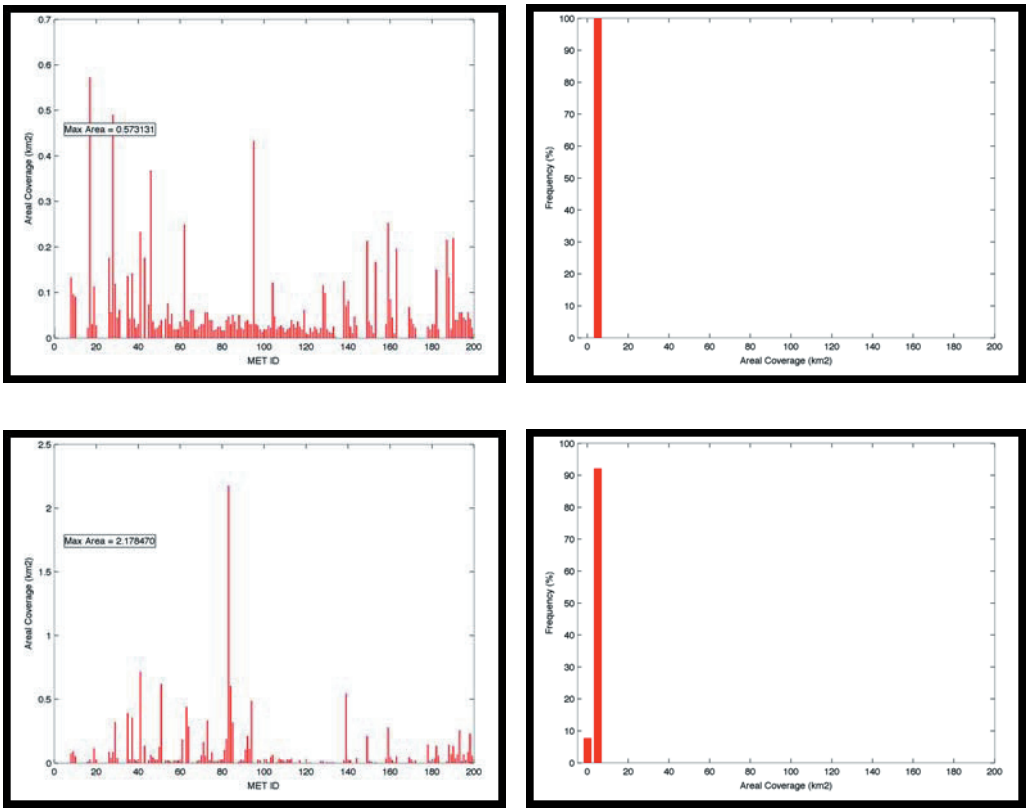

Figure 49. As in Figure 38 for CaseID 8FA

3.4.5.2. CaseID 8RA

As illustrated below, 100% of the resulting dosage footprints were less than 1 km^2, while 100% of the surface deposition results were less than the deposition threshold.

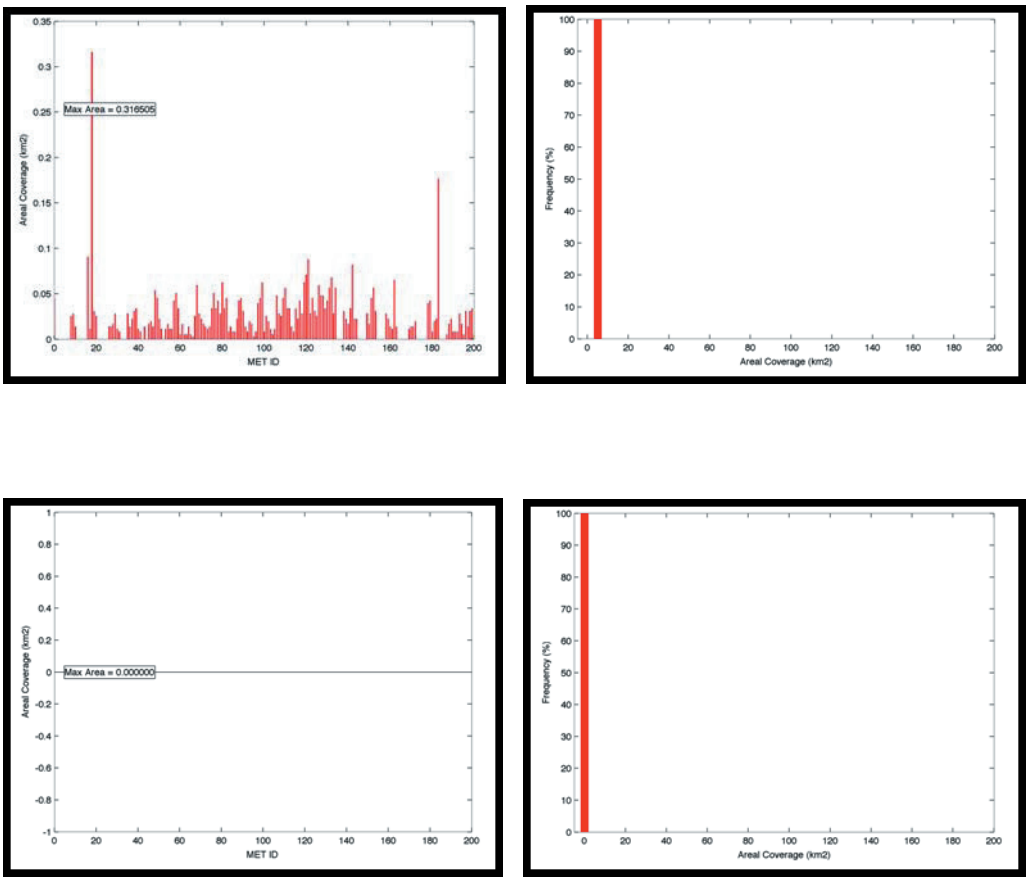

Figure 50. As in Figure 38 for CaseID 8RA

3.4.6. Scenario 11

3.4.6.1. CaseID 11FA

As shown, just over 50% of the simulation results in dosage footprints less than 200 km^2, ~ 20% between 200 and 400 km^2, 15% between 400 and 600 km^2, and the remaining 15% spread between 600 and 2000 km^2. Surface deposition footprints ranged from 0 to 200 km^2 (~60%), 200 to 400 km^2 (~ 10%), 400 to 600 km^2 (~20%), and from 600 to 1100 km^2 (~10%).

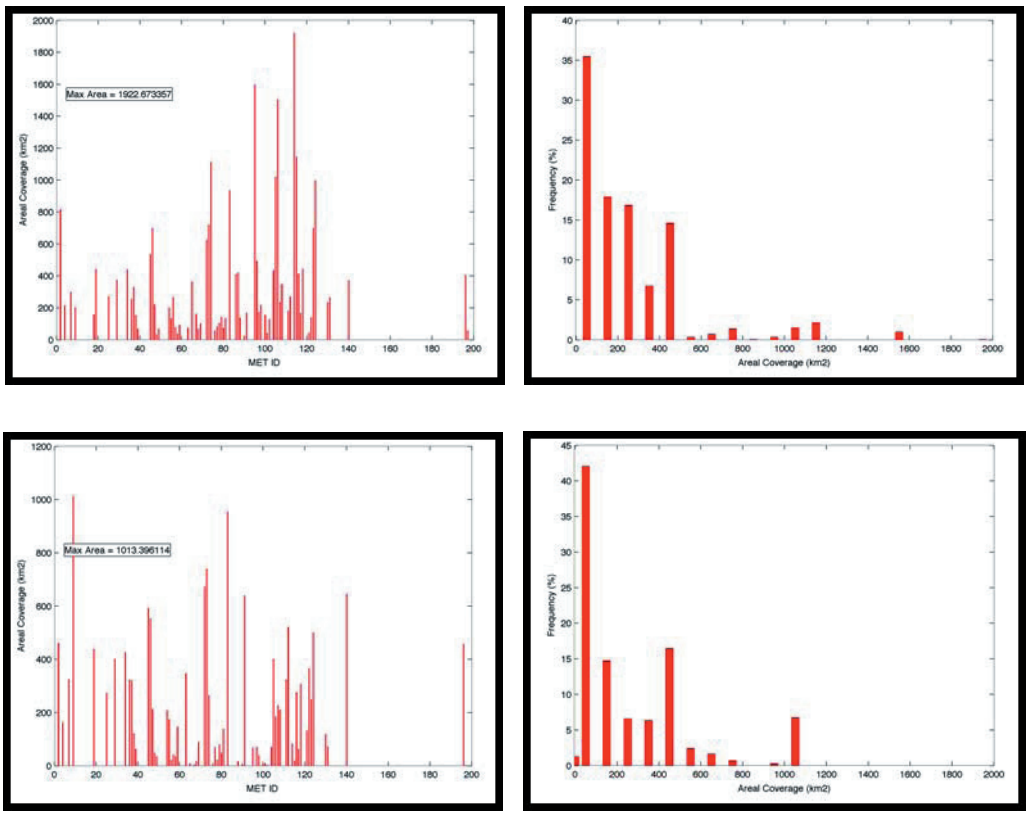

Figure 51. As in Figure 38 for CaseID 11FA

4.0 Summary

In order to estimate the potential health and economic consequences from an accidental or intentional airborne release of pathogen, from the proposed NBAF facility, aerosol fate and transport simulations were performed to estimate downwind pathogen exposure to susceptible animal and human populations. Utilizing aerosol release parameters derived for each airborne transport scenario/pathway, aerosol airborne concentrations and surface depositions were calculated for a range of representative meteorological conditions, for the Manhattan, Kansas region. Resulting inhalation exposure levels and

surface deposition amounts were derived for all surrounding susceptible animal and human population locations, and provided the initial conditions for the determination of any resulting infections and spread of the diseases. For each individual aerosol exposure result, an associated probability of occurrence was provided, based on the relative frequency of the driving meteorological condition. These probabilities were later folded into the final probabilities for each scenario, to determine an overall risk ranking.

A robust analysis of the climatological conditions over the central plains was conducted using a 21-year historical weather database that was specifically designed to support aerosol fate and transport applications. From this analysis, 200 representative weather patterns, and their associated frequency of occurrence, were identified, capturing both the frequently occurring and rare-event weather conditions that are prevalent in the region surround the NBAF.

In addition to the above climatological analysis, a detailed examination of the risks associated with a tornado and high wind event impacting the NBAF facility was performed. The climatological record was examined to characterize the frequencies that tornadoes occur in this region by intensity level. This information was combined with information from peer-reviewed scientific literature to ascertain how often tornados occur as a function of their intensity so that the risk of pathogen containment loss could be estimated and used in the overall SSRA findings. Similarly, the identification and frequencies of high wind events were also determined for the immediate NBAF region. Lastly, the characteristic weather patterns associated with these tornado and high wind events were extracted from the original 200 weather patterns, to determine the likely aerosol transport patterns.

The SCIPUFF model was used to estimate the pathogen dispersion patterns. SCIPUFF is the core dispersion engine inside the DoD's operational HPAC and JEM modeling systems and has been extensively validated for the dispersion of biological pathogens. This model is capable of accurately modeling both the near and far range pathogen dispersion and can incorporate the effects of time-varying meteorology, local effects (e.g. terrain, buildings, land use), and factors that affect the dispersion once the pathogens have been released (e.g. decay, gravitational settling, wet and dry deposition, and evaporation). SCIPUFF model simulations were computed for each of the release event pathway and pathogen type (FMDv and RVFv) over the full spectrum of meteorological conditions derived from the climatological analysis.

The SCIPUFF simulations provided estimates of pathogen concentration time histories and surface deposition, which were then converted into inhalation exposures, based on the location and type of susceptible species. These final inhalation exposure and surface deposition estimates were then passed to the epidemiological models to determine the number of infections, for each release scenario/event pathway and meteorological condition.

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Appendix K: Supporting Epidemiological Modeling Data

(Including file provided electronically: NAADSM Parameters Interviews.xls)

NAADSM Parameters

Sources

Information relevant to determining parameter values for NAADSM was gathered from a wide variety of sources and organized into two tables (provided electronically as "NAADSM Parameters.xls and NAADSM Parameters Interviews.xls") with each row representing a NAADSM modeling parameter and each column representing an information source. Interviews with experts provided additional information about the parameters. These vetted parameters are reviewed in the electronic file entitled NAADSM Parameters Interviews.xls. Sources included:

Table 1: NAADSM Parameters Interviews

- Subject matter experts interviews
- National and local FMD outbreak response plans[33,34,35]
- After action reports from FMD outbreak practice exercises[36,37]
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Table 2: NAADSM Parameters

- Published FMD modeling papers, including a graduate dissertation[38,39,40,41,42,43,44,45,46]

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33 Kansas Animal Health Department. Kansas Incident Specific Plan for Foreign Animal Diseases – Prevention, Preparedness, Response and Recovery. Mar. 2008. Topeka, KS, USA.
34 U.S. Department of Agriculture Animal and Plant Health Inspection Service. (USDA APHIS Foot-and-Mouth Disease Preparedness and Response Plan (FMD-PReP) – Summary Response Plan to the Detection of FMD in the United States (DRAFT). Oct. 2008. Riverdale, MD, USA. Accessed 15 Mar. 2010. <https://fadprep.lmi.org/>.
35 U.S. Department of Agriculture Animal and Plant Health Inspection Service. APHIS Plan Appendix B. Foot-and-Mouth (FMD) Preparedness and Response Plan (PReP) – Federal, State and Local Actions, Timelines, and Responsibilities for Responding to FMD Outbreaks (DRAFT). Oct. 2008. Riverdale, MD, USA. Accessed 1 Apr. 2010. <https://fadprep.lmi.org/>.
36 Giovachino, Monica, Rosemary Speers, Dorothy Morgan, David Catarious, and Elizabeth Myrus. Operation Palo Duro: Policy and Decision-making in Response to an FMD Outbreak. Final Version. May 2007. The CNA Corporation. Accessed 27 Apr. 2010. <https://fadprep.lmi.org/>.
37 SES, Inc. Multi-State Partnership for Security in Agriculture (MSPSA) Functional Exercise After Action Report / Improvement Plan (AAR/IP). Dec. 2009. Topeka, KS, USA.
38 Pendell DL. "Value of Animal Traceability Systems in Managing a Food and Mouth Disease Outbreak in Southwest Kansas." Graduate Dissertation, Kansas State University. 2006.
39 Carpenter TE et al. "A simulation model of intraherd transmission of foot and mouth disease with refrence to disease spread before and after clinical diagnosis." Journal of Veterinary Diagnostic Investigation. 16. 2004.
40 Schoenbaum MA and Disney WT. "Modeling alternative mitigation strategies for a hypothetical outbreak of foot-and-mouth disease in the United States." Preventative Veterinary Medicine. 58. 2003.
41 Ward MP et al. "Simulation of food-and-mouth disease spread within an integrated livestock system in Texas, USA." Preventative Veterinary Medicine. 88. 2009.
42 Bates TW et al. "Description of an epidemic simulation model for use in evaluating strategies to control an outbreak of foot-and-mouth disease." American Journal of Veterinary Research. 64(2). 2003

- NAADSM default modeling parameters [47]
- Summary column of information from Table 1

Determination of parameter values for NAADSM (except starting units)

Published NAADSM parameter values were identified during a literature search of peer-reviewed journals and government reports. All published values were considered and a consensus value selected from the literature. In many cases, the NAADSM default values, which are not necessarily based on the best scientific evidence, were significantly different from values used in peer-reviewed publications and were therefore not included in the selection of the consensus values. In very few cases were the NAADSM default values close to the consensus value used in the model. Because there was a wide variety of parameter values reported in the literature, a sensitivity analysis for each of the parameter values that we did not use in our baseline model was performed to determine the effect on the results (see Sensitivity Analysis Section).

For peer-reviewed publications, parameters were evaluated based on the quality of the source used by the author to determine that parameter. Notional parameters were disregarded if another source was available. Parameters that used experimental data from a peer-reviewed journal article or retrospective analysis of a recent FMD outbreak were used over parameters based on a single subject matter expert interview. If any one source was found to be exemplary in its analysis of a particular value, that value was preferentially used. For example, in the case of disease transition state parameters (such as, latent period for Cow-Calf product type) a thorough meta-analysis of all previous primary source literature was performed in Mardones 2010, so the parameter listed in this paper was used as the NAADSM parameter. [48]

The best sources as determined by the criteria listed above were used to determine the NAADSM parameter value:

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43 Ward MP et al. "The Potential role of wild and feral animals as reservoirs of foot-and-mouth disease." Preventative Veterinary Medicine. 80. 2007.

44 Mardones F, Perez A, Sanchez J, Alkhamis M, Carpenter T. Parameterization of the duration of infection stages of serotype O foot-and-mouth disease virus: an analytical review and meta-analysis with application to simulation models. Vet Res. 41(4). 2010

45 Yoon H et al. “Simulation analyses to evaluate alternative control strategies for the 2002 foot-and-mouth disease outbreak in Republic of Korea.” Preventive Veterinary Medicine. 74. 2006.

46 Elbakidze L et al. “Economics Analysis of Mitigation Strategies for FMD Introduction in Hightly Concentrated Animal Feeding Regions.” Applied Economic Perspectives and Policy 31(4). 2009.

47 Harvey N., Reeves A., Schoenbaum M.A., Zagmutt-Vergara F.J., Dube C., Hill A.E., Corso B.A., McNab B., Cartwright C.I., & Salman M.D. (2007) The North American Animal Disease Spread Model: A simulation model to assist decision making in evaluating animal disease incursions. Preventative Veterinary Medicine. 82, 176-197.

48 Mardones F, Perez A, Sanchez J, Alkhamis M, Carpenter T. Parameterization of the duration of infection stages of serotype O foot-and-mouth disease virus: an analytical review and meta-analysis with application to simulation models. Vet Res. 41(4). 2010

- For single point values, all best source values were averaged to determine the NAADSM parameter.
- For probability distribution functions all best source functions that were not triangular distributions were converted into the triangular format (triangular(a,b,c)) by estimating what the equivalent triangular function would be, where a is the minimum value, b is the point at which the maximum probability occurs and c is the maximum value). An average was found at points a,b and c and the consensus function was given as a triangular distribution. Where there was a single best source with a non-triangular distribution function, the best source function was used. Where the majority of best sources for a parameter listed the same function that function was used and an average value was not found.

Values were identified for sensitivity testing:

- For single point values, the maximum and minimum values described by the best sources were tested as part of the sensitivity analysis when multiple values were described and when there was a significant range between the maximum and minimum value.
- For probability distribution functions, those functions listed by best sources that were significantly different at any one point were tested.

