NATIONAL BIO AND AGRO-DEFENSE FACILITY
Science and Technology Directorate/Office of National Laboratories

NATIONAL BIO AND AGRO-DEFENSE FACILITY

FINAL ENVIRONMENTAL IMPACT STATEMENT

APPENDIX D

POTENTIAL ECONOMIC CONSEQUENCES OF PATHOGEN RELEASES FROM THE PROPOSED NBAF

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U.S. DEPARTMENT OF HOMELAND SECURITY

POTENTIAL ECONOMIC CONSEQUENCES OF PATHOGEN RELEASES FROM THE PROPOSED NATIONAL BIO- AND AGRO-DEFENSE FACILITY (NBAF)

D.1 INTRODUCTION AND BACKGROUND

The proposal to construct the NBAF at the current location[1] of the Plum Island Animal Disease Center (PIADC) or at one of five other alternative sites on the U.S. mainland poses a different set of health and economic risks than does the current facility. Although the construction of a technologically advanced NBAF should further reduce the probability of a pathogen release to the surrounding environment compared to the existing facility, the proposed facility would have an expanded research mission to include the study of pathogens that could adversely affect livestock, wildlife, and possibly human health. An accidental release of these pathogens could have economic consequences. Furthermore, compared to the existing PIADC, a potential release of pathogens from a mainland facility might more readily affect commercial livestock, wildlife, and possibly human populations, depending on the alternative site's proximity to livestock-producing areas and the density of human populations. Under some scenarios, a pathogen release could cause a major disruption to the United States Agricultural Economy. In particular, the accidental release of pathogens from the proposed research facility could have significant economic impacts if commercial livestock were exposed or if the pathogen were to infect wildlife used for sporting consumption or which could become endemic reservoirs of disease to domesticated animals, wildlife, or humans beings.

The potential for economic losses under a worst case scenario is non-trivial. An outbreak of foot and mouth disease (FMD) in Britain during 2001, for example, resulted in GDP losses of approximately £2.5 billion ($5 billion)[2]. Economic losses extended well beyond the livestock sector; the tourist sector was particularly adversely affected because large swaths of the rural country side, where tourist frequent, were quarantined. In the U.S., secondary industries such as transportation would be adversely impacted. The U.S. could experience even larger losses if an FMD outbreak were to occur here. The U.S. is a larger country with an integrated and mobile livestock industry. A recent study by researchers at Kansas State University, for example, estimated an outbreak of FMD could cost the State of Kansas alone nearly a billion dollars[3]. A multi-state outbreak would obviously increase the magnitude of economic losses beyond this estimate.

The release of other pathogens to be studied at the proposed research facility could have the potential to damage regional economies, and possibly the national economy, if rapid containment is not achieved. A concern would be the short-term effects of an outbreak as well as potential long-term effects to the economy if the pathogen were to become permanently established in the environment resulting in an epidemic or chronic disease capable of affecting livestock and possibly human populations.

This technical appendix utilizes a case study and literature review approach for assessing the potential economic damage to the U.S. economy if one of the pathogens proposed for study at the NBAF were to be released into the surrounding environment. The appendix does not assess the probability of accidental release or evaluate the cause of release (e.g., accidental release or bioterrorism); these assessments are thoroughly evaluated in Section 3.14. Instead, this technical appendix provides a review of relevant studies and research regarding economic costs of previous outbreaks of the pathogens being evaluated or simulations having been performed by academic researchers or agencies. To the extent feasible, the current study applies these event outcomes to the regional characteristics of each proposed alternative site to assess their relative economic vulnerability to possible pathogen releases from the NBAF. In short, the conclusions of this technical appendix are derived from a review of the publicly available literature on disease outbreaks. No risk or

[1] Under one proposed alternative, the new facility could still be located on Plum Island but not necessarily on the current physical site of the PIADC.
[2] Blake, Sinclair, Sugiyarto: *The Economy-Wide Effects of Foot and Mouth Disease in the UK Economy.* Nottingham University Business School (not dated).
[3] K-State Researchers Predict That an Outbreak of Foot-And-Mouth Disease Could Cost Kansas Nearly a Billion Dollars, Nov. 27, 2007; http://www.smartmoney.com/news/pr/index.cfm?story=pr-20071127-002647-1604.

economic modeling has been performed, although the characteristics of the relevant economic regions of influence are used to distinguish, where possible, the magnitude of losses among the different alternative sites.

Although the NBAF would study a number of pathogens determined as high priority by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service and the Department of Homeland Security, only three pathogens are evaluated for this appendix.

- Foot and mouth disease virus (FMDV)
- Rift Valley fever virus (RVFV)
- Nipah virus (NiV)

The diseases caused by these three pathogens sufficiently cover the spectrum of outcomes likely to occur if any of the pathogens to be studied at the proposed NBAF were to release to the surrounding areas and infect animal and human populations.

FMD is the most well known and documented of the three diseases. FMD is not a threat to human populations, except as a laboratory acquired infection (LAI). There have been 40 human cases noted since 1921. FMD does not transmit from human to human. It has the capacity to wreak havoc on the livestock economy in countries where outbreaks have occurred. In the United States, effective vigilance programs have prevented any FMD outbreaks on the mainland since the 1920s. The recent events in England, however, can serve as case studies for evaluating the potential for this disease to adversely impact the agricultural sector.

NiV and RVF viruses also pose potential threats to both livestock and human populations. Unlike FMD, human infection with these viruses can result in relatively high morbidity and mortality rates[4,5,6]. Recent outbreaks of RVF in eastern Africa and Saudi Arabia resulted in hundreds of deaths and huge losses to the livestock sector[7]. There is great concern among public health officials and agricultural research scientists that the RVF virus could become rapidly established in the United States, resulting in endemic infections with greater morbidity and mortality than the West Nile Virus. Although there have been no recorded cases of RVF in the United States, its introduction through inadvertent importation of infected mosquitoes, or as the result of bioterrorism, poses real threats to the public health and the economy.

NiV, first detected in Southeast Asia in 1997–99, has resulted in the hospitalization and death of infected humans, and swine although no infections have yet been reported in the United States. NiV likely poses a smaller threat than the other two viruses because its only known vector does not occur in the Western hemisphere, but much remains to be learned about its epidemiology. It is still believed that the release of this pathogen under certain conditions could cause a variety of economic losses in the surrounding areas.

The remainder of this appendix presents for each of the three pathogens a review of the literature on how past FMD, RVF, and Nipah outbreaks have affected animal and human populations and the economic impacts of these outbreaks. Based on this literature and specific case studies, the analysis will generate a range of potential economic impacts and compare the relative economic vulnerability of the six alternative sites, based on proximity and size of commercial livestock industry, prevalence of sport hunting region, climate, and the density of human populations for the two pathogens that cause human morbidity and mortality. It must be emphasized that the analysis is based on the available literature and that no new studies or modeling have been performed in support of this appendix[8].

[4] CDC: Update: outbreak of Rift Valley fever – Saudi Arabia, August – November, 2000. *MMWR* 49(43):982-985, Nov. 3, 2000.
[5] Eaton BT, Broder CC, Middleton D, Wang C: Hendra and Nipah viruses: different and dangerous. *Nature Reviews, Microbiology* 4:23-35; 2006
[6] CDC: Rift Valley fever outbreak – Kenya, November 2006 – January 2007. *MMWR 56*(04): 73-6; Feb 02, 2007.
[7] *Benefits and Costs of Compliance of Sanitary Regulations in Livestock Markets: the Case of Rift Valley Fever in Ethiopia*. A. Nin Pratt, P. Bonnet, M. Jabbar, S. Ehui, C. de Haan; April 2004.
[8] Lawrence Livermore National Laboratory (LLNL) at the request of DHS, evaluated the potential impact of an FMD release at the 6 candidate sites using an existing model and a limited set of assumptions. The results of this preliminary study are summarized at the end of the FMD section.