NAADSM Transit Data

Purpose

The purpose of the NAADSM model is to predict the epidemiological fallout from a range of scenarios that could result in the release of FMDv from the NBAF in Manhattan, KS. The model also includes many of the states surrounding Kansas in its initial analysis of disease spread. However, given the flow of livestock across state lines, there is the potential for an infected animal to be transported out of the primary study region and into other regions of the country. To account for this, animal in-shipment and out-shipment data was analyzed to calculate the probability that cattle or swine would be transported from any state in the primary region to any state in a secondary region. This information was used to generate add-on models that would simulate a foreign animal disease in a secondary region if triggered by livestock movement during initial model runs.

Determining State Regions

The first task was to determine which states other than Kansas were of interest for the model. This was accomplished by reviewing the *Interstate Livestock Movements* report[49], which showed the distribution of cattle and swine across the United States. From this distribution map, regions were drawn around states with the greatest numbers of cattle and swine. The resulting primary region consisted of states near to, and including Kansas. These states were Kansas, Oklahoma, Nebraska, Iowa, Missouri, Colorado, Texas, Arkansas, South Dakota, Minnesota, and Wisconsin. The secondary states were states that were not close or bordering Kansas, but had significant numbers of cattle or swine that would be of a concern

49 Shields, Dennis A., Mathews, Jr., Kenneth H. “Interstate Livestock Movements.” Economic Research Service, USDA. June 2003. Accessed 15 Mar. 2010.Available: <http://www.ers.usda.gov/publications/ldp/jun03/ ldpm10801/ldpm10801.pdf>.

during a foreign animal disease outbreak. The secondary states included California, Florida, North Carolina, Illinois, Indiana, Ohio, Michigan, Pennsylvania, and Kentucky.

Collecting Animal Shipment Data

If available, livestock out-shipment data was collected from the primary states and in-shipment data from the secondary states because only the unidirectional flow of livestock from any primary state to any secondary state was necessary for the model. Cattle and swine movements between primary states, between secondary states, and from secondary states to primary states were not considered for this task.

To obtain the most current and reliable information available, the majority of the final data was collected via personal correspondence with the individual states. From telephone and email correspondence with animal industry and agricultural departments, complete in-shipment and/or out-shipment data sets were gathered from both primary and secondary states, as listed below in **Table 1**. When both in-shipment and out-shipment data was available for any state, in-shipment data was used preferentially for the final data set, as states may record the number of animals coming into a state with more accuracy than those leaving the state.[50] Additionally out-shipment data for Wisconsin[51] was obtained from the state National Agricultural Statistics Service (NASS) field office. However, not all states maintain such records or have them available, so there were some data gaps.[52]

Table 1: Sources for cattle shipment data by state

State	Type of Data	Source
Pennsylvania	In-shipment	Bureau of Animal Health and Diagnostic Services, Pennsylvania Department of Agriculture
Michigan	In-shipment	Animal Industry Division, Michigan Department of Agriculture
Kentucky	In-shipment	Office of the State Veterinarian, Kentucky Department of Agriculture
Illinois	In-shipment	Illinois Department of Agriculture
Indiana	In-shipment	Indiana State Board of Animal Health
North Carolina	In-shipment	Veterinary Division, North Carolina Department of Agriculture and Consumer Services
California	In-shipment	California Department of Food and Agriculture
South Dakota	Out-shipment	South Dakota Animal Industry Board

50 Shields, Dennis A., Mathews, Jr., Kenneth H. “Interstate Livestock Movements.” Economic Research Service, USDA. June 2003. Accessed 15 Mar. 2010.Available: <http://www.ers.usda.gov/publications/ldp/jun03/ ldpm10801/ldpm10801.pdf>.

51 USDA National Agricultural Statistics Service, Wisconsin Field Office. “Wisconsin Agricultural Statistics.” August 2009. Accessed 26 Mar. 2010.Available: <http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/ Annual_Statistical_Bulletin/09as_inside3web.pdf>.

52 Personal correspondence with state departments in Kansas, Oklahoma, Nebraska, Iowa, Missouri, Colorado, Arkansas, Wisconsin, Florida, and Ohio.

Table 1: Sources for cattle shipment data by state		
State	Type of Data	Source
Minnesota	In-shipment and Out-shipment	Minnesota Board of Animal Health
Texas	In-shipment and Out-shipment	Program Records Department, Texas Animal Health Commission
Wisconsin	Out-shipment	USDA National Agricultural Statistics Service, Wisconsin Field Office

The next source of information used to determine many of the missing values was the *Interstate Livestock Movements* report.[53] This was the more comprehensive source of information, but the majority of its data was from 2001 [54], making it less current than the values obtained directly from the states. This report contained the numbers of cattle and swine moved from any state in the U.S. to any other state; however, this data set was generated from individual state sources. This was problematic, as some states did not have in-shipment data available. To address this problem the report tallied the out-shipments to any particular state as a way to record the number of livestock imports a state received if that state did not have in-shipment information available.[55] However, some states lacked both out-shipment and in-shipment data, or only had data for cattle but not swine and vice-versa.[56] As a result, even after generating a state's in-shipment data from other states' out-shipment data there were numerous gaps in this data set. Additionally the report failed to indicate which data was actually in-shipment data and which was a summation of other states' out-shipment data, so there was no easy way to distinguish which data was the most accurate. Thus it was only used to determine the values that could not be obtained from personal correspondence with the states themselves.

53 Shields, Dennis A., Mathews, Jr., Kenneth H. "Interstate Livestock Movements." Economic Research Service, USDA. June 2003. Accessed 15 Mar. 2010.Available: <http://www.ers.usda.gov/publications/ldp/jun03/ ldpm10801/ldpm10801.pdf>.
54 Extrapolated from Shields, Dennis A., Mathews, Jr., Kenneth H. "Interstate Livestock Movements." Economic Research Service, USDA. June 2003. Accessed 15 Mar. 2010.Available: <http://www.ers.usda.gov/publications/ldp/jun03/ ldpm10801/ldpm10801.pdf>.
55 Shields, Dennis A., Mathews, Jr., Kenneth H. "Interstate Livestock Movements." Economic Research Service, USDA. June 2003. Accessed 15 Mar. 2010.Available: <http://www.ers.usda.gov/publications/ldp/jun03/ ldpm10801/ldpm10801.pdf>.
56 Extrapolated from Shields, Dennis A., Mathews, Jr., Kenneth H. "Interstate Livestock Movements." Economic Research Service, USDA. June 2003. Accessed 15 Mar. 2010.Available: <http://www.ers.usda.gov/publications/ldp/jun03/ ldpm10801/ldpm10801.pdf>.

In-shipment Estimates

After collecting both in-shipment and out-shipment data as described above there were still a few values that remained unknown, and so a method had to be established to generate these values. Since data was available on the total number of 2008 in-shipments for all secondary states[57], it was determined that these values could be multiplied by the percent of total U.S. cattle and swine each primary state contained. For example, if Missouri had 4.62% of the nation's swine, then it would account for 4.62% of California's total hog in-shipments. Knowing that California imported 59,000 swine in 2008[58], then using this formula Missouri should have out-shipped 2,726 swine to California.

To determine the percent of total U.S. cattle and swine within primary state, the total number of these animals in the U.S. as of January 1, 2008 or December 1, 2007, respectively, was divided by the total number of cattle and swine in each individual primary state as of 2008 or 2007.[59,60] This assumed that the percentage of U.S. total cattle or swine that a primary state contained would be equivalent to the percentage of its in-shipments each secondary state received from that state.

Evaluating Estimates

The method for obtaining estimates of the movement of cattle and swine required certain assumptions, most notably that the percent of livestock that a state owned would be equivalent to the percent of its total in-shipments a second state received from that first state. However, there might have been regional or international flows that came into play. For example, Indiana imported 279,035 hogs from Canada in 2008[61]; however, the calculations of the percentage of livestock each primary state had was based on the total number of U.S. cattle, and did not take into account the numbers of cattle that came sources outside the U.S.

With this in mind, it was necessary to compare these estimates to real values obtained from NASS or personnel correspondence data. Therefore, for those data points that had both real values from actual

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57 Agricultural Statistics Board. "Meat Animals Production, Disposition, and Income: 2008 Summary." USDA National Agricultural Statistics Service. May 2009. Accessed 15 Mar. 2010. Available: <http://usda.mannlib.cornell.edu/usda/current/MeatAnimPr/MeatAnimPr-05-29-2009.pdf>.
58 Agricultural Statistics Board. "Meat Animals Production, Disposition, and Income: 2008 Summary." USDA National Agricultural Statistics Service. May 2009. Accessed 15 Mar. 2010. Available: <http://usda.mannlib.cornell.edu/usda/current/MeatAnimPr/MeatAnimPr-05-29-2009.pdf>.
59 USDA National Agricultural Statistics Service. "U.S. & All States Data - Cattle All." USDA-NASS Quick Stats. Accessed 25 Mar. 2010. Available: <http://www.nass.usda.gov/QuickStats/PullData_US.jsp>.
60 USDA National Agricultural Statistics Service. "U.S. & All States Data - Hogs and Pigs." USDA-NASS Quick Stats. Accessed 25 Mar. 2010. Available: <http://www.nass.usda.gov/QuickStats/PullData_US.jsp>.
61 USDA National Agricultural Statistics Service, Indiana Field Office. "Livestock." Indiana Agricultural Statistics. 2008-2009 ed. Accessed 17 Mar. 2010. Available: <http://www.nass.usda.gov/Statistics_by_State/Indiana/Publications/Annual_Statistical_Bulletin/0809/livestock_all.pdf>.

data sets and estimates, the difference between the estimates and real values was divided by the real values. This number equaled the fold difference between the estimated values and the true values. Reviewing these fold differences allowed the SSRA team to determine how accurate the estimates were, as the closer the fold difference was to zero, the more closely the estimate was to the real value received from NASS or personal correspondence.

Deriving the Probability of Livestock Movement

Once the data set containing the numbers of cattle and swine that were moved interstate was complete it was necessary to determine the probability of cattle and swine in each primary state moving to each secondary state.[62] To do this the numbers of cattle and swine that any primary state moved to any secondary state was divided by the total number of cattle or hogs in each primary state. These annual probabilities were then divided by 365 to create a chart of the daily probability of livestock movement among states. These values for cattle are presented below in Table 2.

Table 2. The probability that any bovine will move from a primary state of origin (rows) to a secondary state of destination (columns) daily.

State of Origin	Pennsylvania	Indiana	Ohio	Michigan	Kentucky	North Carolina	Florida	California	Illinois
Kansas	6.09E-09	1.01E-06	5.56E-08	6.62E-07	4.48E-08	1.61E-08	3.43E-07	2.89E-06	4.30E-07
Missouri	4.51E-09	1.64E-06	1.48E-06	5.16E-07	7.95E-07	2.77E-08	1.44E-07	8.19E-08	6.26E-06
Nebraska	1.79E-06	1.03E-07	1.48E-06	7.16E-08	6.13E-08	9.92E-09	1.02E-07	5.78E-06	7.75E-07
Colorado	3.86E-07	6.07E-06	1.48E-06	8.22E-07	6.32E-09	1.69E-08	2.72E-07	6.06E-06	2.40E-06
South Dakota	6.29E-08	4.44E-08	4.78E-07	6.15E-08	8.15E-08	9.63E-09	2.86E-07	1.94E-06	3.70E-06
Minnesota	6.35E-07	1.23E-07	5.62E-07	9.01E-07	3.11E-07	8.33E-08	3.42E-09	5.31E-07	6.16E-08
Iowa	4.22E-07	2.65E-06	1.65E-07	1.43E-06	1.48E-07	9.71E-08	1.09E-07	1.95E-06	5.90E-06
Oklahoma	4.41E-08	7.08E-07	1.48E-06	6.09E-08	1.17E-07	1.23E-07	6.35E-07	2.69E-06	5.78E-08
Texas	5.84E-09	9.43E-07	4.69E-08	3.70E-07	5.12E-07	1.31E-07	1.03E-06	7.63E-06	2.03E-07
Arkansas	6.05E-09	1.24E-06	9.00E-07	4.34E-07	1.67E-08	3.12E-07	1.05E-07	2.88E-08	3.07E-07
Wisconsin	3.64E-06	1.46E-05	4.62E-06	4.78E-06	6.00E-07	1.14E-08	1.22E-07	2.15E-07	1.91E-05

Also, because Kansas was the focal state the probability of cattle movement from Kansas to Wisconsin and Minnesota was calculated, even though they were primary states. These values are presented in Table 3.

62 This number does not include animals destined for immediate slaughter. Sources: Agricultural Statistics Board. "Meat Animals Production, Disposition, and Income: 2008 Summary." USDA National Agricultural Statistics Service. May 2009. Accessed 15 Mar. 2010. Available: <http://usda.mannlib.cornell.edu/usda/current/MeatAnimPr/MeatAnimPr-05-29-2009.pdf>. For state sources, refer to Table 1.

Table 3: The probability that any bovine will move from Kansas to any secondary state, Wisconsin, or Minnesota daily										
Pennsylvania	Indiana	Ohio	Michigan	Kentucky	North Carolina	Florida	California	Illinois	Minnesota	Wisconsin
6.09E-09	1.01E-06	5.56E-08	6.62E-07	4.48E-08	1.61E-08	3.43E-07	2.89E-06	4.30E-07	1.06E-06	2.62E-06

These calculations had to take into account the multitude of years that the movement data came from and that swine and cattle inventories are not done at the same time of year. Cattle inventory to determine state totals is performed on January 1 of each year, while the swine inventory is performed on December 1. Since December 1 of the previous year is closer to January 1 than December 1 of that same year, swine movement data was matched with the inventory for the previous year, while cattle movement data was matched with the inventory from the same year (e.g. if the number of cattle moved was taken from 2005 data, the January 2005 NASS cattle inventory total was used; if the number of swine moved was from 2005 data, the December 2004 NASS swine inventory total was used). Using this method ensured that each animal movement data value was divided by the most accurate state inventory for the year it was pulled from to obtain the most accurate probability of livestock transport possible.

Estimating the Numbers of Infectious Cattle that Move to Secondary States

Using the NAADSM model outputs of the numbers of newly infected animals[63] per day for a given outbreak scenario, the number of Kansas cattle that were transported to any secondary state can be calculated. For each day of an outbreak the cumulative total of infected cattle was multiplied by the probability of an animal going to any given state (recorded in Table 3), which resulted in the number of infected animals that had been transported to any secondary state at each day. The number of infected animals that were moved from Kansas into a secondary state as of the day of the first detection of the disease in Kansas could then be used to model the start of an outbreak in that secondary state.

Vector Data

Estimating Mosquito Bite Rate

The experimental methodology for assessing mosquito bite rate varies widely. First, mosquitoes are either trapped or counted in real time. Typical trapping experiments include a host-baited trap (i.e. human- or bovine-baited) or a CO_2-baited miniature light trap. Typical real time experiments involve either an exposed human who makes a count of mosquitoes attracted to him or an exposed test animal with a human counter close by to count attracted mosquitoes. Each of these methods has drawbacks and advantages. For baited trap experiments (host or CO_2) mosquitoes are typically allowed to fly into a trap and then are unable to fly out. At set intervals all mosquitoes are removed from the trap, typically with a vacuum apparatus. The researcher may then simply count the total number of mosquitoes in the enclosure, count the total number of female mosquitoes in the enclosure, count only one specific

[63] The number of newly infected animals includes both swine and cattle. However, because the number of infected swine is relatively low compared to that of cattle, for the purpose of modeling cattle transit they were included in the total number of infected animals.

species of mosquito in the enclosure or count the number of engorged mosquitoes in the enclosure. Data are typically reported as a bite rate, regardless of methodology. CO_2-baited traps have been shown to result in some bias in the species collected, as certain species are more reliant on CO_2 for finding a host. In the case of real-time experiments, with an exposed host, each mosquito that lands is counted or each mosquito that bites is counted. Again, both types of experiments may be reported as a bite rate.

Engorgement Rate

As many studies report a landing rate instead of a bite rate it was necessary to determine how often a mosquito bites a host. A study, which investigated efficacy of different insecticide treatments for cattle, counted the number of engorged and non-engorged female mosquitoes of a specific species that were trapped on an untreated or treated cow. Mosquitoes were given 10 minutes post-trapping in a cattle-baited trap to finish feeding before being collected (data summarized in **Table 4)**. This data was used to calculate an average engorgement rate, which was used in conjunction with experimental data for trapping rate to calculate a bite rate. It was estimated that about 88% of trapped *Aedes* spp. mosquitoes are engorged.[64] It was assumed that other species of mosquitoes were engorged at a similar proportion, as specific data was not found.

Table 4. Engorged and Non-Engorged Mosquito Counts for Control Animals in an Insecticide Efficacy Study.[65]

Mosquito	Engorged	Non-engorged	% Total Population Engorged
Aedes melanimon Test 1	184.3 ±115.5	9.7 ± 4.0	95%
Aedes melanimon Test 2	327.0 ± 270.4	52.7 ± 66.3	86%
Aedes melanimon Test 3	177.3 ± 70.4	19.7 ± 18.5	90%
Aedes melanimon Test 4	164.0 ± 26.2	18.7 ± 14.2	90%
Aedes dorsalis Test 1	90.7 ± 54.5	7.0 ± 4.0	93%
Aedes dorsalis Test 2	95.0 ± 44.3	37.7 ± 53.2	72%
Aedes dorsalis Test 3	83.3 ± 50.1	8.7 ± 6.7	91%
Aedes dorsalis Test 4	33.0 ± 15.7	6.0 ± 7.0	85%

Human Bite Rate

Data was collected from multiple sources to calculate an approximate bite rate over a 24-hour period for humans in Kansas (**Table 5**). More weight was given to studies conducted in close proximity to Kansas or in a similar climate. The most accurate data was assumed to come from experiments where data was derived from exposed humans reporting bite number over a period of time. The drawback to this type of experiment is that the period of exposure is typically very short, usually from 1 to 5 minutes, resulting in a large margin of error when the data is used to extrapolate a bite rate over a 24-hour period. While several papers were found that report the mosquitoes' attraction to human hosts, only a

64 Schmidtmann ET et al. "Suppression of Mosquito (Diptera: Culicidae) and Black Fly (Diptera: Simuliidae) Blood Feeding from Hereford Cattle and Ponies Treated with Permethrin."Journal of Medical Entomology. 38(5). 2001.

65 Schmidtmann ET et al. "Suppression of Mosquito (Diptera: Culicidae) and Black Fly (Diptera: Simuliidae) Blood Feeding from Hereford Cattle and Ponies Treated with Permethrin."Journal of Medical Entomology. 38(5). 2001.

few papers reported data in such a way that a bite rate per 24-hours or a landing rate per 24-hours could be extrapolated. The high end of the bite rate was derived from a study of mosquito landings on summer campers that extrapolates to 3,347 bites per 24-hours (approximately 139 per hour) if the group of humans were near a water source at dusk and took no anti-mosquito precautions. A lower bite rate was derived from an Alaska study involving humans wearing mosquito repellant that reported 86.4 bites per 24-hours (3.6 bites per hour).