D.2 FOOT AND MOUTH DISEASE

Description

FMD is caused by an aphthovirus of the family *Picornaviridae.* It is a viral disease affecting livestock (i.e., all cloven-hoofed animals including cattle, pigs, sheep, goats, deer, and bison) causing fever and blisters on the feet, mouth, teats, and coronary bands and is spread from one infected animal to another either directly or indirectly. The disease rarely affects humans—historically only as a laboratory-acquired infection.

The disease was recognized in the 16th century but the causative agent first identified as a virus in 1897 by Friedrich Loeffler, a German bacteriologist. After World War II, the disease spread throughout the world and was no longer confined to a select few countries. In the mid-1990s, endemic areas included Asia, Africa, and parts of South America except for Chile, which was disease free[9]. New Zealand is disease free and in fact, has never seen a case of FMD on its shores[10]. Most countries in the EU are declared FMD free and have stopped FMD vaccination.

FMD is, perhaps, widely known for the devastation it caused to the livestock and associated industries in the U.K. in 2001. This outbreak caused great economic losses to the livestock/agribusiness industry and the rural tourism industry. The outbreak also caused the cancellation of many farm and livestock-related events, sports and leisure activities, and the postponement of the general election for a month. People entering and leaving farms were required to have their shoes and vehicles disinfected. These biosecurity and export controls helped contain the out break to the U.K. and prevent the spread to other countries, such as Ireland. Since 2001, there have been other confirmed cases of FMD and two suspected cases of FMD in the U.K.; however, these cases did not result in large-scale outbreaks and were stemmed through the previous educational outreach for early reporting and through culling and quarantine of all livestock in these areas.

Signs

The average incubation period of the virus is generally 2–14 days, but this can vary. Signs of the disease include:

- A high temperature that drops after 2 to 3 days
- Lameness with a reluctance to move
- Sticky and foaming saliva
- Blisters and ruptured vesicles on mouth, nose, tongue, teats, and coronary bands
- An abrupt drop in the milk flow of infected cows
- Spontaneous abortion
- Reduced food intake
- Swelling of the testicles in mature males
- Weight loss

These signs are seen in other diseases similar to FMD, such as vesicular stomatis, bluetongue, bovine viral diarrhea, and foot rot in cattle and other animals. Animals with these signs must be tested to rule out FMD, which poses far more danger to the health of the herd and the livestock in the surrounding area. There are cases where animals may be carriers of the virus and thus are able to spread the disease. These carrier animals have recovered from the disease.

Cattle are particularly susceptible since they may acquire the virus through airborne particles or through direct contact with the virus. Because of a variable length in the incubation time, animals may not show clinical signs for several days. The clinical evolution of the disease, from infection (or first sign) to recovery, is *on average* 20 days for cattle and 13-14 days for pigs and sheep. The ultimate fate of many infected animals is isolation and slaughter, resulting in direct economic losses. Exports of meat are banned. Slaughtering occurs even though 95% of animals recover within 3 weeks with little or no treatment. Slaughter of infected animals

[9] March 2002, *Foot and Mouth Disease (www.doh.wa.gov/ehp/ts/zoo/foot-and-mouth-disease.pdf).* Washington State Department of Health.
[10] Biosecurity New Zealand: New Zealand remains vigilant following UK Foot and Mouth case, August 4, 2007. http://www.biosecurity.govt.nz/media/04-08-07/foot-and-mouth. Accessed April 20, 2008.

occurs to reduce the spreading of the disease and to regain trading status with other countries, thus restoring some economic balance.

Pigs are vulnerable to the disease, although the clinical signs are somewhat different. Blisters are more severe in the hoof areas of pigs rather than cattle, but pigs tend to experience fewer mouth blisters. Pigs are considered amplifying hosts because they concentrate the virus in their respiratory secretions, resulting in a high concentration of aerosolized virus particles, which could potentially contribute to the transmission between susceptible animals. Whereas cattle can shed the virus from 6 to 24 months, pigs carry it for only short periods. Ultimately, despite these differences, the fate of infected pigs is the same as for cattle: isolation and slaughter[11].

FMD Around the World

FMD has historically been widespread around the world, but the largest outbreak of FMD in an FMD-free country occurred in the U.K. in 2001, in which 2,000 animals were infected by the Type O Pan Asia strain, and more than 6.6 million animals had to be slaughtered. (It should be remembered less than one-third of those animals actually had the disease, but in-contact animals were depopulated to stop the progression of the disease.) This outbreak was the largest one in recorded history. It was so extensive because the time between infection of the animals and detection of the disease was delayed. Additional delays occurred because of delayed mitigation efforts. The most recent confirmed case of FMD in the U.K. in August of 2007 was believed to have been associated with an accidental pathogen release from the Pirbright site into a water drainage system[12].

The last of nine recorded outbreaks of FMD in the United States occurred in 1929 in California. Other outbreaks have occurred in Africa, South America, Asia, and parts of Europe. North America, most of Europe, Central America, Australia, and New Zealand have been confirmed FMD free, although some minor outbreaks have previously occurred in these countries.

The World Organization for Animal Health (OIE) specifies countries to be in one of three disease states:

- FMD present with or without vaccination,
- FMD free with vaccination, and
- FMD free without vaccination.

Countries want to gain and maintain the third classification because this means that they are at low risk and have the greatest access to export markets. Risks to the U.S. continue to occur because of its large livestock industry which is susceptible to the disease. FMD is still causing problems in other parts of the world, especially South East Asia, making preparedness essential to the prevention of an outbreak in the U.S. However, the U.S. livestock industry faces several differences versus the industry in the U.K. Some of those differences, which may be strengths and some may be vulnerabilities, include:

- High concentration of livestock due to intensive U.S. animal husbandry practices in certain areas throughout the country potentially facilitating the speed of disease spread.
- Lack of disease knowledge among some agricultural producers or failure to report disease outbreaks. Sometimes this fear of reporting is from lack of knowledge; sometimes it is because of fear of the economic losses associated with slaughtering and/or quarantine.

[11] D. Bickett-Weddle. Foot and Mouth Disease (Presentation); *Center for Food Security at Iowa State University, 2006.*
[12] Health and Safety Executive, *Final Report on Potential Breaches of Biosecurity at the Pirbright Site 2007*, September 7, 2007. www.hse.gov.uk/news/archive/07aug/finalreport.pdf

Transmissibility

Some strains of the FMD virus (FMDV) are more easily transmitted by aerosol than other strains. Consequently, the virus may be transmitted by aerosol transmission by spreading from infected animal(s) to uninfected animal(s). Transmission can also occur through physical contact. Sheep and often goats have very mild clinical signs and may spread the disease easily because of failure to recognize the disease. Cattle can spread the virus to other animals for up to 4 days before any signs begin to show. Pigs are the predominant source of aerosol generation and tend to shed a high quantity of the virus once they have been infected (although for shorter time periods than cattle). The virus is more easily transmitted in situations where there is high animal density and high mobility of human beings and animals. Nonetheless, despite their high production of aerosol laden FMD, pigs are the more resistant to contracting the infection than are cattle or sheep[13].

Transmission of FMDV may be through ingestion, direct contact, or aerosols. Transmission through ingestions or direct contract requires far greater volumes of the virus. The virus can also be carried by a variety of hosts not susceptible to the disease such as human foot traffic, feed trucks, and birds, dogs, cats, and rodents, etc. The virus has been found in garbage, especially where there is infected uncooked meat. In the U.S., it is illegal to feed uncooked garbage to swine. Therefore, the laws in the U.S. would reduce the risk of FMDV transmission associated with garbage. The virus is susceptible to drops in pH. When an infected animal dies, there is a drop in the pH of the body and the virus dies. FMDV may survive for a short time in bone marrow and lymph nodes after rigor mortis, until the pH drops below 6.0.

An affected animal can recover and may remain a carrier and transmitter of the virus. Cattle have been observed to be carriers for up to 3 years, sheep for 9 months, goats for 4 months, and 5 years for the American buffalo[14]. With the currently available vaccine, animals that are vaccinated or immune animals exposed to infection may also become carriers. New vaccines are in development to change this paradigm.