Table 5. Literature Summary for Mosquito Trapping, Landing and Biting Experiments With Human-Baited Traps

Mosquito	Host	"Bites"/24 hours	Method	Season; Location
Aedes spp. & *Ochlerotatus* spp.[66]	Human	3,984 Landings (would probably be less due to time count was taken)	Landing counts for 5 min at dusk	June-August; Lake side campsite, Wisconsin
Aedes spp. & *Ochlerotatus* spp.[67]	Human wearing insect repellant	2,352 Landings (would probably be less due to time count was taken)	Landing counts for 5 min at dusk	June-August; Lake side campsite, Wisconsin
Probably *Culiseta impatiens*[68]	Human	28,495 Bites (high error, projected from several minute long exposures)	Bite counts	June; Alaska
Probably *Culiseta impatiens*[69]	Human wearing 35% DEET	86.4 Bites	Bite counts	June; Alaska

Cow Bite Rate

For the purposes of the RVF model, it was important to determine the number of bites per 24-hours a cow receives in Kansas. Based on the data in **Table 6,** assuming that 88% of landings would result in a bite, it could be estimated that cattle could experience 4,000-6,000 bites per 24-hours. However, CO_2-baited traps collected in Kansas after a flood documented considerably fewer mosquitoes (**Table 7**). The average number of mosquitoes trapped per night (16 hour period) was 144 (the total of all mosquitoes collected each night either by light or gravid traps summarized in **Table 7**), while the number trapped per night that could potentially transmit RVFv was estimated to be 126 based on the species reported[70]. Based on this 16-hr data, it was estimated that the 24-hr rates would be 216 mosquitoes with 189 potentially able to transmit RVFv. The difference between the animal study (**Table 6**) and the light and

66 Boulware DR. "Passive Prophylaxis with Permethrin-Treated Tents Reduces Mosquito Bites Among North American Summer Campers." Wilderness and Environmental Medicine. 16. 2005.
67 Boulware DR. "Passive Prophylaxis with Permethrin-Treated Tents Reduces Mosquito Bites Among North American Summer Campers." Wilderness and Environmental Medicine. 16. 2005.
68 Lillie TH. et al. "Effectiveness of Personal Protection Against Mosquitoes in Alaska." J. Med. Entomol. 25(6). 1988.
69 Lillie TH. et al. "Effectiveness of Personal Protection Against Mosquitoes in Alaska." J. Med. Entomol. 25(6). 1988.
70 Harrison BA. et al. "Rapid assessment of Mosquitoes and Arbovirus Activity after Floods in Southeastern Kansas, 2007." J Am Mosquito Contol Assoc. 25(3). 2009.

gravid trap study (**Table 7**) may be due to the ability of a cow to produce significant amounts of CO_2 and thus attract more mosquitoes.

Table 6. Literature summary for mosquito trapping, landing and biting experiments with either bovine- or CO_2-baited traps

Mosquito	Host	"Bites"/24 hours	Method	Season; Location
Aedes spp., *Culex* sp., *Culiseta* sp.[71]	Hereford Heifer Calf	10,070 trapped	Bovine baited trap	June-August; Flooded Riverside, Wyoming
Aedes spp., *Culiseta* sp.[72]	Hereford Heifer Calf	7,082 trapped (1% male)	Bovine baited trap	July; Riverside, Wyoming
Aedes spp., *Culiseta* sp.[73]	None	38,646 trapped	CO_2-baited miniature light trap	July; Riverside, Wyoming
Probably *Aedes* spp. & *Ochlerotatus* spp.[74]	None	1,800 trapped (900 at night, assumed night=12 hrs)	CO_2-baited miniature light trap	June; Unpopulated Lake side campsite, Wisconsin
Psrophora spp.,[75] *Culex* spp., *Anopheles* spp.	CO_2-baited trap	5,136 trapped	trapped	April-October; Acadia Parish, LA near large cattle herds
Psrophora spp.,[76] *Culex* spp., *Anopheles* spp.	CO_2-baited trap	3,214 trapped	trapped	April-October; Jefferson Parish, LA near urban with a mosquito control program ongoing

Table 7. Mosquitoes trapped in CO_2-baited traps in southwestern Kansas during a flood, bolded species suspected to carry RVF

	Light Traps		Gravid traps	
Species	**Total No. Collected for 62 nights**	**No. per night**	**Total No. Collected for 89 nights**	**No. per night**
Ae. vexans	3985	64.2	31	0.3
Culex pipiens complex	17	0.2	2,775	31.2
Ae. albopietus	607	9.8	249	2.8
Cx. erraticus	697	11.2	8	0.1

71 Pennington RG, Lloyd JE. "Mosquitoes captured in a bovine-baited trap in a Wyoming pasture subject to river and irrigation flooding." Mosquito News. 35(3). 1975.
72 Lloyd JE and Pennington RG. "Mosquitoes collected in a CO2-baited CDC miniature light trap and a bovine-baited trap in Wyoming." Mosquito News. 36(4). 1976.
73 Lloyd JE and Pennington RG. "Mosquitoes collected in a CO2-baited CDC miniature light trap and a bovine-baited trap in Wyoming." Mosquito News. 36(4). 1976.
74 Boulware DR. "Passive Prophylaxis with Permethrin-Treated Tents Reduces Mosquito Bites Among North American Summer Campers." Wilderness and Environmental Medicine. 16. 2005.
75 McLaughlin RE, Focks DA. "Effects of cattle density on New Jersey light trap mosquito captures in the rice/cattle agroecosystem of southwestern Louisiana." Journal of the American Mosquito Control Association. 6(2). 1990.
76 McLaughlin RE, Focks DA. "Effects of cattle density on New Jersy light trap mosquito captures in the rice/cattle agroecosystem of southwestern Louisiana." Journal of the American Mosquito Control Association. 6(2). 1990.

Table 7. Mosquitoes trapped in CO_2-baited traps in southwestern Kansas during a flood, bolded species suspected to carry RVF				
	Light Traps		Gravid traps	
Species	**Total No. Collected for 62 nights**	**No. per night**	**Total No. Collected for 89 nights**	**No. per night**
Cx. salinarius	249	4	205	2.3
Ochlerotatus trivittatus	354	5.7	0	
Psorophora columbiae	325	5.2	0	
Anopheles quadrimaculatus s. l.	171	2.7	0	
Ps. horrida	119	1.9	0	
An. punctipennis (Say)	168	2.7	0	

Host Preference

Data on mosquito host preference compiled from the scientific literature is summarized in Table 8.

Table 8. Literature review of mosquito host identification through typing of blood meals								
Mosquito	**Cow**	**Pig**	**Other livestock[A]**	**Human**	**Avian**	**Small Mammal[B]**	**Unknown/ Other**	**Location**
*Aedes spp.77**	31/46C (67%)	1/46 (2%)	5/46 (11%)	1/46 (2%)	0/46 (0%)	1/46 (2%)	7/46 (15%)	Ricelands, Rural TX
*Aedes spp.78***	4/405D (1%)	0/405 (0%)	5/405 (1%)	25/405 (6%)	24/405 (6%)	270/405 (67%)	77/405 (19%)	Urban & Rural Iowa§
Culex salinarius79	2/2 (100%)	0/2 (0%)	0/2 (0%)	0/2 (0%)	0/2 (0%)	0/2 (0%)	0/2 (0%)	Ricelands, Rural TX
*Culex spp. 80****	2/222 D (1%)	2/222 (1%)	2/222 (1%)	0/222 (0%)	109/222 (49%)	38/222 (17%)	69/222 (31%)	Urban & Rural Iowa§
Culex tarsaiis81	36/307 (12%)	1/307 (<1%)	17/307 (6%)	4/307 (1%)	199/307 (65%)	32/307 (10%)	18/307 (6%)	Agricultural area, Utah

[A]Includes sheep, horses
[B]Includes dogs, cats
[C](number of mosquitoes with that blood type)/(total number of mosquitoes)
[D]Cattle and deer
*None from the list of species of interest in Kansas
**Includes Aedes trivittatus, Aedes vexans, Aedes triseriatus, Aedes stimulans
***Cx. restuans, Cx. Pipiens, Cx. Salinarius, Cx. Tarsalis
§Davenport, Des Moines, Dubuque, Iowa City, Sioux City, and Waterloo and rural localities Hornick and Story City

77 Kuntz KJ, Olson JK, Rade BJ. "Role of domestic animals as hosts for blood-seeking females of Psoropha columbiae and other mosquito species in Texas ricelands." Mosquito News. 42(2). 1982.
78 Ritchie SA, Rowley WA. "Blood-feeding patterns of Iowa Mosquitoes." Mosquito News. 41(2). 1981.
79 Kuntz KJ, Olson JK, Rade BJ. "Role of domestic animals as hosts for blood-seeking females of Psoropha columbiae and other mosquito species in Texas ricelands." Mosquito News. 42(2). 1982.
80 Ritchie SA, Rowley WA. "Blood-feeding patterns of Iowa Mosquitoes." Mosquito News. 41(2). 1981.
81 Andersen DM, Collett GC, Winget RN. "Preliminary host preference studies of Culex tarsaiis Coquillett and Cuuseta inorata (Wiluston) in Utah." Mosquito News. 27(1). 1967

Review of Mosquito Control Measures

Livestock treatments to prevent mosquito bites

According to SME interviews many of the farms in Kansas utilize some sort of pest control, often in the form of ear tags. As a result, some mosquito bite mitigation will already be in place as ear tags can reduce the mosquito bite rate by 17-55% (**Table 9**). Additional interventions may be necessary following an outbreak of RVF to reduce mosquito bite rate and disrupt the transmission cycle. Topical application of insecticide is the most promising form of bite rate mitigation as it has been shown to reduce bite rate by up to 87% (**Table 9**).

Table 9. Reduction in mosquitoes in bovine baited traps in response to different mitigation techniques

Mosquito	Mitigation	% Reduction
Aedes melanimon[82]	Pour on permethrin-treated concentrate	87 %*
Aedes dorsalis[83]	Pour on permethrin-treated concentrate	83 %*
Aedes vexans[84]	Saber tag	55%
Aedes vexans[85]	Ivomec	50%
Aedes vexans[86]	Ectrin tag	46%
Aedes vexans[87]	Ectrin spray	43%
Aedes vexans[88]	Terminator tag	17%

*4 Days after treatment

82 Schmidtmann ET et al. "Suppression of Mosquito (Diptera: Culicidae) and Black Fly (Diptera: Simuliidae) Blood Feeding from Hereford Cattle and Ponies Treated with Permethrin."Journal of Medical Entomology. 38(5). 2001.
83 Schmidtmann ET et al. "Suppression of Mosquito (Diptera: Culicidae) and Black Fly (Diptera: Simuliidae) Blood Feeding from Hereford Cattle and Ponies Treated with Permethrin."Journal of Medical Entomology. 38(5). 2001.
84 Loftin KM, Byford RL, Craig ME and Steiner RL. "Evaluation of cattle insecticide treatments on attraction, mortality, and fecundity of mosquitoes." Journal of the American Mosquito Control Association. 12(1). 1996.
85 Loftin KM, Byford RL, Craig ME and Steiner RL. "Evaluation of cattle insecticide treatments on attraction, mortality, and fecundity of mosquitoes." Journal of the American Mosquito Control Association. 12(1). 1996.
86 Loftin KM, Byford RL, Craig ME and Steiner RL. "Evaluation of cattle insecticide treatments on attraction, mortality, and fecundity of mosquitoes." Journal of the American Mosquito Control Association. 12(1). 1996.
87 Loftin KM, Byford RL, Craig ME and Steiner RL. "Evaluation of cattle insecticide treatments on attraction, mortality, and fecundity of mosquitoes." Journal of the American Mosquito Control Association. 12(1). 1996.
88 Loftin KM, Byford RL, Craig ME and Steiner RL. "Evaluation of cattle insecticide treatments on attraction, mortality, and fecundity of mosquitoes." Journal of the American Mosquito Control Association. 12(1). 1996.

Post Hurricane Interventions

Much of the literature available on emergency mosquito control measures in developed countries reports on aerial insecticide spraying missions to control mosquito populations in areas impacted by hurricanes. Mosquito control campaigns were undertaken and reported in the U.S. following Hurricanes Hugo, Andrew, Charlie, Frances, Ivan and Jeanne. [89,90,91]

Hurricane Hugo[92]

According to an internal naval memo, a four-part mosquito control program was carried out at the Charleston Naval Weapons Station following Hurricane Hugo. The campaign included land and aerial spraying and larvaciding and both mosquito and larval stage populations were significantly reduced. Landing rates decreased from 75/min to 3/min in one area and from 80/min to 25/min in another area. The report provides some recommendations for ground spraying operations, which is unique among the hurricane intervention case studies. Specifically, the "buffalo turbine" was found to be a very useful piece of equipment of administering larvacides and for insecticide spraying and the largest obstacle to the operation was a lack of personnel.

Hurricane Andrew[93]

Following Hurricane Andrew, mosquito control efforts were undertaken in both Florida and Louisiana in areas affected by the hurricane. The mosquito control campaigns are briefly outlined by the CDC and provide examples of the problems that might be encountered in a mosquito control campaign and a single example of the efficacy of a single spraying mission.

In Florida, treatment of over 650,000 acres with aerial application of insecticide was undertaken for 50 days to control the mosquito population. The overall efficacy of the effort is not reported, however, the results of a single mission (99,000 acres sprayed September 11) were a reduction in daytime landing rate from 14.3 mosquitoes per minute to 0.4 mosquitoes per minute. Additionally, the reduction in CO_2-baited encephalitis vector survey (EVS) trap collection for a single species was reported: 550 *Aedes taeniorhynchus* per night was reduced to 20 per night.

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89 Simpson JE. "Emergency Mosquito Aerial Spray Response to 2004 Florida Hurricanes Charley, Frances, Ivan and Jeanne: An Overview of Control Results." Journal of the American Mosquito Control Association. 22(3). 2006.
90 Team Leader, Vector Control Team Three (VCT-THREE. DISASTER RELIEF FOR VECTOR CONTROL TO CHARLESTON NAVAL WEAPONS STATION FOLLOWING HURRICANE HUGO. Internal Navy Memo. 2 Nov 89.
91 CDC. Emergency Mosquito Control Associated with Hurricane Andrew -- Florida and Louisiana, 1992. MMWR 42(13).1993. http://www.cdc.gov/mmwr/preview/mmwrhtml/00020129.htm
92 Simpson JE. "Emergency Mosquito Aerial Spray Response to 2004 Florida Hurricanes Charley, Frances, Ivan and Jeanne: An Overview of Control Results." Journal of the American Mosquito Control Association. 22(3). 2006.
93 Team Leader, Vector Control Team Three (VCT-THREE. DISASTER RELIEF FOR VECTOR CONTROL TO CHARLESTON NAVAL WEAPONS STATION FOLLOWING HURRICANE HUGO. Internal Navy Memo. 2 Nov 89.

In Louisiana, both aerial and ground spraying was undertaken on 788,000 acres for 36 days after Hurricane Andrew. This campaign was able to immediately reduce the mosquito population, but only short-term. No data were provided on this campaign, but the fact that this campaign only had short-term efficacy can be explained in part by an explosion in the mosquito population following the hurricane. The mosquito population in Florida, in contrast, was not affected by the hurricane; there was simply greater human exposure due to the destruction of shelter.

Hurricanes Charlie, Frances, Ivan and Jeanne[94]

Simpson published an especially detailed account of mosquito control measures taken in 2004 when four hurricanes hit Florida in a period of four months, which was used as a case study to quantitatively determine the efficacy of aerial insecticide spraying. Following each hurricane, affected areas experienced an increase in mosquito populations, an increase in human exposure to mosquitoes and impairment of local mosquito control operations. In response, Florida put together a Mosquito Control Incident Response team to survey affected areas to identify amplified mosquito populations through trapping, and then treat affected areas by aerial insecticide spraying. Spray missions occurred on nights with favorable weather conditions and applied 0.667 oz/acre of Dibrom pesticide from 300 feet.

Drawing from thirty-six missions, the typical parameters and outcomes of a spraying mission were determined (Table 10). The typical spraying mission occurred 1-2 days after a region had been identified as having a mosquito problem through trapping and lasted 1-2 nights, spraying an average of 179,138 acres. On average, a spraying mission caused a total reduction in the mosquito population of 67.7%, and a reduction in the *Culex nigripalpus* species of 64.1%.

The least effective spraying missions were in the southern portion of the state, especially in Desto and Hendry Counties. The study implies that the reasons for this disparity are complex, including variations caused by the hurricane itself, variations in post hurricane weather and prevalence of certain species of mosquitoes (ex. *Culex* spp.). Notably, both of these counties were hit by Hurricane Charlie, the earliest (August) and most destructive of the four hurricanes.[95] Lafayette County, in the northern portion of the state, also showed poor response to aerial spraying, although it was hit by the weaker, late season hurricane Jeanne. Again, there was no clear reason for this disparity.

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94 Simpson JE. "Emergency Mosquito Aerial Spray Response to 2004 Florida Hurricanes Charley, Frances, Ivan and Jeanne: An Overview of Control Results." Journal of the American Mosquito Control Association. 22(3). 2006.
95 Pasch RJ et al. "Tropical Cyclone Report, Hurricane Charley, 9 - 14 August 2004." http://www.nhc.noaa.gov/2004charley.shtml. Accessed on April 15, 2010.