FMDV spreads via:

- Contaminated vehicles used to transport animals
- People wearing contaminated clothing after interacting with animals
- Uncooked, illegal garbage and infected raw meat fed to susceptible animals
- Importing infected animals
- Contaminated water sources shared by infected and susceptible animals
- Use of infected semen from an infected animal for artificial insemination

Virulence

FMD is an airborne aphtovirus within the *Picornaviridae* family, first identified in 1897. The viruses of this family are small (25-30 nm), non-enveloped icosahedral viruses that contain single-stranded RNA genetic material. There are seven serotypes (A, O, C, SAT1, SAT2, SAT3, and Asia1) of the virus and once an animal is infected, if it survives it may become a carrier of that particular strain for a period of time. These serotypes show regionality, with O being the most common strain.

Response Options to Outbreak and Prevention Measures

FMD is one of the most difficult animal diseases to control. Containment via movement controls and eradication are the ultimate goals of responding to an FMD outbreak and are currently the only measures that can be used to quickly reacquire FMD-free status. As noted earlier, in almost all cases throughout history,

[13] A.I. Donaldson & S. Alexandersen, *Predicting the Spread of Foot and Mouth Disease by Airborne Virus, Rev. sci. tech. Off. int. Epiz.*, 2002, 21 (3), 569-575

[14] Donaldson, A.I.: *Epidemiology of Foot-and-Mouth Disease: the Current Situation and New Perspectives*, ACIAR proceedings (50), Canberra, 1994, pp. 9-15.

infected animals have been depopulated. This is primarily for economic reasons—studies[15] have shown in areas where eradication is a possibility, it is more cost-effective to depopulate affected herds than to treat them since treatment is only palliative. Other studies[16] have shown that the use of highly efficacious vaccines may be a cost-effective strategy for FMD control if there are no plans to depopulate any animals. New vaccines in development may make vaccination a more attractive alternative. Even though an FMD outbreak would cause death to only about 5% of the animals infected, it causes abortion, debilitation, rapid weight loss, and significant reduction in production of milk in cows, all representing significant economic losses to livestock producers. Most young animals that do survive develop myocarditis (inflammation of the heart muscle), which can lead to eventual death. Additionally, rehabilitation time compared to the animal's life span on the farm is too long for nursing back to health to be cost-effective. In any case, any country experiencing an outbreak would be subject to a total ban on its exports, suggesting eradication by slaughter may be necessary to regain a trading status. During an FMD outbreak, there are a large number of animals to dispose of and if handled appropriately, risks of further spreading and can be minimized.

One possible prevention measure is vaccination. However, vaccination provides immunity to the virus for only 6 months in most cases (and it is not certain if this immunity is complete). One reason for this is the virus's high variability as it continually evolves and mutates, and there is large variation between serotypes. Therefore, vaccines must be strain specific. So it is costly to vaccinate a large number of animals twice a year. Vaccination also has trade implications. New vaccines in development may eliminate the trade barriers and reduce the number of animals needing slaughter, but those developments are not available at the time of this writing.

Potential Impact to Food Chain and Economic Impacts

An outbreak of FMD would have severe impacts to the economy and food chain due to disease control measures, and temporary export bans of meat and animal products. In the 2001 U.K. outbreak, for example, an estimated 4 million animals were slaughtered for disease control, and 2.6 million for livestock welfare. Also, with movement restrictions, healthy animals normally sent to market are forced to be retained at the production site, resulting in higher costs to the producer.

Additional affects are related to income lost due to export bans and price changes in the domestic market. Products that would normally have been sold overseas have to be sold on the domestic market, thus increasing the domestic supply. This increased supply coupled with assumed lower demand puts downward pressure on prices. Losses associated with reduced milk production both during and after the 2001 U.K. outbreak were approximately £35 million ($70 million). In the 2001 U.K. outbreak, the rural tourism industry was also greatly affected. However, the U.S. tourism industry is not based on similar recreation activities. Other related industries that could be negatively affected in economic terms include meat processing, feed, inter-industry trade and transportation, and meat by-product industries. The estimated total effects of FMD on the United Kingdom's GDP in 2001 were estimated at £2.5 billion ($5 billion), or about a 0.3% decline[17].

Several studies[18] have been done to estimate the potential economic impacts that would arise from an FMD outbreak in the U.S. and various states. Projected impacts to the U.S. livestock industry of an FMD outbreak

[15] Randolph, T.F., et al.: The economic impact of foot and mouth disease control and eradication in the Philippines. *Rev Sci Tech*, December 2000, 21(3):645-661.
[16] Bates, T.W., Carpenter, T.E., Thurmond, M.C.: Benefit-cost analysis of vaccination and preemptive slaughter as a means of eradicating foot and mouth disease. *American Journal of Veterinary Research*. July 2003, 64(7):805-812.
[17] Blake, Sinclair, Sugiyarto. *The Economy-Wide Effects of Foot and Mouth Disease in the UK Economy.* Nottingham University Business School (not dated).
[18] Ekboir, Javier M. *Potential Impact of Foot-and-Mouth Disease in California: The role and contribution of animal health surveillance and monitoring services.* UC Davis Agricultural Issues Center, 1999; Pendell, Dustin; Leatherman, John; Schroeder, Ted; Alward, Gregory. *The Economic Impacts of Foot-and-Mouth Disease Outbreak: A Regional Analysis.* Selected paper prepared for presentation at the Western Agricultural Economics Association Annual Meeting, Portland, OR, July 29-August 1, 2007.

similar in scale to the 2001 U.K. outbreak have been estimated to range from $10 billion to $30 billion[19]. Losses at the state level would vary; depending on the size and composition of the state's livestock industry. In California, for example, an FMD outbreak could cost its agriculture sector between $8.5 billion and $9 billion depending on the severity of the outbreak[20].

It must be strongly emphasized that the studies cited in this Appendix, including the studies performed by other Federal government organizations such as the USDA and the Lawrence Livermore National Laboratory (LLNL) were not conducted in conjunction with the current EIS and thus the results of these studies presented below are in no way connected to or reliant on the risk and threat assessments and associated assumptions discussed in the main body of the EIS. As stated above, the primary purpose of this Appendix is to provide the reader with a summary of the range of possible outcomes of pathogen release based on studies, simulations and documented outbreaks in other countries. The Appendix does not purport to present detailed estimates for all possible outcomes of an accidental pathogen release to the surrounding environment at any of the candidate sites.

Site-Specific Economic Risks

The economic effects of an FMD outbreak are caused mainly by the costs associated with trade bans imposed on affected countries, and from the culling and quarantining of affected animals and herds. Government costs to implement control measures are a third potential source of major costs associated with an FMD outbreak. If an accidental release of this pathogen occurred in a densely populated livestock area, there is the possibility of economic consequences. However, this pathogen only affects cloven-hoofed animals. If infected animals are identified quickly, large-scale outbreaks can be prevented, thus lowering the economic risks.

Nonetheless, the costs of an outbreak are likely to be substantial. One modeling study by researchers at Kansas State University found that an FMD outbreak could cost the Kansas livestock industry nearly $1 billion[21]. This study presents three release scenarios; an FMD outbreak that develops within a cow-calf herd, an outbreak that develops within a medium sized feedlot, and an outbreak that is simultaneously introduced to five large feedlots. Regional economic losses of $36 million, $199 million, and $945 million respectively, are anticipated to arise from the outbreak scenarios described. Livestock movement, meat processing, and trade, would come to a complete halt if there were an outbreak in the state.

The Economic Research Service (ERS) of the USDA, in a study of the economic impact of Foreign Animal Disease evaluated how an outbreak of FMD would affect the agricultural sector. The USDA ERS study is an independent study and had no direct relationship to the analysis and scenarios developed as part of the DEIS. The study simulated an outbreak of FMD using the North American Animal Disease Spread Model (NAADSM) and then linked the results of that model with USDA's quarterly models to project economic impacts to the agricultural sector over 16 quarters.[22] Total losses to capital and management over 16 quarters was estimated to range between $2.773 billion and $4.062 billion. The losses are largely attributable to lower prices for meat. This is because the ensuing trade embargoes would increase the overall supply to domestic consumers; the model assumes that trade bans would have a greater influence on supply to the domestic market than would the culling of herds. The model assumed that all U.S exports of animal meat (beef, pork, and lamb), as well as exports of live animals (cattle, swine, lambs and sheep), are halted during the full quarters of the outbreak and for one quarter after the last case is detected.

[19] Thompson, D., P. Muriel, D. Russell, P. Osborne, A. Bromley, M. Rowland, S. Creigh-Tyte, C. Brown: Economic Costs of the Foot and Mouth Disease Outbreak in the United Kingdom in 2001. *Revue Scientifique et Technique de l'Office International des Epizooties* 21:675-687, 2002. *Backgrounder: Foot and mouth disease.* http://www.avma.org/reference/backgrounders/fmd_bgnd.asp.
[20] Ekboir, Javier M. *Potential Impact of Foot-and-Mouth Disease in California: The role and contribution of animal health surveillance and monitoring services.* UC Davis Agricultural Issues Center, 1999.
[21] Kansas State University (November 29, 2007). Foot-and-Mouth Disease Could Cost Kansas Nearly a Billion Dollars. *Science Daily*.
[22] Philip L. Paarlberg, Ann Hillberg Seitzinger, John G. Lee, and Kenneth H. Mathews, Jr.(May 2008) The Economic Impact of Foreign Animal Disease/ERR-57, Economic Research Service/USDA

A limited study, performed independently of the EIS risk assessment, by the Lawrence Livermore National Laboratory (LLNL) estimated the economic costs of an FMD outbreak for the six candidate sites. LLNL conducted both a qualitative analysis of an aerosol release from the six proposed NBAF sites as well as an analysis of seven scenarios related to the potential impact of an FMDV release in the vicinity of each of the six candidate sites. The qualitative assessment of the aerosol release indicated that New York would have the lowest impact and Kansas the highest impact.

For the economic impact scenarios evaluated that involved a single initial outbreak, economic impacts in Kansas and North Carolina were the largest, while outbreaks initiated in New York resulted in the smallest impacts.

The LLNL study assumed that once the first FMD case is detected a series of baseline control measures are implemented without resource constraints. These control measures include: contact reductions for direct and indirect contacts in designated control zones; stoppage of all interstate movement of livestock out of the affected states; closing of all sales yards within designated contact zones, trace-back and trace forward of direct contacts for one generation; slaughter of confirmed infected herds after a species-dependent delay, no pre-emptive depopulation of non-infected herds; and no vaccination.

Despite the implementation of these control measures, which are assumed to limit the duration of the outbreaks to 51 days or less, the FMD outbreaks result in foreign trade bans lasting up to 185 days. It is these bans that predominate projected economic impacts for all of the sites.

As seen in the table D.2-1, under the LLNL scenario, total projected impacts from a Kansas outbreak would reach $4.2 billion compared to a $2.8 billion loss from an outbreak originating in New York. Losses accruing to foreign trade bans are $2.7 and $3.1 billion, respectively for New York and Kansas outbreaks, respectively, a relatively small difference. However, because of the size of the livestock sector in the state of Kansas, industry disruption costs would exceed $1 billion compared to only $31 million in New York. The total costs of outbreaks at the other sites are estimated to range of $3.35 billion in Georgia to $4.1 billion in Texas. Losses resulting from disruption to facilities operating in the affected states accounts for most of the differences in total cost. In short, it is the size of the livestock industry in the affect state that serves as the main discriminator among the candidate sites in terms of economic losses. For a fuller understanding on LLNL's methodology the reader is referred to the full report that is included in the administrative record.

Table D.2-1 — Average Estimated Economic Impact from a Single Random Introduction of FMDV into a Susceptible Livestock Premises in Each of the Counties Proposing to Host the NBAF

Proposed NBAF Site	Duration of Surveillance[23] (Days)	Duration of foreign trade bans (days)[24]	Value of foreign trade lost ($ million)	Industry Disruption loss [25] ($M)	Direct costs ($M)	Total Costs ($M)
Georgia	47	185	3,100	154	94	3,350
Kansas	51	189	3,100	1,001	97	4,200
Mississippi	47	185	3,100	216	94	3,400
North Carolina	47	185	3,000	430	94	3,500
New York	44	182	2,700	31	93	2,800
Texas	46	184	3,100	940	93	4,100

D.3 RIFT VALLEY FEVER

Description of Pathogen

Rift Valley fever, a zoonotic disease, is one of the World Organization for Animal Health (OIE) Listed Diseases requiring urgent notification[26]. First isolated in 1930 in the Rift Valley of Kenya, RVF has since reached epidemic proportions in eastern Africa, emerging irregularly in Kenya every 3 to 10 years. The first human cases of RVF were not reported until 1951, when an estimated 20,000 persons were infected during an epizootic of cattle and sheep in South Africa. Reported RVF events came exclusively from sub-Saharan Africa until 1977-1978, when approximately 18,000 persons were infected and 598 deaths were reported in Egypt[27]. More recently, RVF outbreaks have occurred in Yemen, Saudi Arabia, Sudan, and Tanzania, although, to date, no cases in animals or humans have been reported in North America or Europe.

The pathogen causing the illness is an arbovirus, which belongs to the *Phlebovirus* genus in the *Bunyaviridae* family. The RVF virus in animals is primarily vectored by mosquitoes of the genus *Aedes*, although several other mosquito species endemic to the U.S. have been shown to be capable of transmitting the virus as well. In particular, certain species of *Culex* (e.g., *C territans, C. salinarius*) have also been shown experimentally to be capable vectors of RVF[28]. Other biting insects such as ticks and black flies appear to retain the capacity to reservoir and vector the disease during epidemics as well. Viral transmission to humans has also been reported through other mechanisms, including the handling of infected animal tissue during slaughtering or butchering, assisting with animal births, conducting veterinary procedures, or from the disposal of carcasses or fetuses. Accordingly, certain occupational groups such as herders, producers, slaughterhouse workers, and veterinarians are considered at a higher risk of infection than the general population. The virus infects humans through inoculation, for example, via a wound from an infected knife or through contact with broken skin, or

[23] The duration of surveillance includes the mean number of days that surveillance control measures were in place during the simulated epidemics plus 42 days additional days, which is the assumed minimal amount of time (three maximal incubation periods for FMD) it would take to conduct surveillance to prove freedom from disease.
[24] The duration of the foreign trade ban is the mean duration of the outbreak plus 180 days. One hundred and eighty days is a modeling assumption for the duration of the foreign trade ban. The time required to conduct surveillance to prove freedom from disease was assumed to be included in the overall time it takes to recover foreign trade
[25] While foreign trade loss scales with outbreak duration (which is largely driven by the time it takes to recover foreign trade), industry disruption loss is determined by a combination of outbreak duration and the livestock demographics for the impacted areas. It should also be noted that industry disruption loss reduces supplies, and therefore would tend to counter the potential effect of domestic surplus supply created by loss of foreign export trade. However, in these cases, the supply impact was found to be negligible compared to the volume of foreign trade.
[26] The World Organization for Animal Health (OIE) recently consolidated its list of notifiable diseases so that diseases formerly on the “A” and “B” lists are now on a single list. The overriding criterion for a disease to be listed is its potential for international spread. Other criteria include a capacity for significant spread within naïve populations and the zoonotic potential. Each criterion is linked to measurable parameters: if a disease fulfils at least one of these parameters, then it becomes notifiable. Previously, RVF was listed in the OIE “A List” which included 15 diseases that have a high potential for rapid spread, serious economic or public health consequences, and significant impact on the international trade of animals and animal products.
[27] Rift Valley Fever Virus; Working Group; 24-26 August 2004 Summary Report and Recommendations; ANSER; Arlington, VA.
[28] Gargan, et al. *Am J Trop Med Hyg* 38:440-446, 1988.

through inhalation of aerosols produced during the slaughter of infected animals[29]. The aerosol mode of transmission has also led to infection in laboratory workers[30]. Nonetheless, the major outbreaks of human illness that have occurred in recent years have reached well beyond these populations of elevated risk, and the disease's dispersion during these outbreaks was certainly enhanced as the result of mosquito and/or other arthropod transmission of the virus.