Table 10: Spray mission information and percent control of mosquitoes[96]							
Days between 1st trap and spray	# of spray days	Days after spraying 2nd trap set	Acres treated	% Culex reduction	%Total reduction	Location	Month
2	2	1	190879.9	73.2	95.3	Desoto County, FL	October
1	1	1	157091.0	91	93.6	Bradford County, FL	October
4	1	1	145456.0	90.9	93.4	Gilchrist County, FL	October
3	1	1	128001.0	94	93.2	Seminole County, FL	September
1	1	1	139637.0	77.9	91.3	Bradford County, FL	October
2	2	1	174549.0	99	88.9	Sumter County, FL	October
2	1	1	133819.0	67.9	88.9	Baker County, FL	October
2	2	2	197819.0	87.4	88.6	Putnam County, FL	October
3	3	1	110622.0	78.4	85.8	Madison County, FL	October
2	1	1	98911.0	76.2	84.6	Okeechobee County, FL	October
8	2	1	89794.0	78.4	82.3	Union County, FL	October
1	1	1	168726.0	77.1	80.9	Glades County, FL	October
6	1	2	244364.0	78.9	79.8	Volusia County, FL	October
1	1	2	99297.0	73.5	74.7	Okeechobee County, FL	September
2	2	1	325821.0	73.4	73.6	Volusia County, FL	September
1	1	1	4150.0	80.8	71.8	Glades County, FL	October
1	2	1	161285.0	78.4	71.3	Hardee County, FL	August
1	1	1	116364.0	48.4	70	Dixie County, FL	October
1	1	1	197818.0	67.1	68.5	Putnam County, FL	October
1	2	1	401454.0	67.6	67.7	Marion County, FL	September
1	2	1	180931.2	48.5	66.7	Hendry County, FL	August
1	2	1	168726.9	66.4	64.9	Hardee County, FL	August
8	2	1	152242.0	66.5	63.8	Osceola County, FL	October
2	1	1	192000.0	63.3	62.2	Flagler County, FL	September
2	2	1	162908.8	69.3	61.6	Hardee County, FL	October
7	1	1	226910.0	67.6	61.1	St. Johns County, FL	October
5	2	1	155152.0	38.6	58.8	Taylor County, FL	October
2	2	1	281211.0	57.2	57.9	Osceola/Polk Counties, FL	September
2	1	0	157091.0	17.1	53.4	Suwannee County, FL	October
2	3	0	122544.0	48	51.7	Hardee County, FL	August
4	3	1	402154.0	43.8	48	Polk County, FL	October
2	5	1	258806.8	32.5	46.8	Desoto County, FL	August

96 Simpson JE. "Emergency Mosquito Aerial Spray Response to 2004 Florida Hurricanes Charley, Frances, Ivan and Jeanne: An Overview of Control Results." Journal of the American Mosquito Control Association. 22(3). 2006.

Table 10: Spray mission information and percent control of mosquitoes[96]							
Days between 1st trap and spray	**# of spray days**	**Days after spraying 2nd trap set**	**Acres treated**	**% Culex reduction**	**%Total reduction**	**Location**	**Month**
1	3	1	203636.5	43.9	36.3	Desoto County, FL	August
6	2	1	118691.0	33.3	34.3	Lafayette County, FL	October
1	2	1	199757.7	17.8	20	Hendry County, FL	August
3	3	1	180363.8	34.4	6.7	Desoto County, FL	August

APPENDIX L: NAS PRELIMINARY QUESTIONS AND RESPONSES

U.S. Department of Homeland Security
Washington, D.C. 20528

July 28, 2010

Dr. Ronald Atlas
Chair, *Committee on the Evaluation of the SSRA for the Planned NBAF in Manhattan, Kansas*
The National Academies
500 Fifth Street, N.W.
Washington, D.C. 20001

Dear Dr. Atlas,

On June 30, 2010 DHS submitted the National Bio and Agro-Defense Facility (NBAF) Site-Specific Biosafety and Biosecurity Mitigation Risk Assessment (SSRA) to the "National Research Council (NRC) Committee on the Evaluation of a Site-Specific Risk Assessment for the Department of Homeland Security's Planned NBAF in Manhattan, KS" hereinafter referred to as the "Committee." The Committee is charged with assessing the adequacy and validity of the SSRA. After initial review of the SSRA, the Committee held a public meeting July 13, 2010 to ask questions to DHS and Signature Science, LLC (prime contractor for the SSRA). This letter provides additional information in response to Committee questions asked during the public meeting, as well as provides answers to 35 written questions sent to DHS by the Committee on July 16, 2010. A copy of this letter will be added as an appendix to the SSRA.

Overall Questions

NAS Meeting Questions:

1) What is the conclusion of the overall Risk once the risk assessment is completed?

Response: Given the combination of proven biocontainment design and robust operation procedures and response planning, the NBAF operations in Manhattan, KS overall brings extremely low risk relative to the greater risk of the intentional or accidental introduction of FMDv by an external source. We appreciate the Committee's interest in receiving a single overall estimate of risk related to operating the NBAF in Manhattan, KS, however the purpose of this Risk Assessment (as mandated by Congress) was to perform a site-specific assessment of risks related to the current site, design and research plans for NBAF which could be used to develop effective design, operations and response risk mitigation strategies. Our approach considered recommendations from a previous NRC committee[1] which suggested answering the following list of overarching questions as part of understanding risks for a high containment laboratory: (1) What could go wrong?, (2)

[1] The National Research Council (NRC) report "*Technical Input on Any Additional Studies to Assess Risk Associated with Operation of the National Emerging Infectious Diseases Laboratory*" *Boston University, 2008.

What are the probabilities of such a sequence of events?, and (3) What would be the consequences of such a sequence of events? The scope of the SSRA was to perform an integrated scenario-based risk assessment that clearly identifies the risk release scenarios once the NBAF is operational. Each scenario was analyzed extensively to determine the potential pathways, likelihood, and impact of a release by integrating the results of the plume, epidemiological and economic modeling to determine the overall risk of each scenario. Each scenario was found to have low risk with respect to the safe operations of the NBAF. Even the highest risk ranked scenarios have very low risk with respect to normal safe operations. A summary of the complete analysis for each scenario can be found in SSRA Table 6-4, Accidental Cases Ranked by Risk Dollars. The SSRA answered the guiding questions above and integrated this information by ranking the scenarios by "risk dollar." Figure ES-6, Percentage of Risk Consequence by pathway illustrates that cumulatively the vast majority (97%) of the risk space is found in the fomite/vector/carrier transport pathway. Ultimately, the risk rankings were used to develop and then prioritize the recommendations (i.e. risk mitigations) found in SSRA Section ES4.2.

2) What is the radius around the facility which is at risk for infection?

Response: Figures are provided that describe the maximum distance at which an exposure could occur for each scenario within the air and deposition pathway (see New Figures 1-6 in response to question 5 below). These new figures and existing Tables 3-32, 3-33 and 3-34 within the SSRA provide information which will be used to inform the emergency response effort. These figures indicate that the Emergency Response Planners, while considering the low probability of release, include an area that is at a minimum 70km from the NBAF in their planning effort due to the maximum plume downwind range (FMDv).

DHS will engage the local, state, regional, and Federal officials in emergency response planning (ERP) to assure an integrated and coordinated response to emergency situations. The NBAF ERP will be informed by the SSRA and will build upon existing city, state, and regional emergency response plans in Kansas for foreign animal diseases (FAD) and other large livestock pathogens. For example, the State of Kansas has implemented an Incident Response Plan (IRP) for FADs that covers prevention, preparedness, response, and recovery. This IRP recognizes that effective FAD control requires close coordination of local, state, regional and Federal agencies to minimize the impact on the agriculture industry and commerce. The ERP will delineate the steps and actions needed for mitigation, preparedness, response, and recovery. Each of these areas will have clearly defined processes and plans for local, state, and regional officials to follow in the event of a FAD outbreak, contamination, or specific type of emergency involving the NBAF. For example, the ERP will define mitigation requirements (e.g., establishing effective area quarantine, movement controls, surveillance and response zones). The preparedness steps require frequent review of planning efforts and updated necessary plans and procedures that are a result of findings from training, exercises or actual incidents.

Specific response protocols will be used following the initial stages of an outbreak, based on modeling results and local response capabilities to ensure rapid containment. Knowing

that the infection distance is highly dependent upon both the scenario resulting in a release and the meteorological conditions during a release, the emergency response planning will incorporate appropriate modeling tools, as well as results of drills and exercises held with emergency responders. This will assist responders in understanding the potential spread of a pathogen and facilitate the development of flexible and effective plans.

The SSRA recommends on page 366 a robust solution for emergency planning which ensures "validated dispersion and plume modeling software tools and the necessary related expertise should be offered to the state and local emergency management officials to inform the decision-making process during response and recovery." The following page includes an observation that there should be on-going education programs to "inform the community about signs and symptoms for those diseases being studied at the NBAF." Additionally, the SSRA provides pertinent site and regional agricultural and veterinary infrastructure information that will provide for informed planning for Emergency Response in the event of an FMD outbreak from the NBAF. To implement effective quarantine and movement controls in the unlikely event of a release, response zones will be established as soon as possible after the determination of a confirmed case of FMD.

3) What is the risk assessment (if possible as a probability) and impact (as dollars) of FMD introduced intentionally or accidentally from an external (international) source?

Response: While the purpose of this SSRA was not to assess the overall risk of an intentional or accidental release of FMD from an external (international) source, the ease with which FMD could be accidentally or intentionally introduced into the United States and the impact of this has been well documented by: 1) specific real-world examples, 2) the academic/scientific community, and 3) the government. The risk of operating the NBAF is extremely small compared to the greater risk the Nation faces from an intentional or accidental introduction from an external source. It is because of this risk DHS believes there are significant benefits to operating the NBAF in Manhattan, KS, including rapid diagnosis and response to possible foreign animal disease outbreaks and access to research programs and expertise which will allow greater advancements in countermeasure development. These advancements will further mitigate the overall known risk of an accidental or intentional release of FMDv by an external source into the United States.

The most recent example of an accidental introduction and the associated economic impacts can be found in the literature on the 2010 outbreak of FMDv in Japan. This accidental introduction caused a ripple of economic impacts on the Japanese agricultural market. Additionally, the academic/government e.g., (USDA Economic Research Service) community published on the economic impacts of foreign animal disease outbreak (found to be quite variable and dependent on the speed of disease spread, duration of the outbreak and the response) in the United States.

1. Paarlberg, P.L., A. Hillberg Seitzinger, J.G. Lee, and K.H. Mathews, Jr. (May 2008). Economic Impacts of Foreign Animal Diseases. USDA Economic Research Service Report Number 57, 71 pages.

- Study assessed results of a hypothetical outbreak of FMD and the modeling framework included effects of the FMD episode on all major agricultural products and assessed these effects on aggregate supply, demand and trade over 16 quarters. Total losses to livestock-related enterprises over 16 quarters ranged between $2,773 million and $4,062 million depending on disease intensity level, duration of the outbreak and the response scenario.

2. Ekboir, J.M. (1999)..Potential impact of Foot-and-Mouth Disease in California: The Role and Contribution of Animal Health Surveillance and Monitoring Services. Davis: University of California, Agricultural Issues Center.
    - Concluded that losses, using conservative estimates, would be $6 billion to $13 billion even if the outbreak were contained within California and eradicated within 5-12 weeks.
3. Paarlberg, P.L., J.G. Lee, and A. Hillberg Seitzinger. (April 1, 2002). Food Animal Economics: Potential revenue impact of an outbreak of foot-and-mouth disease in the United States. JAVMA, 220 (7):988-92.
    - Stated that the loss of export markets and reductions in domestic demand arising from consumer fears could cause an estimated decrease of $14 billion (9.5%) in US farm income.
4. Pendell, D.L., J. Leatherman, T.C. Schroeder, and G.S. Alward. (October 2007). The Economic Impacts of a Foot-And-Mouth Disease Outbreak: A Regional Analysis. Journal of Agricultural and Applied Economics. 39:13-33. October 2007.
    - Estimated impacts of different introductions of FMD in southwest Kansas ranging from $35million to ~$1 billion.
5. Whellis, M., R. Casagrande, and L.V. Madden. (July 2002). Biological Attack on Agriculture: Low-Tech, High-Impact Bioterrorism. Bioscience. 52(7):569-576
    - Concluded that because bioterrorist attack requires relatively little specialized expertise and technology, it is a serious threat to U.S. agriculture and can have very large economic repercussions.

The U.S government has acknowledged the risk of a FMD incursion within the United States. Specifically, on January 30, 2004, President George W. Bush signed Homeland Security Presidential Directive 9 (HSPD-9) establishing a national policy to defend the agriculture and food system against terrorist attacks, major disasters, and other emergencies. The National Science and Technology Council's Foreign Animal Disease Threat Subcommittee identified FMD as one of the top-priority diseases in the 2008-2012 Research and Development Plan for High Consequence Foreign Animal Disease Threats stating "An incursion of FMD within U.S. borders could result in severe disruption of the dairy, cattle, and swine industries and allied sectors, the loss of export markets, and stop movement restrictions that would create significant disruption to the national economy."

Plume Modeling

NAS Meeting Questions:

4) How did the fate and transport dispersion modeling efforts account for uncertainty?

Response: A full analysis of the model parameters which were believed to contribute to the largest plume modeling uncertainties was performed. Other model parameters were chosen based on the best available data sources and references. It can be argued that the largest contributors of plume modeling uncertainty are the atmospheric inputs of wind speed, wind direction, atmospheric stability, and mixing depth. Therefore, emphasis was first placed on fully capturing the site specific variances of these inputs, as described in Section 3.4.4 of the NBAF SSRA, and more comprehensively in Appendix J. Baseline values for the remaining input parameters (release location, amounts, etc) were specified based on available site specific and scenario specific data sources, including:

- The NBAF Design Partnership (NDP), which provided information used to define aerosol release locations and source size based on exhaust system specifications.
- Oak Ridge National Laboratory (ORNL) 2006 Landscan Landuse/LandCover database, which provided estimates of canopy heights and roughness lengths at ~ 1km grid spacing over the NBAF region.
- NBAF location site survey, which provided information used to verify the canopy height specifications, derived from the ORNL database.
- Exhaustive literature reviews and SME discussions to define source release amounts and particle size distributions.

Due to the computational burden of fully exploring the entire parameter uncertainty space, associated with these inputs, "reasonable worst case" estimates were used, as defined by the US EPA, which would result in conservative estimates of downwind exposure. The US EPA defines "reasonable worst case" as "A semi quantitative term referring to the lower portion of the high end of the exposure, dose, or risk distribution. The reasonable worst case has historically been loosely defined, including synonymously with maximum exposure or worst case. As a semi quantitative term, it is sometimes useful to refer to individual exposures, doses, or risks that, while in the high end of the distribution, are not in the extreme tail. For consistency, it should refer to a range that can conceptually be described as above the 90th percentile in the distribution, but below about the 98th percentile."

The methods, outlined above, allowed for the main drivers of uncertainty to be fully characterized, while also ensuring conservatism in the remaining parameter input space. Additionally, for any one set of parameter inputs, the SCIPUFF model provided an estimate of uncertainty (in terms of a predicted concentration mean and variance), due to plume meandering and small scale turbulent diffusive effects. Ideally, one would use this additional variance either to estimate the 95th or 99th percentile exposure or to estimate the probability of exceeding a specific exposure threshold at a particular downrange location. For assessing exposure at a single isolated point, this is an appropriate methodology. On the other hand, if one is more interested in estimating spatially correlated exposures at

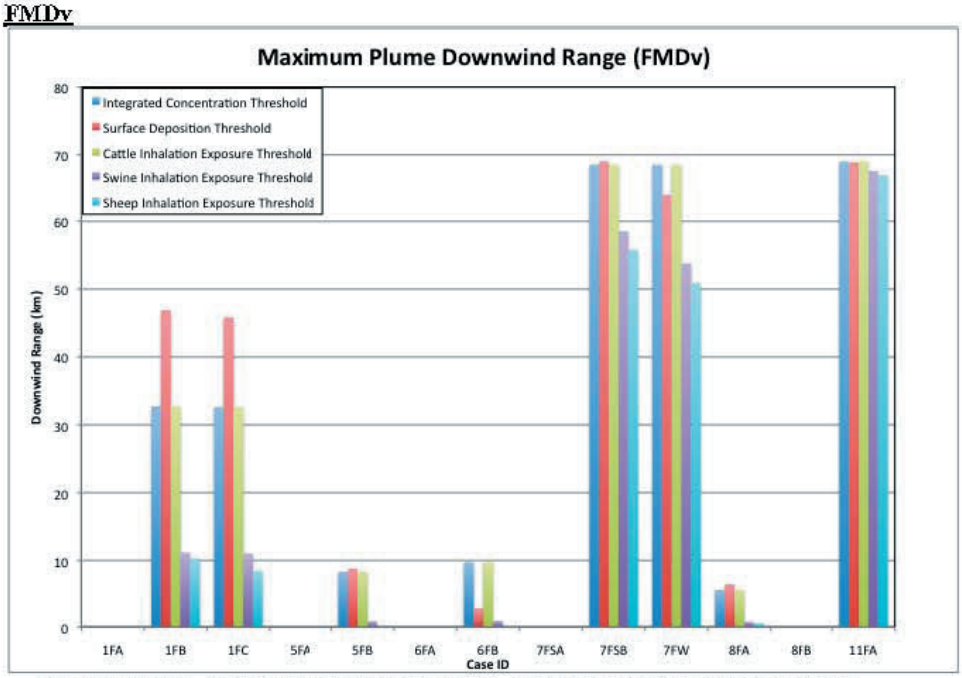
multiple locations (as was the case for the SSRA analysis), the utilization of this variance is no longer valid. In these circumstances it is more appropriate to ignore these variances and use the SCIPUFF predicted means. It was this latter approach, which was used to estimate both the likely number and spatial distribution of farms impacted from an aerosol release. Additionally, SCIPUFF was executed in a "semi-deterministic" fashion, by ignoring the meandering components of the wind field and only including the effects of the "diffusive" eddies which actually dilute the cloud (e.g. "conditional" dispersion). The absence of unresolved meander effects adds a degree of uncertainty regarding the plume location and orientation, when using a single set of input parameters to characterize a single exposure event. Even so, it is believed that this uncertainty was reduced by fully capturing the larger scale meteorological wind direction/speed variances, as described previously, which also impact the larger scale plume location and orientation.

Lastly, the utilization of 24-hour time-integrated concentrations to derive subsequent inhalation exposure estimates, versus the use of short term concentration time averages, was another method (and perhaps the most effective method) of reducing the plume modeling uncertainty.

5) Can the SSRA team provide a chart of plume radius for each scenario?