The sustainability of the virus in a given environment is significantly facilitated by transovarial transmission, whereby the offspring of infected mosquitoes are also infected. This attribute provides a durable mechanism for maintaining the virus in nature since the eggs of infected mosquitoes can survive for protracted periods, even under arid conditions. A RVF virus infection typically results in a significant viremia in the primary host, infection of secondary arthropod vector species, and collateral transmission to humans.[31]

Affected Populations

Animal Populations

RVF can affect many species of animals including domestic livestock such as cattle, sheep, goats, buffalo, camels, and non-domestic animals such as monkeys, gray squirrels, and other rodents. In Africa, where the RVF is endemic, cattle and sheep are considered the primary hosts for amplification of the virus. Viremia with moderate disease, however, has been reported in adult cats, dogs, horses, and some monkeys; however, severe disease can occur in newborn puppies and kittens. Rabbits, pigs, guinea pigs, chickens, and hedgehogs are resistant to the disease[32]. Information is limited on the possible role of wildlife in the maintenance and amplification of RVF in Africa[33]. Unlike WNV, which is also spread by mosquitoes and has become endemic in much of the United States, RVF does not affect wild or domesticated birds. Hence, these animals do not appear to play a role in the maintenance and dispersal of the virus in affected areas.

In animal populations, mortality rates are the highest for newly born lambs, adult sheep, and calves. The mortality rate for infected lambs can exceed 90%, with calves and adult sheep also suffering mortality rates of up to 70%.

In all infected animals in which the disease becomes clinical, the animal typically suffers fever, anorexia, and an overall weakness. The incubation period is 3 days for sheep, dogs, and cattle, and as little as 12 hours for lambs. For pregnant sheep and cattle, infection results in very high rates of abortion. For example, in reported outbreaks of RVF, abortion rates in introduced European breeds of sheep and cattle were found to range from 40% to 100% in Southern Africa and from 80% to 100% in Egypt in the 1977 epidemic[34]. Infected dairy cows suffer from a decrease in milk production[35].

Human Populations

RVF manifests itself in the vast majority of individuals that become infected. In fact, in contrast to West Nile Virus, which has no clinical manifestation in 80% of infected individuals, approximately 90% of humans infected with RVF virus show clinical signs of the disease. The overall mortality rate is approximately 1%, but persons infected with the RVF are much more likely to die than those infected with the WNV[36,37,38,39].

[29] World Health Organization: Rift Valley Fever Fact Sheet. September 2007. Available online at http://www.who.int/mediacentre/factsheets/fs207/en/. Accessed January 3, 2008.
[30] World Health Organization; ibid. 2007.
[31] Rift Valley Fever Virus; Working Group; 24-26 August 2004 Summary Report and Recommendations; ANSER; Arlington, VA.
[32] National Agricultural Biosecurity Center; Rift Valley Fever Fact Sheet, Kansas State University, 2007.
[33] Developing a Research Agenda and a Comprehensive National Prevention and Response Plan for Rift Valley Fever in the United States, Conference Summary. Seth C. Britch, Kenneth J. Linthicum, and the Rift Valley Fever Working Group. Volume 13, Number 8, August 2007.
*Gargan et al. *Am J Trop Med Hyg* 38:440-446, 1988.
[34] Rift Valley Fever Virus; Ramon Flick and Michèle Bouloy. *Current Molecular Medicine* 5:827-834, 2005.
[35] National Agricultural Biosecurity Center; Rift Valley Fever Fact Sheet, Kansas State University, 2007.
[36] CDC: Update: outbreak of Rift Valley fever – Saudi Arabia, August – November, 2000. *MMWR* 49(43):982-985, Nov. 3, 2000.

For the 90% of infected humans manifesting signs, the disease can result in a mild form or a severe form of the disease. In either case, the incubation period for the disease is 2 to 6 days.

Individuals with a mild case of RVF typically experience the illness for a period of 4 to 7 days. The most common clinical signs include a sudden onset of flu-like fever, muscle pain, joint pain, and headache. Some patients develop neck stiffness, sensitivity to light, loss of appetite and vomiting; in these patients, the disease in its early stages may be mistaken for meningitis[40].

As in the case of WNV, a small percentage of infected individuals (1-3%) develop a much more severe form of the disease, which can result in long-term health problems and even death. In these severe cases, one of three different syndromes can develop 1) eye disease (0.5-2% of patients), 2) meningoencephalitis (less than 1%), or 3) hemorrhagic fever (less than 1%).

As described in the World Health Organization's fact sheet[41], these syndromes are characterized as follows:

- **Ocular form:** Typical signs associated with the mild form of the disease are accompanied by retinal lesions. The onset of the lesions in the eyes is usually 1-3 weeks after appearance of the first signs. Patients usually report blurred or decreased vision. The disease may resolve itself with no lasting effects within 10 to 12 weeks. However, when the lesions occur in the macula, 50% of patients will experience a permanent loss of vision. Death in patients with only the ocular form of the disease is uncommon.
- **Meningoencephalitis form:** The onset of the meningoencephalitis form of the disease usually occurs 1-4 weeks after the first signs of RVF appear. Clinical features include intense headache, loss of memory, hallucinations, confusion, disorientation, vertigo, convulsions, lethargy, and coma. Neurological complications can appear later (greater than 60 days). The death rate in patients who experience only this form of the disease is low, although residual neurological deficit, which may be severe, is common.
- **Hemorrhagic fever form:** The signs of this form of the disease appear 2-4 days after the onset of illness, and begin with evidence of severe liver impairment, such as jaundice. Subsequently, signs of hemorrhage then appear such as vomiting blood, passing blood in the feces, small to large areas of bleeding within the skin, bleeding from the nose or gums, heavy menstrual bleeding, and bleeding from venipuncture sites. The case-fatality ratio for patients developing the hemorrhagic form of the disease is high at approximately 50%. Death usually occurs 3-6 days after the onset of signs. The virus may be detectable in the blood for up to 10 days, in patients with the hemorrhagic jaundice form of RVF.

Potential Threat of Rift Valley Fever to the United States

Generalized Health Threat of RVF to the United States

As mentioned earlier, Rift Valley fever is listed on the World Organization for Animal Health's (OIE) notifiable disease list and was previously listed on the Organization's "A" list. There are a multitude of reasons for this placement. First, there are array of animals susceptible to the disease, including commercial livestock, domesticated household pets, and human beings. Second, the virus is effectively transmitted from mosquitoes to animals and from infected mosquitoes to their eggs. These transmission mechanisms under favorable climatic conditions can allow for a sufficient buildup of reservoir virus in a given location and set the stage for a major outbreak in resident animal and human populations. Because a variety of *Aedes* and *Culex* mosquito species, and other biting arthropods, can carry and transmit the disease, rapid and large-scale dispersal of RVF in the United States is possible. This is particularly true for the southern part of the United

[37] *Bioterrorism and Emerging Infections Education; Rift Valley Fever*. University of Alabama, Available online at http://www.bioterrorism.uab.edu/EI/riftValley/summary.asp(1 of 3) Accessed Dec. 21, 2007.
[38] Eaton BT, Broder CC, Middleton D, Wang C: Hendra and Nipah viruses: different and dangerous. *Nature Reviews, Microbiology* 4:23-35; 2006
[39] CDC: Rift Valley fever outbreak – Kenya, November 2006 – January 2007. *MMWR 56*(04): 73-6; Feb 02, 2007.
[40] World Health Organization, Rift Valley Fever Fact Sheet; September 2007.
[41] World Health Organization, Rift Valley Fever Fact Sheet; September 2007.
*CW Woods, et al. Emerging Infectious Diseases 8:138-44, 2002.

States (e.g., Florida and South Texas) where a large variety of mosquitoes capable of transmitting the disease are endemic[42].

A review of the epidemiology of the disease since it was first reported in 1930 and since the first human cases were diagnosed in 1951 shows the geographical range of natural transmission of RVF has been steadily increasing. Although it took approximately 50 years for the disease to appear in Egypt, it required just another 10 years for the disease to emerge in Saudi Arabia and Yemen. As noted in the RVF Working Group in 2004, “Regardless of how RVF may be introduced, the nature of its vector-borne epidemiology means that if it is not rapidly contained it would spread as rapidly as WNV, but with far more serious consequences”[43]. RVF can have a devastating effect on commercial livestock, due the high mortality rate of young infected animals and its effect on pregnant sheep and cattle.

Further exacerbating the threat of RVF is the fact that the disease is difficult to detect during the early stages of an outbreak. Often detection is confirmed only after large numbers of animals and human beings have already been infected and a large reservoir of virus has been built-up. This scenario would be particularly likely in the United States, where RVF detection in either the human or animal populations could be subject to much delay and misdiagnosis because neither physicians nor veterinarians in the U.S. would have any practical experience or little academic knowledge of the disease. Only limited testing and identification for the virus and disease are currently available. Hence, an investigation of a potential RVF outbreak outside of East Africa, Saudi Arabia, or Yemen would likely be initiated only after the occurrence of acute signs in a significant number of animals or human beings was observed. This awareness might arise only after the sudden death of a large number of lambs or the occurrence of an “animal abortion storm” in a region with favorable climatology for the principal vector[44].

Once an outbreak occurred, containment would have to be accomplished through vector control and quarantine and destruction of exposed livestock. Human infections would be further stemmed by ensuring that occupational hazards are minimized and workers who work with livestock are properly protected. Like WNV, however, if an outbreak were to occur it is quite possible the virus would become permanently established, with a constant increase in geographical extent, until much of the country would be affected. It is worth recalling the first outbreak of WNV occurred in New York City in 1999 and by the year 2005, human cases of WNV were reported in 43 states and the District of Columbia[45]. The disease is now considered firmly established in the United States with year to year variability in reported cases likely to be determined by annual weather patterns. For example, 2007 saw a decrease in reported WNV human cases in the Washington, DC. region from previous years largely because of unusually dry conditions throughout the summer and fall seasons. A return to more normally wet conditions could easily reverse this trend.

Generalized Economic Threat of RVF to the United States

The economic consequences of RVF could be significant if it became established. The impacts could encompass large economic losses to the livestock sector and economic losses due to morbidity and mortality of infected human beings. The latter costs would include costs of inpatient and outpatient treatment, loss of work productivity, and premature death of working persons. Other costs would involve public response measures, including vector control. Because RVF signs manifest themselves in a higher percentage of infected persons than does WNV and the disease kills a higher percentage of its victims, the per capita cost of RVF is likely to be higher than for WNV. To put this threat into context, it is helpful to review the economic costs of the WNV to the United States since the first outbreak in 1999. One study estimated the cost of invasive species to the United States economy and projected the annual economic cost of vector control and premature human deaths resulted in losses exceeding $1 billion per year[46].

[42] Gargan et al.: *Am J Trop Med Hyg* 38:440-446, 1988.
[43] Rift Valley Fever Working Group, 2004, Op. Cit.
[44] Ibid, 2004.
[45] Center for Disease Control: West Nile Virus–Statistics, Surveillance and Control - Maps 2005.
[46] Aquatic Nuisance Species in the New York State Canal and Hudson River Systems and the Great Lakes Basin: An Economic and Environmental Assessment. David Pimentel; Environmental Management, Vol. 35, No. 5, pp. 692–701 2005.

Other studies have focused on economic losses due to specific outbreaks also indicate the high economic costs from WNV outbreaks. The range of costs on a per capita case is quite large depending on the outcome of the disease. For example, one study indicated that on average treatment costs for mild cases were approximately $200 (in 2003 dollars); treatment for neurological-invasive cases, $38,417; and cases requiring institutional care, $138,078[47].

A retrospective study of the impacts of the WNV outbreak in Louisiana in 2002 gives further insight into the high costs of an outbreak[48]. Using conservative estimates on the number of individuals infected, since it was likely the disease at the time was being underreported, the authors estimated the economic cost of WNV to the state was about $20.1 million. This total included three categories of costs: 1) medical costs (inpatient and outpatient); 2) nonmedical costs, such as productivity losses caused by illness and premature death, costs of transportation for a patient to visit a health care provider, and childcare expenses; and 3) costs incurred by public health and other government agencies for epidemic control. When per capita costs were extrapolated to the U.S. as a whole, it was estimated that 2002 national costs attributed to the WNV approached $139.8 million. The national estimate does not include mosquito abatement and prevention costs (mosquito control capabilities vary tremendously from state to state), which accounted for approximately half of the costs in Louisiana. Other WNV outbreaks have caused significant morbidity and mortality in horse populations. One epidemic in Colorado and Nebraska is estimated to result in economic losses of about $2.75 million.

These WNV cost estimates are conservative and would likely be overtaken by RVF if that virus were to become established in the United States.

To get an idea of the magnitude of the potential economic threat of RVF to the United States, the Rift Valley Fever Working Group developed a scenario in which the virus is brought to the United States by a bioterrorist[49]. Under this scenario, the terrorist disperses the virus in an aerosol mist within stockyards strategically chosen in California, Louisiana, and New York. The scenario’s projection of economic losses is based on approximately 400 to 600 sheep and 20 and 30 humans becoming initially infected by the action at each site. The scenario also assumes that the action occurs at the end of a wet spring, which would optimize dispersal of the virus via mosquitoes.

Based on these initial conditions, the scenario assumes some of the livestock are shipped across state lines, and within 5 days the infected animals have become sufficiently viremic to infect biting mosquitoes. In fact, by day 5, according to the scenario, RVF is effectively introduced into the local mosquito populations throughout California, Georgia, Louisiana, New York, and Pennsylvania. These mosquitoes in turn begin to infect local animal and human populations at each location. It is not until day 27, by which time the number of infected animals and humans have tripled, does the U.S. government identify the disease as RVF. This long delay in identifying and responding to the illness outbreak is attributable to the lack of experience of veterinarians and physicians in diagnosing RVF.

The scenario assumes cooling weather is the chief factor in quelling the epidemic but not until more than 12,000 animals have been infected and 1,029 humans are known to have been infected. By the end of the year, 114 human deaths are attributed to the attack, and individuals with permanent disease-related disability number in the hundreds. Most worrisome, the scenario projects it would only take 2 more years for the disease to appear in all 48 contiguous states. The economic impact to the country is estimated to exceed $50 billion due to losses in the livestock and related industries, public health, trade, and tourism sectors[50].

[47] Cost-Effectiveness of Alternative Blood-Screening Strategies for West Nile Virus in the United States. Caroline T. Korves, Sue J. Goldie, Megan B. Murray. *PLoS Medicine* February 2006, Volume 3.

[48] West Nile Virus Economic Impact, Louisiana, 2002. Armineh Zohrabian, et. al. Emerging Infectious Diseases. Available online at http://www.cdc.gov/eid. Vol. 10, No.10, October 2004.

[49] Rift Valley Fever Working Group, 2004, Op. Cit.

[50] Because the effect of RVF on wildlife in the United States is not well understood, particularly those species consumed for sporting and subsistence activities, it is not possible to speculate on the potential economic losses to recreational hunting and other related sectors if the disease were to become established in this country.

Presumably, economic losses would continue for years until an effective vaccine were developed so as to sufficiently reduce the reservoir of virus in susceptible populations.