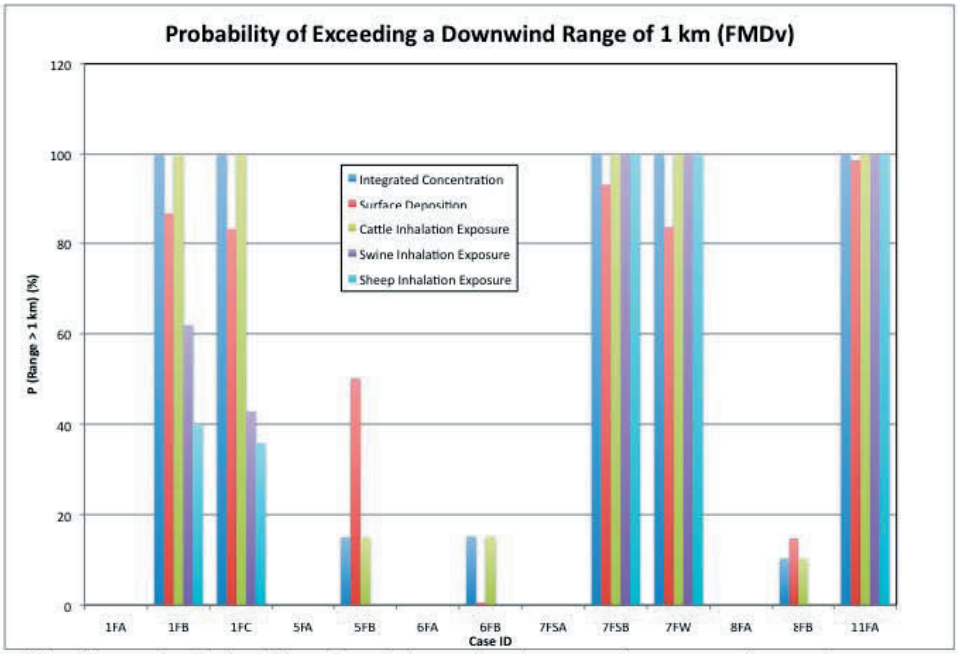
Response: Tables 3-32, 3-33 and 3-34 of the SSRA provided the probability of exceeding an area greater than or equal to 1km^2, 10km^2 and 100km^2 respectively for each case modeled in the air and deposition pathway. However, to provide additional clarity for the Committee, additional figures (New Figures 1 through 6) were generated that represent the maximum downwind ranges (in km) which received a time-integrated concentration, surface deposition, and inhalation exposure greater than or equal to 48.4 PFU-s/m^3, 0.1 PFU/m^2, and 0.1 PFU, respectively, over all meteorological conditions for FMD and RVF. These new figures and existing Tables 3-32, 3-33 and 3-34 within the SSRA provide information which will be used to inform the emergency response effort. These figures indicate that the Emergency Response Planners, while considering the low probability of release, include an area that is at a minimum 70km from the NBAF in their planning effort due to the maximum plume downwind range (FMDv).

FMDv



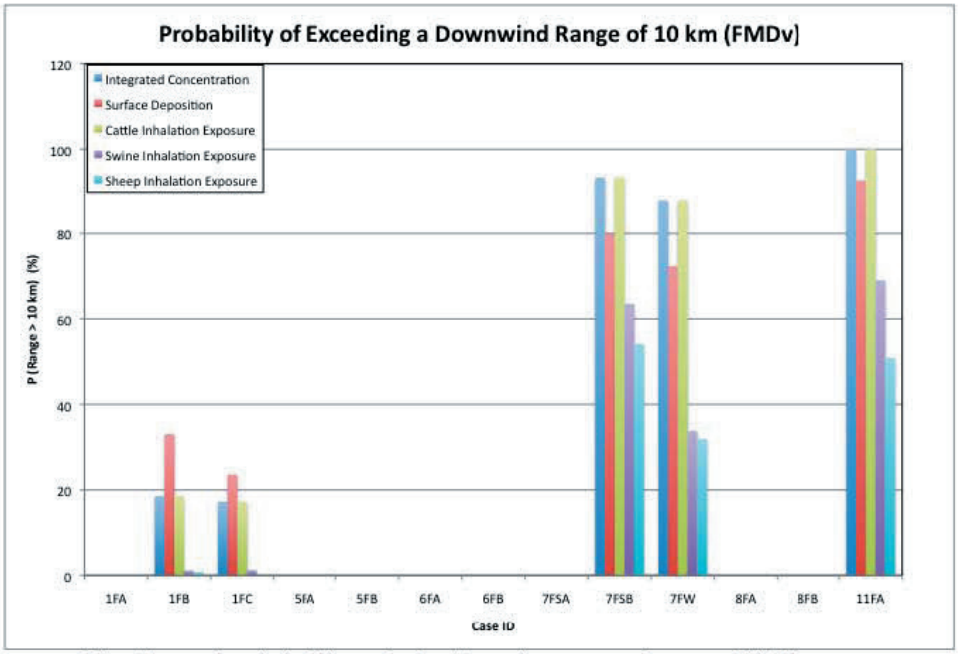
New Figure 1: Maximum downwind range, which received a time-integrated concentration, surface deposition, and inhalation exposure of FMDv greater than or equal to 48.4 PFU-s/m^3, 0.1 PFU/m^2, and 0.1 PFU, respectively, over all meteorological conditions.

7



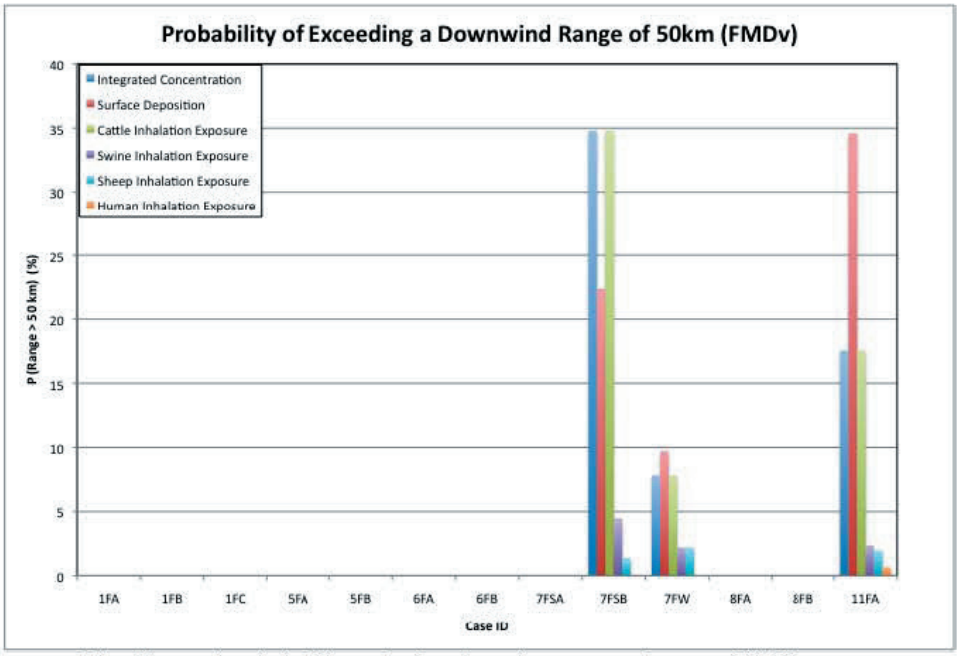
New Figure 2: Probability of receiving a time-integrated concentration, surface deposition, and inhalation exposure of 48.4 PFU-s/m^3, 0.1 PFU/m^2, and 0.1 PFU greater than 1km downrange from the NBAF.

8



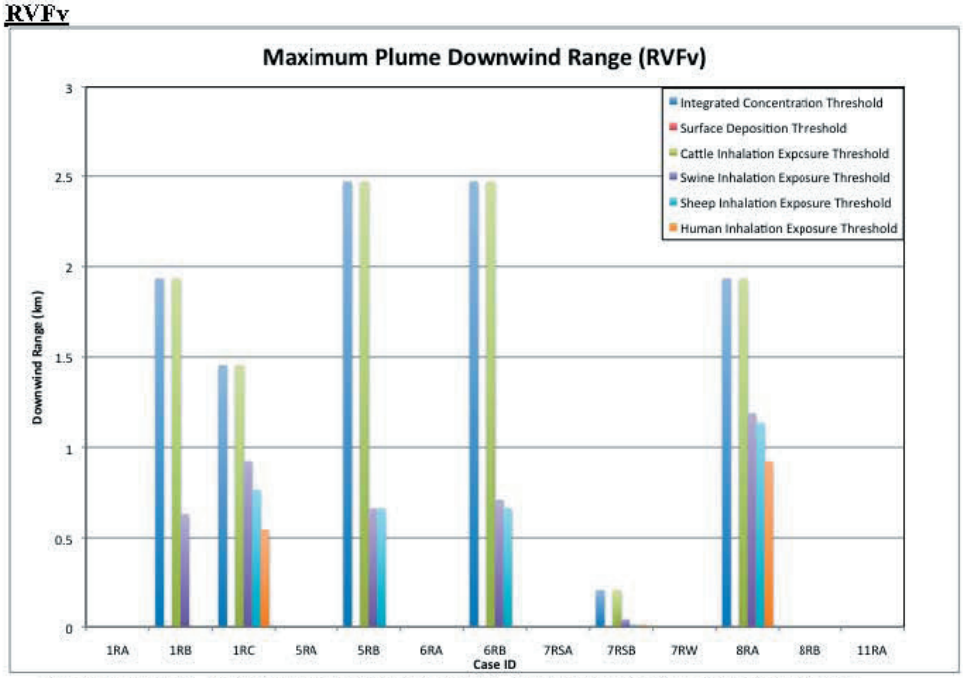
New Figure 3: As in Figure 2, for 10km downrange from the NBAF.

9

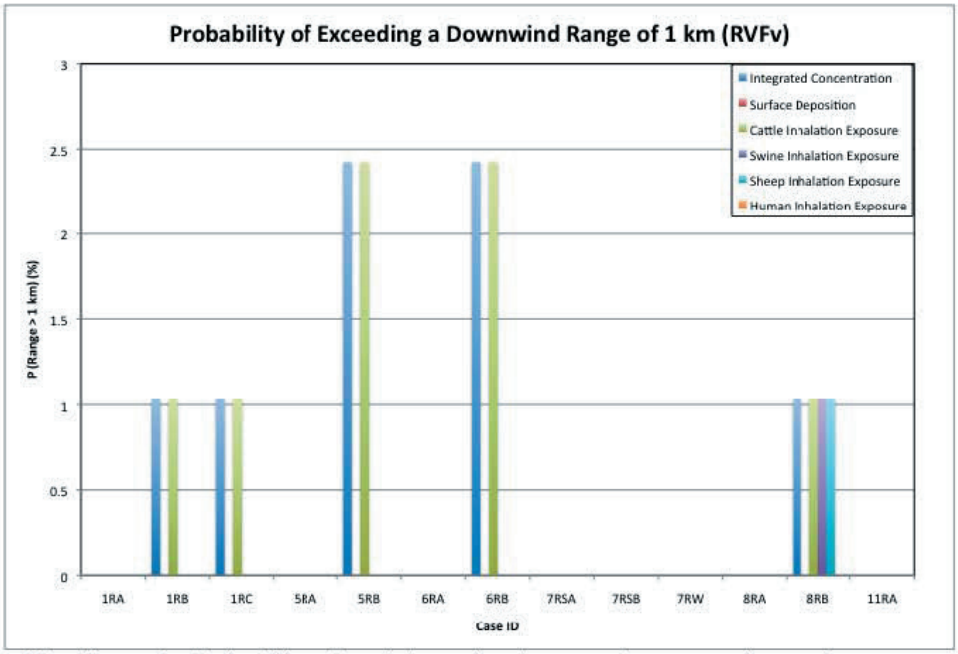


New Figure 4: As in Figure 2, for 50km downrange from the NBAF.

RVFv



New Figure 5: Maximum downwind range, which received a time-integrated concentration, surface deposition, and inhalation exposure of RVFv greater than or equal to 48.4 PFU-s/m^3, 0.1 PFU/m^2, and 0.1 PFU, respectively, over all meteorological conditions.

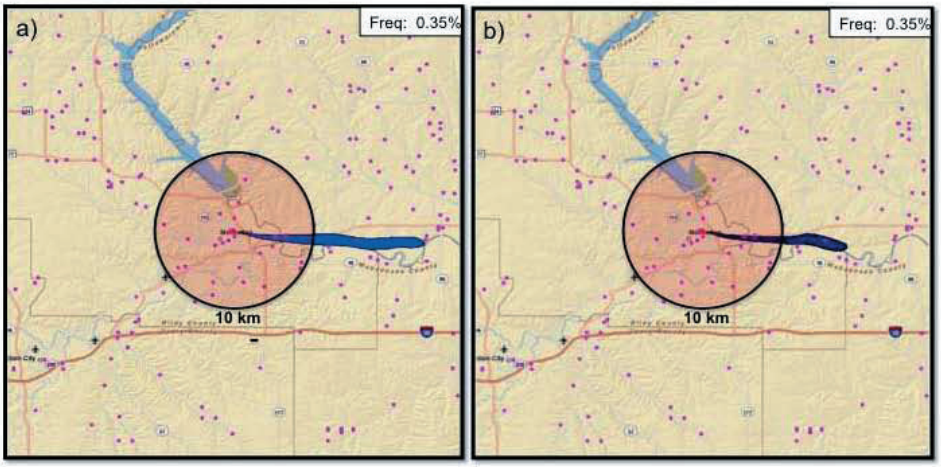


New Figure 6: Probability of receiving a time-integrated concentration, surface deposition, and inhalation exposure of 48.4 PFU-s/m^3, 0.1 PFU/m^2, and 0.1 PFU greater than 1km downrange from the NBAF.

12

6) Can the SSRA team include scales for source data?

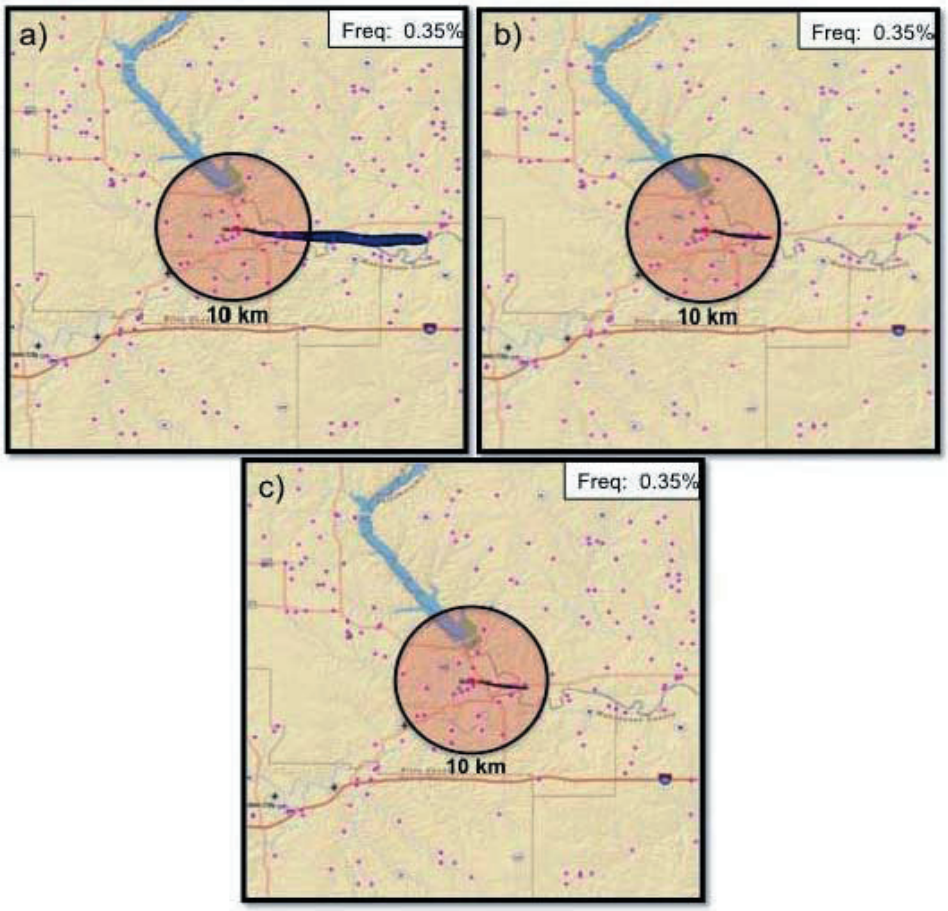
Response: The following figures related to fate and transport dispersion modeling source data now contain relevant scales shown in radii around the NBAF site and will replace existing named figures in the SSRA.



Replacement Figure 3-47: a) Time-integrated Airborne Concentration and b) Surface Deposition for Case 1FB, Met ID 159.

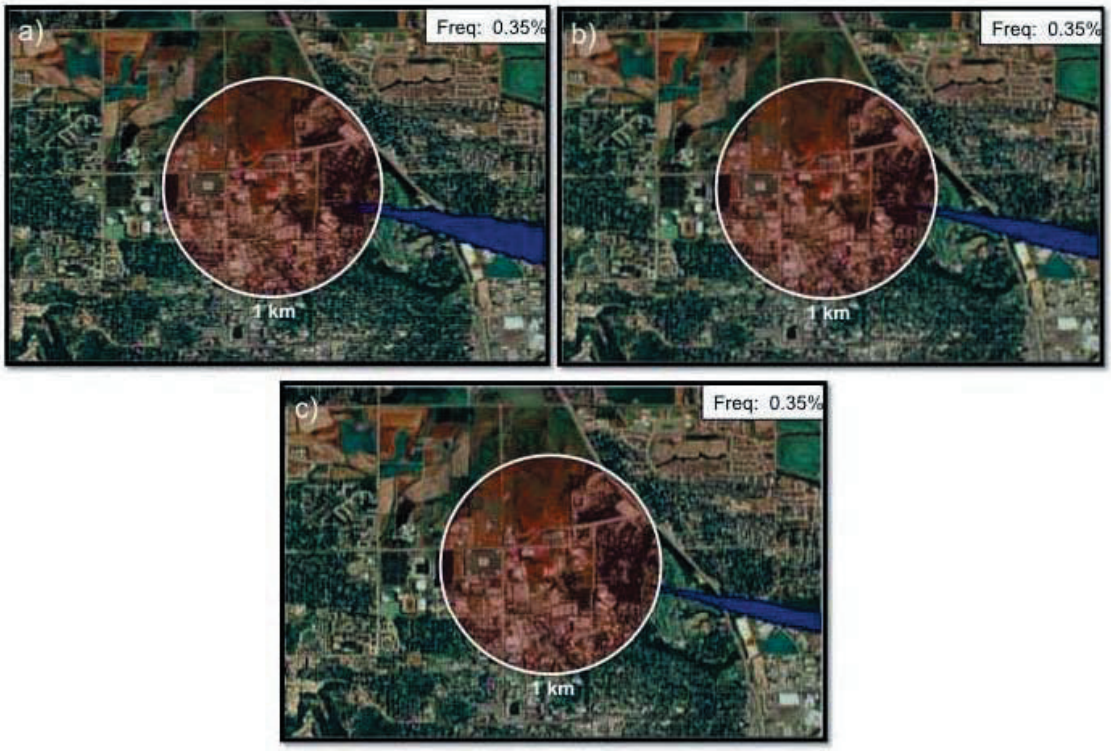
Replacement Figure 3-48: Zoomed in View of a) Time-integrated Airborne Concentration and b) Surface Deposition for Case 1FB, Met ID159.

13



Replacement Figure 3-49: a) Cattle Inhalation Exposure, b) Swine Inhalation Exposure, and c) Sheep Inhalation Exposure for Case1FB, MetID 159.

14



Replacement Figure 3-50: Zoomed in View of a) Cattle Inhalation Exposure, b) Swine Inhalation Exposure, and c) Sheep Inhalation Exposure for Case 1FB, MetID 159

7) Are additional data available to NAS for a thorough analysis of the modeling performed?

Response: STAR will provide any data, scripts, or code requested by the NAS committee directly, to support their analysis of the SSRA Final Report. Please contact Mr. George Bieberbach (303-710-5174, gbieber@starinst.org) or Dr. Paul Bieringer (303-250-7233, paulb@starinst.org) and ensure DHS is informed of any requests.

Epidemiological Modeling

NAS Meeting Questions:

8) Why was NAADSM used in this SSRA (as opposed to a network model)?

Response: The SSRA team did not use a network model because the data necessary to underpin such a model was not available. Although a network model could have been used, the lack of information would vitiate any advantage the model would have over a model such as NAADSM because the links in the network would have to be estimated based on very limited data.

At the beginning of the project, the team hypothesized that it would be difficult to obtain data on animal movements within and between states from producers. During the project, the team confirmed this hypothesis by attempting to obtain data from three sales-barns. At first, despite repeated and persistent contacts from the SSRA team, the team was unable to obtain data regarding animal movements to and from these facilities. With the help of personnel from Kansas State University, who had a working relationship with the owners of these facilities, some information was given to the SSRA team. The quantitative information provided included shipments out of state (which require a health certificate). The facility owners did not provide detailed information about shipments within state, but were able to qualitatively describe their buyers and suppliers (for example "90% of our buyers are large feedlots in the Southwest of the state"). Although health certificate records were valuable in some instances, they were not readily available from all the facilities from which they were requested.

To match the granularity of the model used in the SSRA analysis, animal movement (and indirect contact information) would have to be obtained from more than 10,000 facilities of five different types, of various sizes and in seven states. The SSRA team determined that geography informs the network as does the size of the facility (for example, the large feedlots in the Southwest tend to receive animals from sales-barns as opposed to smaller feedlots in central Kansas, and small cow-calf operators in the East tend to sell their animals through the sales-barns near Manhattan whereas larger operators tend to sell their animals directly to feedlots). Given that, collecting sufficient information to feed a network model would be prohibitively difficult, if at all, possible. Additionally, as stated in section 4.2.1, the NAADSM model provided numerous strengths including the ability to consider spatial distribution of susceptible animals, specific collections of animals of varying susceptibilities and control actions specific to the type of animals. It has been used widely in the academic community to evaluate the efficacy of a variety of control measures that were considered in this project and it has been used in the modeling of outbreaks in Kansas. Two measures were implemented to address the concern of considering long-distance spread: 1) special sales barns locations were developed and built into the NAADSM model 2) inter-regional animal transport data was used to trigger further runs of the NAADSM model. Further details on this analysis may be found in Section 4.2.1.

9) Explain the uncertainty in the parameters of the model.

Response: Regarding the parameters used in NAADSM, there are two types of evidence basis. Parameters that are likely to be within the ability of local stakeholders to estimate (such as culling capacity) were based on a consensus of estimates drawn from a variety of knowledgeable stakeholders (as described in Appendix K). Parameters not likely to be estimated accurately by local stakeholders (such as indirect contact rates) were based upon a consensus of values published in the peer reviewed literature on NAADSM. In each case, significant uncertainty exists as to the true value of these parameters, so extensive sensitivity analysis was performed (described on pages 219-235 of the report).

Two approaches were used in the sensitivity analysis. In the first approach, all values published in the peer reviewed literature were tested, one at a time. In the second approach, a parameter was varied from its base value regardless of the appearance of these

alternate values in the literature. This second approach was used to explore the effects on the resulting outbreak should detection or control approaches vary from the baseline. These results inform estimates of the benefit of improving detection and control measures (or the cost of not achieving the estimates for the efficacy of detection and control measures).

Because the SSRA team strove to ensure that each parameter had the strongest possible evidence basis, the team did not alter *baseline* parameters (especially as it relates to control measures) without a solid evidence basis. That is, local stakeholders, for whom the control of livestock disease is central to their daily lives, are probably more familiar, than the SSRA team, with the complexity of mass culling and the resources that could potentially be available. Although some of these parameters may seem optimistic to outsiders, local stakeholders informed us that their plans include the mobilization and training of all slaughterhouse workers (who would otherwise be out of work), the National Guard and other resources to control an outbreak of FMD. Also, if a different baseline value were chosen for this parameter, an evidence basis would have to be found to support this new value and the SSRA team found that the evidence supporting specific other values was insufficient.

That being said, the sensitivity analysis on pages 219-235 presents an analysis of the effect of changing these parameters by more than an order of magnitude in many cases. This analysis should be sufficiently robust to enable reviewers to determine the impact of changing any parameter in NAADSM.

One aspect that was not explored in the formal sensitivity analysis (because it was not a NAADSM parameter) was the threshold mean inhaled dose to produce an infection (0.1 pfu) of FMDv. Facilities that hold more than 100 animals and received a dose in excess of this value were predicted to develop at least one infection. Examining the data from the plume modeling, if this value were increased to 1pfu, no aerosol transport pathway would result in an infection at a livestock facility beyond the NBAF. If this value were decreased to 0.01 pfu, a greater proportion of aerosol releases would result in at least one infected premises and more premises would be infected per release. We know from the analysis performed (page 189) that the number of premises initially infected by surreptitious releases has little impact on the magnitude of the outbreak. Therefore, the output is insensitive to this parameter for every outbreak that occurs from a release (that is, the average impact of an outbreak will not change assuming an outbreak occurs in the first place). However, if this parameter was decreased, outbreaks would result more frequently from the sets of releases modeled, increasing the overall risk posed by any aerosol release pathway. This increase in risk is extremely modest for most of the catastrophic release scenarios (where the NBAF is partially or completely destroyed), such as a Tornado and High-Wind Event, because the vast majority of meteorological conditions lead to an outbreak given the default parameter.

It should be noted that the uncertainty surrounding the probability of infection from very low dose aerosols in large herds is likely irreducible because the experiment would be prohibitively expensive to carry out (this experiment would require a series of controlled dose experiments with each experimental group consisting of 1,000 large animals). For this reason (and to facilitate comparison to release pathways in which the probability of an

infection occurring after an accident at the NBAF is impossible to accurately estimate—such as the Fomite pathway), the impact from each aerosol pathway is presented using a threshold value as the baseline to calculate the probability that an outbreak would occur (and the initial distribution of infected premises) and presented assuming that an infection occurs after the release (initiation assumed). In this way, risks from the various pathways can be compared without the underlying uncertainty in the probability of the initiation of the outbreak.

10) How was NAADSM modified to include Sales Barns?

Response: In order to address NAADSM's inability to manage long-distance animal movement, a production type, "sales-barn," was added to the existing production types (cow-calf, swine, dairy, and feedlot) in the scenario parameters section, as described on pg 176 of the report (*Including Sales Barns in the NAADSM model*). As a production type, sales-barns were treated like any other cattle operation in the disease options section because more than 90% of the animals handled in the sales-barns near the NBAF site are cattle. The only NAADSM parameters for which sales-barns are treated differently from the other operations is under disease spread, since this is the section where the addition of sales barns would make a difference in the spread of FMD to adjacent states. The implementation of sales-barns within the contact spread parameters is described on pg 177 (*Sales barn and State-to-State Contact Parameters*). This part of the document describes how the baseline contact rates were determined as well as the probability of infection and the distance distribution of recipient units. Shipping delay functions were based on expert testimony describing the amount of time an animal would typically be in the sales-barn or with other animals before reaching the recipient herds. Stop movements were adjusted to reflect the closing of sales barns which would reduce the animal movement from 100% to 0% within 24-hrs. Sales-barn production type combinations were limited to cow-calf, dairy and feedlot operations in Kansas, as the disease source with sales-barns as the recipient. In turn, Sales-barns could be the disease source for out-of-state cow-calf, dairy and feedlot operations, as well as feedlots in Kansas. Because swine are not typically sold in the sales-barns near the NBAF site, no contact between sales-barns and swine operations was modeled.

11) Please explain why the outputs of NAADSM described in the report are not easily extrapolated to match those of another model.

Response: Modeling was used in this study primarily to identify the release pathways of greatest risk and to ascertain the relative importance of control and mitigation measures in order to reduce the risk of performing cutting-edge science with high-consequence livestock and zoonotic pathogens at the NBAF. For this reason, the *absolute* impact of any outbreak predicted by the models used is less important than the *relative* impact between scenarios and the reduction in impact that various control and mitigation measures afford. Given the primary purpose of the study, comparing the results with models which analyze the impact of outbreaks in different areas would not augment the analysis. For example, it is unlikely the recommendations in the report would change if the estimated cost of the outbreak were $10Bn or $30Bn.

Given the complexity and scale of US agriculture and irreducible uncertainty in parameterizing some aspects of a foot and mouth disease outbreak (e.g. What is the

chance than an infected deer would infect a nearby cattle herd?), no model can predict the extent or duration of an outbreak in the US with certainty. Hence, the SSRA results are critical to informing the design and operations to further mitigate an already extremely low risk of operating the NBAF in Manhattan, Kansas.

In order to determine why two models differ in their results is extremely difficult and beyond the scope of this analysis. Even if two models were given the exact same question (the consequences of an outbreak in Manhattan, for example), understanding why they produce different results requires extensive testing of both models (the manipulation of input variables to determine the consequences on the results) and, likely, access to the code underlying the models. Without these resources, any hypothesis regarding the reasons behind the differences in output between two models would simply be conjecture. DHS remains confident that NAADSM was a valid model to use to perform the analysis.

12) Address the risk of contaminated fodder.

Response: Although the SSRA team considered the risk that an aerosol would contaminate feed that would be consumed by animals at the infected premises (as explained, for example, on page 196 and 256), the team did not consider that contaminated fodder could be transported to cause infections elsewhere.

The SSRA team has information that enables only a partial consideration of the risk from this component, including:

- The amount of pathogenic material deposited on the ground at any given site (which is low)
- The decay rate of the pathogen on fodder (which is low)
- The oral mean infectious dose for cattle and swine of FMDv (which is much greater than the inhalational mean infectious dose)

Given these data points, the risk posed by the transport of infected fodder outside of the area seems to be much lower than the risk that an infection would occur from inhalation. Furthermore, as long as the contaminated fodder causes an infection in the same part of Kansas as aerosol infections are initiated, the impact would not vary much from what is predicted currently. However, calculating the risk posed by the transportation of contaminated feed out of the region requires the following information, which the SSRA team does not possess and predicts, may be very difficult to obtain:

- The location of farms that produce feed that is shipped elsewhere
- The percent of feed on those farms that is used offsite
- Steps used to process the feed that may impact the concentration or viability of the pathogen
- Storage conditions and time in storage of the feed (temperature, humidity and protection from rain, which may washout the pathogen)
- Amount of mixing of feed from various sources
- The amount of feed consumed by an animal from any given source
- The location of farms that use feed from a potentially contaminated farm

Given these unknowns, the best the SSRA team can estimate at this time is that the risk from the transport of feed contaminated by an FMDv aerosol generated at the NBAF is extremely low, but not zero. However, the risk from the initiation of an outbreak by this mechanism is certainly significantly less than the risk posed by direct aerosol exposure and therefore the current estimates adequately represent the true risk from aerosol generating scenarios.

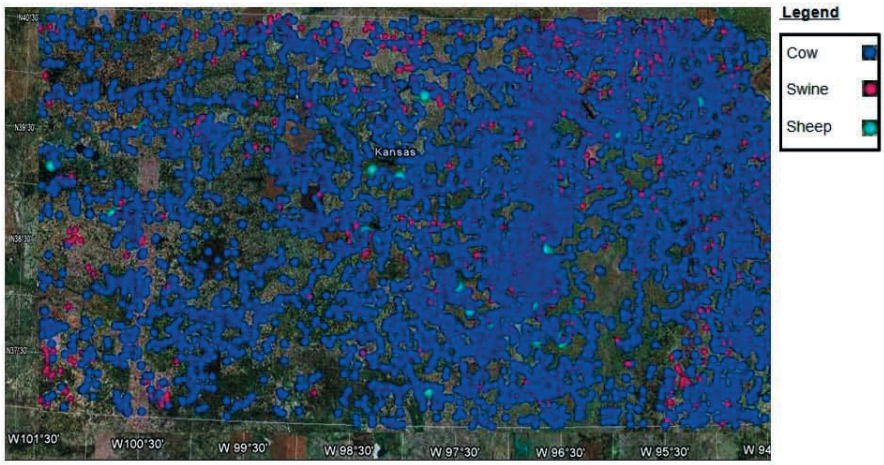
NAS Follow-Up Written Questions:

13) Figure 4.1 has Texas shaded in red, but Texas is not included in table 4.1 as part of the primary or secondary regions. Which is right?

Response: The states in the primary region as listed in Table 4-10 are correct and include; KS, IA, MO, AR, OK, CO, and NE. The states in the secondary region are CA, IN, WI, MI, SD, TX, IL, KY, OH, PA, NC, FL although only CA, IN, WI and MI received enough animals from the primary region to push the risk of receipt of an animal above 1% in the baseline case. Therefore, only these four secondary states were modeled. Figure 4-1 will be corrected.

14) Figure 4-2: can a higher resolution version of this be included?

Response: Yes, a higher resolution image was created as shown in Replacement Figure ES-3 and 4-2.



Replacement Figure ES-3 and 4-2: Susceptible Livestock Facility Locations in Kansas.

15) Table 4-6: this is a table of presence, not prevalence.

Response: Correct, this table simply lists the mosquitoes present in Kansas, not their relative abundance. Information on relative abundance was obtained from mosquito

trapping experiments performed by Kansas State University from several locations throughout Kansas.

16) Page 175: can you include some citations to NAADSM documentation?

Response: The Citations for NAADSM are as follows:

- Harvey N, Reeves A. *Model Description, North American Animal Disease Spread Model 3.1.* Version 1.1.1. NAADSM Development Team, 2008
- Harvey, N., et al. (2007). "The North American Animal Disease Spread Model: A simulation model to assist decision making in evaluating animal disease incursions," *Preventive Veterinary Medicine.* 82, 176-197, http://www.panaftosa.org.br/Comp/MAPA/431832.pdf.
- Hill, A., and Reeves, A. 2006. User's Guide for the North American Animal Disease Spread Model, 2nd ed. Fort Collins, Colorado: Animal Population Health Institute, Colorado State University. Available online at http://wwww.naadsm.org.

These and other references can be found in the Bibliography starting on page 385 of the SSRA.

17) Page 175: What version number of NAADSM was used for these simulations? If available, what was the most recent revision date of this version?

Response: The SSRA team used version 3.1.23 of the model which was last revised on August 10, 2009

18) Page 176: how long are "long distance animal movements"?

Response: Long distance animal movements were included in the model in two ways. First, based on state records of interstate movement of animals, the number of animals leaving Kansas and shipped to other states was estimated. The furthest state that received a significant quantity of animals from Kansas was California. If the movement of an infected animal were predicted to occur, it would initiate a secondary NAADSM run in the state that received an infected animal.

Secondly, in the primary region, sales-barns are considered to ship animals across Kansas and into other states in the primary region (based on data obtained from three sales-barns near the NBAF site). In Kansas, these animals are biased to move toward the large feedlots in the southwest of the state. For interstate movement, these animals are biased to move toward regions with the most feedlots. Generally speaking, the furthest these animals move in the primary region is to Colorado (typically, eastern Colorado).

19) Page 177: "the concern regarding the inability of the NAADSM model to accurately predict long-distance spread within the primary study region was addressed." Do you mean that these additions accurately and completely describe all long-distance movement issues, or just that this gives a first pass at determining if long-distance dispersal is of importance in the assessment, or something in between?

Response: No, the SSRA team is not claiming that all long-distance animal movements are completely recapitulated in the model. Within the primary region in the model, long-distance movements occur when animals are sent through a sales-barn in Kansas. These animals can be shipped anywhere in the state (but biased to the large feedlots in the

southwest of the state) and to the other states in the primary region. Although it is known that other long distance animal movements are common (large cow-calf operations and swine operations often sell directly to large finishing operations without passing through a sales-barn), the data on these movements was not available and therefore this type of movement is not included in the model. Moreover, sales-barn locations are not modeled in other states; so infections that reach these states are not spread by long-distance animal movement. Shipment of animals from Kansas to states in the secondary region used all data available on the interstate shipment of animals and therefore is probably close to the true value. Furthermore, the SSRA team found that, because livestock operations near the NBAF site tend to be relatively small, the three sales-barns near the NBAF account for more than 90% of the long-distance movement of animals in the region making it likely to host the initial focus of infection and therefore, become the greatest risk of transport before the infection is recognized in the unlikely event of a release. Therefore, for the purpose of a site-specific risk assessment of the NBAF site, this approach, while inadequate in capturing the complexity of the US livestock system as a whole, should be sufficient to capture the additional risk that long-distance animal transport poses to an outbreak originating from the NBAF.

20) Figure 4-8: How long after the start of the epidemic are these snapshots taken?

Response: In figure 4-8, the left-hand panel (without sales-barns) is a figure from a model run to day 25 of the outbreak and the right-hand panel (with sales-barns), was from a model run to day 15 of the outbreak. These are simply "snapshots" and not meant to convey any statistical power. The model without sales-barns was run longer to demonstrate that the dispersed spread shown in the model with sales-barns does not occur even if the model is allowed to run longer.

21) Table 4-7: Can you explain what alpha and beta represent (mu and sigma are more common, but might also be clarified)? Alpha and beta are also used elsewhere in the report.

Response: The alpha and beta variables are used to characterize the Weibull and gamma functions that provide the probability density functions for the length of the disease periods. In both functions, the value of alpha represents the shape parameter while the value of beta represents the scale parameter. At values for alpha lower than 1, the peak of the curve begins at y=0 and has a steep decline followed by a gradual decline. As alpha increases above 1, the peak moves away from y=0 giving the curve an initial incline followed by a decline. Alpha is independent of the location and scale parameters. Beta represents the scale parameter which essentially characterizes the statistical dispersion of the probability distribution. As beta increases, the peak height decreases as the spread increases. In both the Weibull and gamma functions, the location parameter is held as a constant within NAADSM. Some researchers refer to the alpha variable as "kappa" and the beta variable as "lambda" for Weibull functions and "theta" for gamma functions. The mu and sigma variables represent the mean and standard deviation, respectively, and are used to characterize the normal distribution. Mu provides the location of the peak on the x axis and sigma influences the spread and height of the peak. As sigma increases, the peak height decreases and the spread widens. Mu and sigma do not completely describe a Weibull or gamma function, thus, were not given.

22) Page 221: What's the average time to reporting and observation under these assumptions?

Response: When using the parameters, in a typical outbreak, the average time until the outbreak is detected and reported is roughly 15 days from outbreak initiation and 17 days for the p75 case. Typically, the third or fourth generation infections have occurred by this point. On page 219-226, we show how changes in these parameters alter the nature of the outbreak. While changing these parameters has a modest effect on the day that the outbreak is reported (increasing or decreasing by a day or two), there is a significant impact on the extent and duration of the outbreak and the chance that it would spread to other states, underpinning the importance of good disease surveillance and producer education on the signs of FMD and the importance of reporting suspicious cases.