The categories of losses to the livestock sector would include the cost of destruction of infected animals and the loss of exports, even though the loss would be a short-term issue. These loses alone could be huge. As noted earlier, the 2001 FMD outbreak in Britain resulted in a reduction in GDP of $5 billion. Outbreaks in eastern Africa in 1998 and 2000 demonstrate the enormity of losses resulting from livestock being infected with RVF. An export ban by Saudi Arabia and other Gulf countries on livestock products from Ethiopia led to a $136 million reduction in the affected region's GDP, a 36% reduction from the previous year[51].

The scenario created by the RVF Working Group represents a maximum credible event (MCE), one based on external actors bringing in highly concentrated suspensions of RVF virus and then dispersing the pathogen at strategic locations to maximize contamination and sustainability.

The release of the virus from one of the proposed research centers would not likely lead to such dire consequences in the short-term; although if the virus were to become established in the environment surrounding the facility, it would likely spread over time to other areas, eventually causing the magnitude of losses projected for the bioterrorism scenario described above. Potential accidental release mechanisms (non-bioterrorism) could include escape of infected mosquitoes, escape of infected animals, and transmission from laboratory workers infected with the virus (a particularly remote possibility). Critical to establishment of the disease in the surrounding environment would be sufficiently large susceptible animal and mosquito populations so that a reservoir of virus could be built up over time to sustain and disperse the disease. Seasonal timing of the release would also matter, since a release of a small number of infected mosquitoes in the winter at a northern site could lead to the death of the insects before they are able to lay eggs or bite susceptible animals.

In sum, the release of the RVF virus into the uncontained environment could pose a significant risk to the U.S. commercial food chain as well as to the health of the human population. An outbreak, if not quickly identified and stopped could lead to rapid dispersal of the disease to livestock throughout the United States. Any outbreak would lead to the likely quarantine and destruction of exposed and infected livestock. Some nations would ban the export of U.S. meat products, which in 2006 totaled more than $4 billion. Damage to the livestock industry could be significant given the value of the major livestock (cattle, calves, hogs, and sheep). In the U.S., the beef industry alone was estimated at $95.9 billion in 2006[52].

Beyond damage to the U.S. livestock industry, the establishment of RVF would result in large public health costs for the treatment of symptomatic infections. Although the majority of cases would likely be mild with short-term ill effects to the patients, a small proportion of infected humans would suffer life-long disabling effects, while others would die. Additional economic costs would include loss of wages, reduced productivity, and public costs for vector eradication. Ultimately, the establishment of RVF prior to the availability of an inexpensive and efficacious vaccine could cost the U.S. hundred of millions to billions of dollars per year.

Comparison of Alternative Site's Economic Risks

Establishment of RVF would primarily rely on the amenability of the geographical location to a competent arthropod vector's (e.g., *Aedes* and *Culex* mosquito species) presence and the availability of susceptible viral hosts (animals and humans) to maintain a sufficiently large reservoir of virus for retransmission to biting mosquitoes.

The southern U.S. has a particularly high incidence of *Aedes albopictus*, an invasive mosquito species *A. albopictus* is known to be receptive in field conditions to three Flaviviruses (Dengue, West Nile, and

[51] Benefits and Costs of Compliance of Sanitary Regulations in Livestock Markets: the Case of Rift Valley Fever in Ethiopia. A. Nin Pratt, P. Bonnet, M. Jabbar, S. Ehui, C. de Haan, April 2004.
[52] USDA, National Agricultural Statistical Service: Quick Stats 2006. Available online at http://www.usda.gov/. Accessed January 8, 2008.

Japanese Encephalitis), six Bunyaviruses (Jamestown Canyon, Keystone, LaCrosse, Potosi, Cache Valley, and Tensaw), and one Alphavirus (EEE)[53]. It also has been shown experimentally to be capable of transmitting RVF virus[54]. To date, *A. albopictus* has been found in locations as far north as Minnesota and is endemic in New Jersey counties adjacent to Long Island.

Kansas and New York State mosquito populations, in contrast, are composed of *Culex* species more so than *A. albopictus*, but, as noted earlier, *Culex* species such as *C. territans* and *C. salinarius* have been shown experimentally to be capable vectors of RVF virus.

From a sustainability perspective, there would be some differences in risk between the two more northern sites and the four southern sites. For example, if an infected mosquito of the genus *Aedes* were to escape from the NBAF, a winter escape from the New York or Kansas alternative site might pose somewhat lower risks due to the colder climates and smaller resident *Aedes* populations available for mating and propagation. In addition, a release during particularly cold conditions could lead to the demise of infected mosquitoes before they are able to lay infected eggs or transmit the virus. Overall, the climate and aquatic habitats available to escaping *Aedes* mosquitoes in the southern alternative sites would appear more amenable to sustaining an infected mosquito population.

The potential advantages of the northern sites, however, would diminish if the escaping infected mosquitoes were of the genus *Culex*. *Culex* species already are well-established in these northern areas and are known vectors of the West Nile virus. Hence, the released insects would have a large resident population available for mating and virus transmission purposes.

Under such conditions, the types of long-term economic consequences projected by the Rift Valley Fever Working Group could in fact materialize under a worse case scenario.

Another factor of discrimination among the various alternative sites in terms of economic vulnerability would be the site's proximity to large commercial livestock operations. With the exception of Plum Island, which has no livestock populations in the vicinity of the proposed site, livestock population densities of the counties containing the other five proposed sites are either between 10 and 20 livestock per square kilometer, or between 20 and 30 livestock per square kilometer. In terms of total livestock populations in the surrounding counties, the numbers range from 139,200 for the Athens, Georgia, site to 542,547 for the Manhattan, Kansas, site[55]. In none of the regions in which the alternative sites are located is agriculture among the top generators of jobs or earnings. From an agricultural economic perspective, the mainland sites are not significantly different from each other in terms of risk to the local economy. Plum Island's relative isolation from the surrounding environment, including its distance to livestock areas of any consequence and its prevailing seaward winds, would render that location a lower risk to the regional and national agricultural economy than the mainland sites.

Many of the alternative sites are located relatively close to human populations; for example, Athens is only about 60 miles from Atlanta, Georgia, which has a metropolitan population exceeding 5 million people. Similarly, the Texas site is located on the outskirts of the City of San Antonio, which in 2007 had a population approaching 2.6 million. The Plum Island site is near the New York City metropolitan area, but its location on an island reduces the likelihood of viral transmission to people or animals.

If in fact a release of an infected mosquito were to occur, its ability to infect animals and human beings would also depend on its ability to reach those hosts. Mosquitoes of different species have varying capacity to travel but in most cases the distances are quite limited. *A. aegypti*, in one study, was found to travel no more than

[53] Global Invasive Species Data Base, *Aedes albopictus.* Available online at http://www.issg.org/database/species/ecology.asp?fr=1&si=109. *Accessed January 8, 2008.*
**Rutgers – ref. available for Culex territans [sent as pdf].
[54] Emerging Infectious Diseases, 1997.
[55] Department of Homeland Security; Biodefense Knowledge Center Rapid tracker, August 6, 2007.

200 meters from the release point[56]. *Aedes albopictus* is believed to travel only short distances. However, strong winds could be capable of transporting mosquitoes beyond their normal daily range. Furthermore, because the eggs (at least one) of the vector species are infected, the next generation of mosquitoes will be infected as well. Thus, it is possible that there could be gradual geographical spread of the virus with each new generation of infected mosquitoes.

The generally colder climate of Plum Island compared to the other alternative sites could reduce the ability of mosquitoes (particularly if the released mosquitoes were species of *Aedes*) or their offspring to survive and maintain the virus over time. Hence, from a human health economic perspective, Plum Island could pose a smaller threat compared to the other alternative sites. The other alternative sites are relatively similar in economic health risks, although establishment of infected mosquitoes in one of the southeastern sites could lead to a more rapid dispersal of the disease to larger human populations such as in the Atlanta or San Antonio areas and ultimately lead to a permanent reservoir of virus.