23) In the RVF model, can you explain why no susceptible mosquito compartment was included?

Response: When the SSRA team was originally developing the RVF model, it was desired to have a compartment in the model that tracks the population of uninfected mosquitoes, which could become infected by RVF. However, after consulting the entomological literature and talking to subject matter experts in entomology at Kansas State University, at the USDA, and mosquito trap and repellent developers, it was found that the density of mosquitoes (#/area) in Kansas is unknown. Also, attempts to extrapolate this value from other sources (such as bite rates or mosquito trapping data) were unsuccessful because critical data were unavailable (such as the capture efficiency of traps). For example, the efficacy of a spraying campaign is known not by a reduction in the absolute count of mosquitoes but because fewer mosquitoes were trapped after spraying than before. Therefore, the model had to be developed without this information.

Instead, the model considers that infected hosts "generate" infected mosquitoes (or that there is an unlimited pool of susceptible mosquitoes). Each animal supporting a sufficient viremia will generate infected mosquitoes depending on the bite rate per animal per day and the efficiency of disease transfer from a vertebrate to a mosquito that takes a blood meal. Spraying, which in reality reduces the pool of susceptible mosquitoes, reduces the bite rate of infected animals and thereby reduces the number of infected mosquitoes generated. In this manner, the paucity of data was mitigated in the model.

24) In Appendix I on FMDv and RVFV, the y-axes on the figures are not clear: it is difficult to understand the meaning of "log [% viral viability/minute]." Please provide a lay language definition of the decay rate for the y-axes.

Response: In these charts, the Y-axis represents the decay of viral viability per period of time. The numbers indicate the log reduction of the virus over the described period of time at that humidity. The larger the number, the more decay is occurring (logarithmically). For example, in Figure 2, at 40% RH, the amount of virus viable at time 0 will decrease by four logs after one hour. That is, if there is 1,000,000 pfu of FMDv at time 0, there would be 100 pfu one hour later at 40% RH. In contrast, at high RH, the decay is near zero.

Economic Modeling

NAS Follow-Up Written Questions:

25) The commodity coverage is vague. What commodities are included in the results?

Response: The commodities included in the partial equilibrium model results are wheat, coarse grains, soybeans, rice, forage and pasture, soybean complex (soybean oil and soybean meal), cattle, hogs, poultry, lamb and sheep, beef, pork, poultry meat, lamb and sheep meat, dairy products, and eggs.

26) Why is the format for the economic results inconsistent across scenarios? For the tornado scenario an extensive range of outcomes is reported but all other scenarios report a single, usually the median, outcome. Why not report the minimum, mean, and maximum economic impacts for each scenario?

Response: Given the recent tornado event (June 2008) in Manhattan, KS, special consideration was provided to examine additional cases for this scenario. In all other cases the SSRA estimated the economic effect at the mean, which was predominately larger than the median. We believe the approach to use the mean was sufficiently conservative and valid. The data exists from the epidemiological modeling to estimate the economic effects at p25, p50, and p75. However, this additional effort (compilation of the epidemiological data into a format the economists can use as well as the economic calculations) would take significant time to complete and would require additional clarification from the Committee on exactly what data are required for their analysis. A subsequent email from the Study Director regarding this issue dated 23 July stated "*the committee would like to have the minimum, median, and maximum spread from the NAADSM runs for accidental and self reporting*" made the SSRA team question whether the Committee was requesting economic calculations, or additional epidemiological data as indicated by the 23 July email. In either case, if these additional data points are required, a written request outlining the specific data needed by the Committee and a subsequent conference call with a NAS representative to further clarify the information, is requested by 30 July (the resulting data is not expected to be available until mid-late August and is dependent on the nature of the final request). However, we believe that the approach used in the SSRA remains valid and the additional runs would not affect the end result.

27) Why are the consumer responses to FMD and RVF assumed to be so strong? These diseases cannot be transmitted via meat and dairy products. There is little evidence from the FMD outbreaks in the U.K. and Taiwan or the BSE outbreaks to suggest that consumers would react so negatively.

Response: Several reasons. First, outbreaks of FMD and RVF were assumed not to be repeated events but rather new or novel events for the United States which is historically accurate. Hence, it was assumed that shocks would likely be stronger in an adverse manner for consumers and trade (relative to repeated events). Second, according to WHO fact sheet on RVF it can be transmitted via blood from meat (http://www.who.int/mediacentre/factsheets/fs207/en/):

"The vast majority of human infections result from direct or indirect contact with the blood or organs of infected animals. The virus can be transmitted to humans through the

handling of animal tissue during slaughtering or butchering, assisting with animal births, conducting veterinary procedures, or from the disposal of carcasses or fetuses. Certain occupational groups such as herders, farmers, slaughterhouse workers and veterinarians are therefore at higher risk of infection. The virus infects humans through inoculation, for example via a wound from an infected knife or through contact with broken skin, or through inhalation of aerosols produced during the slaughter of infected animals. The aerosol mode of transmission has also led to infection in laboratory workers."

Hence, there is likely concern for an adverse reaction to RVF. As a result, we assumed a 5% demand shock in the second quarter of the year and 2.5% decrease in the third quarter of the year (Table 5-16).

Third, we assumed any FMD outbreak that required a culling over (less) than 1 million animals resulted in the larger (smaller) demand shock.

28) The consumer response to RVF shows an odd pattern for a disease that is not transmitted via meat consumption. In the first quarter there is no response, then in quarter 2 demand drops 5% which matches the reduction for FMD. Is this pattern because the disease is transmitted via mosquitoes which cannot breed in the January-March quarter? Why do the second and third quarter demand reductions match those for FMD?

Response: As stated above, WHO states that human health risk for RVF exists for those handling raw products. Under assumptions of the model, the outbreak begins in the second quarter of the calendar year, assuming there are no mosquitoes present in Kansas during winter to be of concern in the first quarter of the calendar year.

Since there is likely concern for adverse reaction for RVF, we assumed a 5% demand shock in the second quarter of the year and 2.5% decrease in the third quarter of the year (Table 5-16). This is consistent with a smaller FMD outbreak.

29) Why are not the export loss and recovery adjusted to reflect the severity of the FMD spread? While the assumed trade reductions and recovery are only slightly excessive for the mean case of an accidental release, for the situations where few animals are affected and the outbreak lasts only a few days, the assumed export shocks are excessive.

Response: It is just as debatable how much export shocks should be (as opposed to would be) changed for different levels of outbreaks. If FMD were a common occurrence in the US, certainly, adjusting to the length of the shock makes sense. That said, we followed the recommendation of 2 year trade ban as suggested by the NAS panel. In hindsight, we concur that the export shocks are likely excessive for the accidental release.

30) Why are the export reductions larger and recovery slower for RVF than for FMD? FMD does trigger export restrictions, but the OIE guidelines for RVF require certification and testing that the animal or meat is free of RVF.

Response: RVF is a difficult case with no previous experience in the U.S. Hence, assumptions were made based on information gleaned from reports and experiences in Africa and the Middle East. Historically, RVF has had been almost impossible to eradicate once it has been established. RVF not only affects livestock, but also humans

and is transmitted by mosquitoes. RVF tends to reoccur periodically, contingent upon climatic conditions and other factors.

Suppose RVF were released in Manhattan, KS. If we assume not only all the livestock were eradicated but also all mosquito vectors, then it would be clear that RVF would likely trigger smaller export restrictions. However, it seems unlikely that one would know with certainty that RVF were eradicated within one season. Indeed, if RVF were not detected before it spread among the insect population, then a larger and slower export recovery makes sense. So it is not clear the U.S. could realize a disease-free status in a short amount of time.

31) How comfortable is the research team with the estimate that the individual economic loss per case of RVF is $85,206? The WTP to avoid blindness and death seem low while the WTP to avoid a few days of flu-like symptoms seems high.

Response: The WTP to avoid death coming from survey is low (but not unreasonable) compared to hedonic studies, and as a result, we use the VSL a widely used meta analysis to determine the value of death. That is, the figure $85,206 is an expected cost of illness which includes a 1% chance of death valued at over $8 million per death. The values of blindness and flu-like symptoms seem reasonable and consistent with related literature as described in the text. No data existed to estimate morbidity costs for people in this region. As a result, the survey presented and reported in the report was completed. This represents the best current source of information available. We are not aware of any previous estimates of the value of blindness. The standard errors for parameters are reported in Table 5-21 (numbers in parenthesis), so confidence intervals can be readily calculated. Hence, confidence intervals on the WTP for blindness also can be calculated.

32) What type of producer expectations are used in the analysis?

Response: Naïve expectations were used, see page 301 of the SSRA.

33) For the accidental release the difference in aggregate returns to producers by quarter should be graphed to determine the extent of recovery to baseline at the end of the model simulation time period.

Response: This could be incorporated for the accidental release scenarios with some effort; however the recommendations of the report would not change.

34) Rather than saying that the total economic impact is $32 billion, could the report provide a range for the total economic impact that accounts for the various estimations?

Response: Yes, to avoid individuals only focusing on the one value, a range for the total economic impacts that accounts for the different scenarios could have been included and will be considered as part of the presentation of the final results.

Residuals and Sanitary Treatment

<u>NAS Follow-Up Written Questions:</u>

35) Please clarify how the sanitary system capacity was chosen (summarized in Table 3-2) by explaining the design basis supported with a customary sanitary engineering characterization for the wastewater and slurries generated in the proposed laboratories and animal suites (volume/concentration/physical states: BOD, COD, anticipated pathogen load, TDS, TSS, Temp, pH).

Response: The capacity of each of the two effluent decontamination systems (EDSs) specified in the 15% schematic design was based on an assessment of current and anticipated programmatic space, research needs, animal model requirements, and other laboratory needs of USDA's Animal and Plant Health Service (APHIS) Veterinary Services (VS) and Agricultural Research Service (ARS) programs—both of which will be located at the NBAF. The 15% schematic design incorporates one EDS for BSL-3 (BSL-3E and BSL-3Ag) wastes and one EDS for BSL-4 wastes, as indicated in Figure 3-3 of the SSRA Report. The quantity of effluent from each room in the containment area was assessed for a peak day, and broken down into hourly flows throughout a 24 hour day. All the rooms/activities (showers, autoclave condensates, animal holding rooms/wash downs, etc.) contributing to each of the EDSs were then totaled together to achieve a peak hour by hour flow rate and a peak total volume per day. This peak total volume per day assumes that every room in the facility is operating at peak capacity. This data was also scaled and compared with actual flow profiles generated from existing operations from the Canadian Science Center, in Winnipeg, Canada. NPD has estimated that normal EDS loads will be approximately 70% of the peak loads. For the purposes of the risk assessment, however, 50% of the peak volume was used with the full estimate of improperly treated pathogenic materials as the basis—a conservative approach to estimating the maximum concentration of viable pathogens in the effluent (by minimal dilution) discharged during a day.

The characteristics of the effluent from occupied animal holding rooms will vary, but will be washed down every day. The anticipated wash down protocols include the prior removal of bulk solids (feces, waste feed, etc.) followed by a chemical spray down (specific chemical determined by pathogen/animal model species) and water rinse. (No organic bedding materials will be used at NBAF.) It is recognized that not all of the solids will be removed by the solids removal protocol. Drains in the animal handling rooms will be equipped with a grate and strainer. Large diameter (6") drains with deep (to accommodate pressure differential) P traps will facilitate flow and minimize the potential for clogging. All drains are gravity drains. The consensus of the design team and the panel of subject matter experts convened for the QRA was that wastewater grinders, such as the Muffin Monster®, would not be required—but a final decision on this issue will be made during the next design phase. The high-temperature and high-pressure neutralization in the cooking tank and agitation/mixing that is augmented by steam injection will provide adequate neutralization of pathogens in small particulate elements of the waste stream. The selected cook tanks may also include a particulates strainer as well. Data indicate that all NBAF pathogens will be neutralized with 250°F saturated steam (15 psig) when held for 15 minutes or longer. NDP has selected cook tanks that have an operating range of up to 275°F (300°F maximum temperature) and an operating pressure range of 20-25 psig. (The cook tanks are rated to 125 PSI but pressure relief valves will be set to the 45-50 psi range.)

Specific characteristics of the NBAF containment waste stream will vary with decontamination protocols, animal holding protocols, and other operational considerations. NDP's assessment of the effluent characteristics of other similar facilities lead to the development of Table 3.3.4.3.4-1—Local Limits in the EIS, indicating that discharged effluent characteristics will be compliant with local standards, specifically:

TSS: <350 mg/l
BOD: <300 mg/l
Fats, Oil, and Grease: <100 mg/l
pH: 5.5-9.5
Discharge temperature: <150 F

No viable pathogen load is anticipated from the containment areas—chemical and thermal neutralization are designed to inactivate any pathogenic materials from these sources. Thus, any pathogen load would be consistent with any other domestic/office sanitary sewer load.

36) Define reliability with respect to the operations of sanitary systems. Please provide some basis for the redundancy chosen in the sanitary engineering system [as well as estimate of reliability] given the design and operation of similar systems. What in situ biological indicators will be used, and how often will the sanitary systems be monitored.

Response: Reliability of the EDS, for the purposes of the SSRA, is the probability that the system will perform its required function (neutralization of viable pathogenic materials) for a specified interval under the stated conditions. In this context, the "system" includes laboratory personnel, fixtures, valving, plumbing, holding tanks, cook tanks, and monitoring systems. The system being planned for is designed with all wetted parts to be manufactured from 316L stainless steel. In comparison with other facilities which use similar systems also manufactured from 316L Stainless steel, the technology shows negligible wear over 10 years, and life expectancy is in excess of 25 years. As with all systems, the technology does have moving parts, seals, and valves, all of which are prone to failure and require periodic maintenance and replacement. The system is designed to have redundancy throughout such that no single point of failure will disable the operations. The redundancy of the current configuration being is based on the ability to store a full peak capacity day's effluent volume (in the storage holding tanks), with one extra redundant storage tank (N+1) for the EDS-C system. This will accommodate the capability of storing the effluent to allow for a safe clean-up and shut down of laboratory operations in the event of cooking system failure, until the failure can be repaired and operations can continue. The redundancy for the cook tanks actually exceeds N+1 for both the EDS-C and EDS-4 systems. Since the cook tanks can process multiple cycles per day, the design redundancy changes based on batch size, cycle duration, and time of day. Overall, the failure mode probability (decontamination solution was not included with the effluent, the effluent is processed in a failed cycle, the failed cycle is not observed or reprocessed, and the effluent is released into the sanitary sewer system) was estimated as 1.0E-8 and the estimated frequency was 2.3E-5 events per year, as presented in SSRA Appendix G.

The cook tank system is designed to have two means of biological validation. There will be a drywell in which autoclave indicators can be inserted and retrieved without disruption to the process. The indicators are exposed to the same temperature that the effluent is exposed to and can thus validate the process as often as desired. For the second means of validation, the effluent load is spiked with viable spores (or other viable performance indicators), and samples can be drawn off through a double valve sampling port assembly during or after a cook cycle. This process is significantly more time consuming because of the analytical demands. This process is also more hazardous as the effluent is under pressure during the cooking cycle, so extreme care must be taken in relieving the pressure from the sample port when samples are drawn. Complete effluent decontamination validation will be performed during the commissioning period. Most other similar facilities subsequently validate their process annually (once per year). Between validations, most facilities record time and temperature for each cycle to verify the original sterilization parameters are met.

37) Please provide design basis and operational practices for wastewater / slurry / solids separation (e.g. size distribution, anticipated masses).

Response: The current design includes no specific solids separation of the effluent waste stream prior to decontamination other than by protocol (prior removal of bulk solids (feces, waste feed, etc.)) and the use of grates and screens in the drains. Many of the cook tanks have integral strainer baskets for the removal of sterilized solids prior to effluent discharge. These systems, however, can be problematic and labor intensive and are therefore not part of the NBAF design. Additionally, DHS decided to add an on-site waste water treatment plant on the NBAF campus.

38) Please provide key thermodynamic design metrics and chemical inactivation design metrics as a basis to reliably treat the "sanitary" wastes and slurries generated.

Response: For many years, the industry accepted practice for the successful treatment of effluent from animal holding facilities has been 250°F for 15-20 minutes. The cook tank specifications will require the ability to routinely hold a minimum temperature of 250°F for a period of up to 1 hour. They will have a peak operating temperature capability of 275°F and a maximum temperature of 300°F. In addition to temperature, however, is the need for the cook tank to handle high pressures. The tank specifications will be for an operational limit of 20-25 psig and pressure relief valves set to 45-50 psig. (The tanks will be rated to 125 psi.)

There is no chemical injection in the EDS system, but chemicals are used as protocol dictates in the laboratory and for animal room wash downs. The specific chemicals to be used will be determined at a later date. The choice of materials was driven by providing specifications for 316L, the most resistant and validated system currently available. While the current design does not include the direct injection of chemicals into the cook tank, there are several options for chemicals to be used in the laboratory and for animal holding room wash downs. Some of these chemicals include:

Virkon® S: Often used for animal rooms and for decontamination in many other laboratories, soaps and detergents, calcium hypochlorite, sodium hypochlorite (not recommended because of corrosion issues, etc.

39) Please provide key thermodynamic design metrics and incinerator design metrics as a basis to reliably treat the solid wastes described.

Response: Fixed-facility incinerators have the ability to control temperature and combustion efficiency that an open incinerator does not. The incinerator, as described in the 15% schematic design and assess in the SSRA, has a primary chamber and a secondary chamber that provides a higher-temperature environment for particulate liberated in the primary combustion chamber. The primary chamber is designed to operate at 1600°F. The secondary chamber is designed to operate at 1,800°F and the flow path will be exposed to this temperature for a 2 second retention time.

40) Please provide practical proof of concept and relevant examples the systems and metrics chosen will provide sustained and successful treatment of this mixed animal waste.

Response: There are several facilities that continue to operate and successfully treat mixed animal wastes from laboratory containment areas. Some of these locations include the Plum Island Animal Disease Center (PIADC) BSL-3Ag in New York; the National Animal Disease Center (NADC) in Ames, Iowa; the Animal Health Research Center (AHRC) at the University of Georgia College of Veterinary Medicine BSL-3Ag in Athens, Georgia; the Canadian Science Centre for Human and Animal Health (CSCHAH) in Winnipeg, Canada; and the Australian Animal Health Laboratory (AAHL) in Geelong, Australia. The facilities on this short list of laboratories, which have been visited by the design team as a part of this design process or individually visited by designers include applications of technologies that will be included or considered for the NBAF: incinerators, tissue renderers, alkaline hydrolysis tissue digesters, and liquid effluent cook tanks, similar in design to those proposed for NBAF. NBAF will take advantage of some advances in technology, but the basic process and treatment parameters of time and temperature will remain the same, and all the technologies being proposed have been biologically validated at these facilities.

41) Please provide HVAC engineering information and safeguards that proposed 2 stage incinerator operations will not compromise any of the negative indoor pressure gradients.

Response: In the 15% schematic design, the incinerator is located outside of the containment area (in a containable area) in the basement of the NBAF. The physical connection between the incineration chamber and the containment area is through the loading chute. In the 15% schematic design, a "three-door" system is used to control the flow of air/gases and prevent the compromise of the design pressure gradients. This system, as described in the SSRA, includes "top door", "intermediate door", and a "bottom door." This proposed design has been proven in other facilities. The top door is the primary seal, and seals the laboratory from the incinerator operation. There are two more doors below this, the middle door is a secondary door which is also normally sealed. The bottom door is a fire door which is refractory lined and protects the seals on the middle and top doors. During loading, the top door is opened, and the load is put into the loading chute between the middle door and top door. These two doors are interlocked so that both cannot be opened at one time. After the top door is closed, the fire door and the

middle door open, dropping the load into the primary chamber. This triple door design maintains the pressure gradient between the incinerator chamber and the necropsy room.

Additional Topics

NAS Meeting Questions:

42) Can the SSRA team address the perceived inconsistencies between the QRA and the SSRA?

Response: There were two areas discussed at the NAS meeting to which the panel raised concern about perceived inconsistency between the QRA (Appendix C) and the SSRA; the relevance of deer populations and handling of animals within BSL-4 containment. First, the QRA SME Panel acknowledged the significance of the wild deer population in context of FMDv research at NBAF and in outbreak mitigation response strategy considerations. Specifically, in their Final Report, the QRA Panel recommended that in order to support future research models, the NBAF should consider implementing animal restraint systems to accommodate species (such as white tail deer) not suited to traditional large animal squeeze chute systems. In addition, the Panel recommended that monitoring of a potential wild animal reservoir (wild pigs and deer) be considered during the development of an outbreak mitigation response strategy for FMD.

In Section 4.1 Susceptible Animal, Human and Vector Populations of the SSRA, it is also acknowledged that the wildlife population in Kansas could potentially play a role in the disease spread of a FAD outbreak. The section also included a characterization of the Kansas deer population data that were collected during the SSRA. Based on the available data at the time of the SSRA, it was concluded that although the wildlife population poses a credible risk, the current data were insufficient to incorporate into a quantitative model.

Second, one of the unique elements of risk to assess for the NBAF was its capacity to support research work with zoonotic agents in large animal models in a BSL-4 containment environment. The QRA SME Panel considered this risk during its qualitative assessment of all eight pathogens and endeavored to provide input to inform the design and operations of the NBAF so that potential risks and hazards associated with the BSL-4 level zoonotics research could be addressed at an early stage. On the specific point of NBAF design, it was concluded by the QRA SME Panel that their recommendations were already included, and/or enabled or under consideration for implementation at the NBAF.

The SSRA did not quantitatively model this specific risk, because sufficient data for quantitative modeling are not yet available for the potential zoonotic pathogens (Nipah and Hendra) to be studied under BSL-4 containment. Additionally, the SME panel affirmed the adequacy of the BMBL as the design basis for the NBAF BSL-4. The SSRA team acknowledged, however, the fact that the NBAF will work with Nipah and Hendra in a BSL-4 laboratory --potentially with large infected animals -- and that risk should be considered in informing the design of the facility. As such, Recommendation #13 addressed the need to incorporate basic design features to facilitate the safe and humane movement of animals through the facility in order to minimize risk to personnel and biocontainment.

43) Why wasn't the DOE model for tornado analysis used?

DOE-STD-1020-2002, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities, provides an excellent conceptual framework for natural phenomena design input for facilities that have the potential for the release of contamination—such as nuclear facilities and biocontainment laboratories. This standard recommends the use of ASCE 7 (ASCE 7-10 being the latest version) wind load provisions. DHS and NPD are currently considering the impact of the adoption of the ASCE 7-10 in its on-going design. Fortunately, the straight wind design basis used in DOE-STD-1020-2002 and in the 15% schematic design are both derived from the national wind map. For the purposes of the SSRA, it was determined that a site-specific return period for tornado events, by intensity level, would be useful in estimating the relative risk of a tornado strike that would result in a loss of pathogen containment. The DOE-STD-1020-2002 methods could be applied for the Manhattan, Kansas, location and the resulting relative risks could be reassessed and compared to the site-specific assessment incorporated into the SSRA if required.

44) Can the SSRA team provide additional information regarding the recommendation to use parallel double HEPA standard design?

The Biosafety in Microbiological and Biomedical Laboratories, 5th Edition, describes features of a BSL-3Ag laboratory in Appendix D, Section II. Item 6, repeated below, these BMBL features were identified as an NBAF 15% schematic design variance during the SSRA.

BMBL, 5th Ed., Appendix D-II-6: Supply and exhaust air to and from the containment space is HEPA filtered. Exhaust air is discharged in such a manner that it cannot be drawn into outside air intake systems. The HEPA filters are outside of containment but are located as near as possible to the containment space to minimize the length of potentially contaminated air ducts. The HEPA filter housings are fabricated to permit scan testing of the filters in place after installation, and to permit filter decontamination before removal. Backup HEPA filter units are strongly recommended to allow filter changes without disrupting research. The most severe requirements for these modern, high level biocontainment facilities include HEPA filters arranged both in series and in parallel on the exhaust side, and parallel HEPA filters on the supply side of the HVAC systems serving "high risk" areas where large amounts of aerosols containing BSL-3-Ag agents could be expected (e.g., animal rooms, contaminated corridors, necropsy areas, carcass disposal facilities). For these high-risk areas, redundant supply and exhaust fans are recommended. The supply and exhaust air systems should be equipped with pre-filters (80-90% efficient) to prolong the life of the HEPA filters. Air handling systems must provide 100% outside conditioned air to the containment spaces.

The 15% schematic design does not provide HEPA filters arranged in both series and in parallel on the exhaust side of BSL-3Ag animal handling rooms. The current design includes series HEPA configuration on the exhaust side of animal handling rooms. The BMBL description of HEPA series and parallel requirements is indeed very severe. As suggested in Section 7 of the SSRA (Pg 355, #4): *DHS* will convene *a SME panel to address the issue related to the BMBL requirement for complete redundancy of double*

HEPA (sequential) exhaust filtering systems and if findings indicate that this is not necessary, prepare a written response to the BMBL authors with an alternative suggestion. If a SME panel determines that the series+parallel configuration is necessary, DHS should direct NDP to make the appropriate engineering modifications to the NBAF design. If the SME panel determines that the intent of the BMBL requirements can be satisfied by other alternativesthe BMBL authors should be advised of this observation.

45) Are the mitigation strategies proposed in the SSRA realistic?

Response: The recommended mitigation strategies proposed in this SSRA were to inform the design, operations and response planning efforts for the NBAF at the very early stages of design. Because these recommendations were provided so early in the NBAF design process, the proposed recommendations are much more likely to be implemented with minimal impact to cost and schedule relative to the impact they would have if recommended after NBAF design was complete and/or construction in progress. This SSRA did not include an assessment or estimation of costs, schedule or feasibility of the various mitigation strategies recommended. This is being implemented as part of the design and operational planning effort and will include a thorough cost/benefit and efficacy analysis of the various recommended mitigations (such as disease/pathogen surveillance, facility tornado hardening, implementation of on-going training courses, etc.,).

NAS Follow-Up Written Questions:

46) Table ES-3: It is not clear why item No. 5 recommends an F2 event and F3 for static containment. Please clarify.

The 15% schematic design will prevent the loss of pathogenic material if the facility is struck by an F2 tornado. This includes the hardening of necessary Central Utility Plant elements that are needed to provide necessary services for an orderly (at least as orderly as possible) shutdown after an F2 event. It is anticipated that the shift from a non-F2 structure to an F2-survivable structure will drive the basic design and construction techniques. The new design and construction techniques may present the opportunity to further enhance the hardness of the structure for relatively little marginal cost. Thus, the SSRA recommends that DHS consider hardening the facility for containment to further mitigate the risk of pathogen release in the event of a F3. Given the overall robustness of biocontainment design, it should be noted that the risk of a pathogen release from a tornado remain very low.

47) What are the units of Table 1-1?

Response: The second column in Table 1-1 "NBAF NSF" refers to the NBAF Net Square Feet (the total usable square footage of a facility - the square footage that is measured from the inside wall surfaces[2]), the third column in Table 1-1 "NBAF GSF, refers to Gross Square Feet (the sum of all areas on all floors of a building included within the outside faces of its exterior walls, including all vertical penetration areas, for circulation and shaft

[2] http://www.pdc.cornell.edu/eng/fig/Forms accessed on 21 July 2010.

areas that connect one floor to another[1]). For clarification, these two acronyms can be included in the Glossary of Acronyms and Terms within the SSRA.

48) In the case summary tables, "Likelihood" has a specific statistical meaning in terms of inference that is different from the current usage. It is also redundant compared to the accident frequency statement. Perhaps only the latter would suffice?

Agreed, the suggested change can be made.

49). Table for 1FC, double-negative in the likelihood – is that correct?

Response: No, the likelihood for 1FC should read as 1.3×10^{-6}/50 years, not $1.3 \times 10^{--6}$/50 years, this is a typographical error which can be corrected.

50) In table 6-4, the risk of an aircraft crashing into the lab is given as once every 3 x 10^13 years. Given the size of the lab and one random major airline crash in the continental US every 10 years, order-of-magnitude efforts put this event at 10^10 years, and the current concerns about international terrorism suggest that while still in the category of improbable, estimates that are several orders of magnitude higher are reasonable. Do you stand by the current number? For comparison, the risk of effect from a major solar impact event would be larger.

Response: The methodology used to estimate the frequency of an aircraft crashing into the NBAF is described in US DOE STD 3014-96. Using this method the resulting frequency, F, is 3.5×10^{-4} crashes/year. The parameter listed in Table 6-4 of the SSRA is the case period, $T_c = \sim 3 \times 10^{12}$ years, corresponding to a case frequency, $F_c = \sim 3.5 \times 10^{-13}$ cases per year. The difference in the aircraft crash frequency and the case frequency is the failure of all structural containment features, laboratory containment features, and sample containment features as a result of an aircraft crash in the vicinity of the NBAF. It should be noted, changing the order of magnitude of this case by +3 does not significantly change the risk ranking. This frequency does not include consideration of an intentional act of sabotage or attack.

<u>NAS Follow-up Suggestions:</u>

51) Can you add page numbers to the appendix references?

Response: Page numbers can be added to the appendix references.

52) Can you add legends and distance scales to provide clarity for all maps?

Response: Legends and distance scales can be added to maps for clarity as appropriate

53) Can you recheck some numbers for their appropriate significant figures to reflect the appropriate level of certainty?

Response: Significant figures can be reviewed and adjusted as appropriate.

DHS considers this letter, in its entirety, to be part of DHS's deliberative process, and therefore protected from public disclosure under the Freedom of Information Act, 5 U.S.C. § 552(b)(5). Accordingly, DHS has marked this letter with the following legend: "*This document contains pre-decisional and/or deliberative process information exempt from mandatory disclosure under the Freedom of Information Act, 5 U.S. C. 552(b) (5). Do not release without prior approval of the Department of Homeland Security.*" The National Academies may include this letter in the public access file (PAF) created for this study upon the earlier of: (1) the public release of the SSRA by DHS; or (2) upon the concurrent release of the NRC Committee's Preliminary Letter Report and Final Report to the public. DHS authorizes the National Academies to remove the markings before placing the SSRA in the PAF. Alternatively, upon request, DHS will provide clean copies (markings removed) of the SSRA to the National Academies for placement in the PAF.

DHS would like to thank the Committee for its review of the SSRA and looks forward to delivery of the NRC Committee's Final Letter Report. We will continue to make ourselves available to the Committee to answer further questions or provide additional clarifying information. Please contact James V. Johnson, Director of the DHS S&T Office of National Laboratories at (202) 254-6098 or james.johnson2@dhs.gov.

Sincerely,

James V. Johnson
Director, Office of National Laboratories

Cc: Ms. Peggy Tsai, Study Director and Program Officer, National Academies

35

Homeland Security

August 26, 2010

Dr. Ronald Atlas
Chair, *Committee on the Evaluation of the SSRA for the Planned NBAF in Manhattan, Kansas*
The National Academies
500 Fifth Street, N.W.
Washington, D.C. 20001

Dear Dr. Atlas,

On June 30, 2010 DHS submitted the National Bio and Agro-Defense Facility (NBAF) Site-Specific Biosafety and Biosecurity Mitigation Risk Assessment (SSRA) to the "National Research Council (NRC) Committee on the Evaluation of a Site-Specific Risk Assessment for the Department of Homeland Security's Planned NBAF in Manhattan, KS" hereinafter referred to as the "Committee." The Committee is charged with assessing the adequacy and validity of the SSRA. After initial review of the SSRA, the Committee held a public meeting on July 13, 2010 to ask DHS and Signature Science, LLC (the prime contractor for the SSRA) questions about the analysis. DHS subsequently sent a letter on July 28, 2010 which provided additional information in response to Committee questions asked during the public meeting as well as answers to 35 written questions sent to DHS by the Committee on July 16, 2010.

Per the request of the Study Director, the following details are provided as an addendum to the responses offered to the Committee in the July 28, 2010 letter. Specifically, we are expanding upon the responses to questions 26 and 34, which request the possible ranges of economic impacts associated with the scenarios evaluated, and question 43, which relates to the application of DOE-STD-1020-2002 to the tornado analysis. The conclusions and overall risk rankings are unchanged by the supplemental analysis provided in this letter.

Questions 26 and 34: Economic Analysis

Given the inherent uncertainty and wide range of potential outcomes from an FMD outbreak, economic consequences were assessed to represent a range of the distribution of outcomes provided by the epidemiological model. Attachment 1 is the updated draft of Chapter 5 of the SSRA (revised sections are marked with a line in the border), which has been updated to reflect the additional economic analysis. More specifically, economic consequences are now formally reported for the distribution of outcomes at the P5 level (meaning 5% of the epidemiological model outcomes resulted in a lower value), at the mean, and at the P95 level (meaning 95% of the epidemiological model outcomes resulted in a lower value). In effect this provides lower, average, and upper measures of economic consequences that may arise from an FMD outbreak. Given the small number of infected

and culled animals from the RVF outbreaks reported in the epidemiological outcomes, only the mean of the distribution of outcomes is used to assess economic consequences (as the P95 level would make little difference in the impact on outcomes). For consistency, the RVF table was updated to reflect the same units as the FMD table; however, no new RVF outputs are reported. We have included the 95% confidence intervals related to the human impacts in the revised chapter.

In addition to these data, the revised chapter includes expanded discussions related to price expectations, consumer shocks, trade shocks, regional non-agricultural impacts, and overall FMD impacts, plus additional figures which graphically communicate the dynamic economic impacts across the study period for specific scenarios.

Question 43: Natural Phenomena Hazard

The SSRA team has performed additional research and developed text for the final edition of the report that describes how the methodology used in the NBAF EIS and SSRA is based on the methodology used in DOE-STD-1020-2002, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities. This Natural Phenomena Hazard (NPH) standard was issued in 2002 and provides references and citations for the DOE-preferred methods of assessing natural hazards and, subsequently, risks. The NBAF EIS makes extensive use of DOE methodologies and the SSRA provides additional validation of some EIS assumptions and site-specific details. With regard to wind design and evaluation criteria, both the DOE methodology and the SSRA approach are based on the use of ASCE 7 (also reflected in NBAF basis of design) for determining wind loads produced by straight, hurricane, and tornado winds. Consistent with DOE-STD-1020, the straight wind design basis is derived from the national wind map. Hurricane winds were determined to be non-problematic for the Manhattan, Kansas location. The SSRA also uses the DOE precedent to provide site-specific information where it is available. DOE uses hazard models for specific DOE sites at many locations in lieu of using national, or even regional, seismic or wind data; however, no DOE data was identified for the NBAF site in Manhattan, Kansas.

With DHS' interest in providing a transparent site-specific risk assessment process and the perceived focus of attention on the tornado concerns for the Manhattan, Kansas location, the SSRA team determined that it was desirable to have the best and most site-specific information available on the return period and derived frequency of tornados (by intensity level) for the risk ranking. This approach is consistent with Step 4 of DOE-STD-1023-95, Natural Phenomena Hazard Assessment Criteria (A3.2.2-e), which states:

A tornado hazard analysis consists of the following steps:

Step 1: Compile, obtain, and update as necessary a data set of tornadoes for the area.

Step 2: Develop occurrence-intensity relationship.

Step 3: Develop area-intensity relationship.

Step 4: Calculate probability of a point experiencing tornado intensity.

Step 5: Calculate probability of tornado wind speeds exceeding specified values

The NAS Committee also suggested that it would be useful to present the site-specific return period by intensity level in terms of the Enhanced Fujita (EF) Scale in addition to or in place of the Fujita (F) Scale (used in the draft version of the SSRA). Both the EF and F Scales will be used in the final version of the SSRA report. The F Scale was used in the draft version because the historical data used in the return period calculations was almost entirely presented in terms of the F Scale. The research forum (a group of nationally renowned meteorologists and wind engineers) that developed the EF Scale also developed a correlation methodology for the EF Scale and the F Scale which we will use for the conversions in the final report.

DHS considers this letter, in its entirety, to be part of DHS's deliberative process, and therefore protected from public disclosure under the Freedom of Information Act, 5 U.S.C. § 552(b)(5). Accordingly, DHS has marked this letter with the following legend: "*This document contains pre-decisional and/or deliberative process information exempt from mandatory disclosure under the Freedom of Information Act, 5 U.S. C. 552(b) (5). Do not release without prior approval of the Department of Homeland Security.*" The National Academies may include this letter in the public access file (PAF) created for this study upon the earlier of: (1) the public release of the SSRA by DHS; or (2) upon the concurrent release of the NRC Committee's Preliminary Letter Report and Final Report to the public. DHS authorizes the National Academies to remove the markings before placing the SSRA in the PAF. Alternatively, upon request, DHS will provide clean copies (markings removed) of the SSRA to the National Academies for placement in the PAF.

DHS would like to thank the Committee again for its review of the SSRA and looks forward to delivery of the NRC Committee's Final Letter Report. We will continue to make ourselves available to the Committee to answer further questions or provide additional clarifying information. Please contact James V. Johnson, Director of the DHS S&T Office of National Laboratories at (202) 254-6098 or james.johnson2@dhs.gov.

Sincerely,

James V. Johnson
Director, Office of National Laboratories

Attachment: a/s

Cc: Ms. Peggy Tsai, Study Director and Program Officer, National Academies