More importantly, the economic vulnerability to virus release is more closely associated with the amenability of the site to harbor RVF vectors such that a sustainable reservoir of virus is created. As described above, the main difference between the northern sites and the southern sites is that the climate and geography of the southern sites would facilitate a more rapid buildup of infected mosquito populations and hence a more rapid build-up of the virus reservoir. Plum Island's colder climate and greater isolation from susceptible human and animal populations could provide some margin of safety over the other alternative sites.

Nonetheless, it is likely to be the case that once an infected population becomes established, regardless of the location, the eventual spread of the disease to other parts of the country would be difficult, if not impossible, to prevent. Over time, the losses attributable to agriculture and related sectors and the economic costs of human illness would become significant and would likely exceed the very high annual costs currently associated with the West Nile Virus. These losses could ultimately reach the levels projected by the RVF Working Group in their bio-terrorism scenario; that is the release and establishment of RVF in the United States could lead to losses in the billions of dollars.

D.4 NIPAH VIRUS

Description of Pathogen

NiV, named after Kampung Sungai Nipah (Nipah River Village) where the first viral isolates were obtained, is a paramyxovirus of the genus *Henipavirus*[57]. The genus *Henipavirus* was created to accommodate NiVand the similar Hendra virus. The henipaviruses are distinguished from other paramyxoviruses based on nucleic acid sequences of their RNA genomes. NiV and Hendra virus are the only known paramyxoviruses with the ability to cause fatal disease in both animals and humans.

The first reported cases of NiV occurred in 1998 in Bangladesh among pigs, domestic animals, and humans working in close contact with the infected animals. Originally, the outbreak was mistakenly diagnosed as Japanese Encephalitis, which is common in Asia and displays many of the same signs as NiV. Mosquitoes spread Japanese Encephalitis to humans, and pigs are reservoirs of this disease. Yet NiV is spread through contact with infected human or animal oral nasal secretions or urine and originates from indirect contact with the reservoir host, the "flying fox" fruit bat (*Pteropus* genus). The fruit bats are asymptomatic, and it is still unknown how the *Pteropus* bats contract NiV; therefore, the sustainability of the virus is also unknown.

[56] Russell, et. al.: Mark release-recapture study to measure dispersal of the mosquito *Aedes aegypti* in Cairns, Queensland, Australia. *Medical and Veterinary Entomology*, December 2005.
[57] Wong, Kum Thong, et al. (December 2002). Nipah Virus Infection: Pathology and Pathogenesis of an Emerging Paramyxoviral Zoonosis. *American Journal of Pathology* 161(6):2153-2167, 2002.

Affected Populations

Animal Populations

In almost all of the reported outbreaks in Malaysia, Singapore, India, and Bangladesh, pig farms have suffered in large numbers. A few infections have also been found in cats and dogs, and serologic evidence suggests infection can occur in horses. Pigs have played a significant role in some outbreaks; however, not enough information is known about NiV to rule out possible future outbreaks in other types of animals. While forecasted models of the effect of a NiV outbreak in Australia demonstrate the spread of the disease could remain relatively contained, the outbreaks in Malaysia, Singapore, and Bangladesh were much larger due to weak government enforcement and information dissemination programs[58].

It is not well-known what the effect of NiV on wildlife populations has been. While it is entirely possible for any sort of animal to consume fruit fomites spit out by *Pteropus* bats, spread of the disease from animal to animal occurs (as far as it is known) through consumption or absorption of infected animal secretions. The spread of infection is more likely in areas where many animals share the same space.

Some recent research studies suggest that NiV could be vertically transmissible from mother to fetus[59,60]. Here, two cats, one pregnant female, and one male were inoculated with NiV and regulated closely. The results of the experiment found the male cat showed signs of a fever after day 7, while the pregnant cat's temperature remained relatively constant until peaking rapidly at day 12. Researchers believe pregnancy delays the progression to disease by one week because NiV infects the fetus first.

In the reported cases of pig infection, for pigs older than 4 weeks, morbidity rates were high while mortality was low[61]. While precise statistics are difficult to ascertain, morbidity rates are estimated at about 90% with a low mortality rate of 10%[62]. NiV is indiscriminate in its infection of all ages of pigs. Once a pig is infected, the virus spreads rapidly, yet the low mortality rate impairs a farmer's ability to detect that there is a problem.

At the first stage of introduction of NiV to a pig farm, an explosive outbreak occurs, and the pigs demonstrate signs of a respiratory disease, fever, and nervousness or depression. After a short period of time (1-2 weeks), the signs "settle down." The lingering signs are a chronic respiratory syndrome with 2.5% mortality, 10% loss in feed conversion efficiency, and 20% reduction in viable piglets[63].

Human Populations

NiV is classified as a Biosafety Level 4 organism. It appears to infect humans indiscriminately, regardless of age or prior health status. Outbreak incidents have occurred in regions where the Flying Fox bat of the *Pteropus* genus is present. Thus far, outbreaks have been isolated to Southeast Asia. Furthermore, human to human transmission for health workers has occurred when the basic precautions and sanitary measures for dealing with sick patients went unheeded[64,65,66,67].

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[58] Lam, Sai-Kit. (March 19, 2002). Nipah Virus—a Potential Agent of Bioterrorism? *Antiviral Research* 57:113-119, 2003.
[59] Dimitrov, Dimiter S., Lin-Fa Wang. (2007).
[60] Mungall, Bruce A., et al. (March 26, 2007). Vertical Transmission and Fetal Replication of Nipah Virus in an Experimentally Infected Cat. *The Journal of Infectious Diseases* (196):812-816, 2007.
[61] World Organization for Animal Health (OIE) January 2004. Nipah Fact Sheet. Available online at http://www.cfsph.iastate.edu/Factsheets/pdfs/nipah.pdf. Accessed April 20, 2008.
[62] Garner, M.G., I.F. Whan, G.P. Gard, D. Phillips. (February 5, 2001). The Expected Economic Impact of Selected Exotic Diseases on the Pig Industry of Australia.*Rev. Sci. Tech. Off. Epiz.* 20(3):671-685, 2001.
[63] Garner, M.G., I.F. Whan, G.P. Gard, D. Phillips. (February 5, 2001).
[64] Lam, Sai-Kit. (March 19, 2002).
[65] Chadha, Mandeep S., et al. (February 2006). Nipah Virus-associated Encephalitis Outbreak, Siliguri, India. Centers for Disease Control. 12 (2).
[66] Hsu, Vincent P., et al. (December 2004). Nipah Virus Encephalitis Reemergence, Bangladesh. Emerging Infectious Diseases, the Centers for Disease Control. 10 (12) pp. 2082-2087, 2004.
[67] Luby, Stephen P. (December 2006). Foodborne Transmission of Nipah Virus, Bangladesh. Emerging Infectious Diseases, the Centers for Disease Control. 12 (12). pp. 1888-1894.

As previously indicated, it is believed the fruit bats of the *Pteropus* genus are the reservoir source of NiV[68]. There are currently several hypotheses that try to explain the transmission of NiV from bats to livestock/humans[69].

1. Masticated pellets of virus-contaminated residual fruit pulp dropped by flying bats are consumed by susceptible livestock animals (pigs).
2. Urine from infected animals contaminates pastures or pig sties.
3. Infected fetal tissues or fluids contaminate pastures or sties and are ingested.
4. Fresh date palm sap consumed by humans was contaminated by infected fruit eating bats.
5. Slaughter of infected animals created aerosols that were infectious to humans via the respiratory route.

Based on the existing case studies, it appears person to person transmission can occur when caregivers absorb —orally or through cuts—the secretions of infected animals and humans. However, it appears routine health care precautions could easily prevent such contagion.

In the Malaysia and Singapore outbreaks of September 1998–May 1999, the outbreaks first spread from bats to pig farms. Animals interacting with these pigs, such as cats, dogs, and horses also contracted NiV. During the 35-week outbreak period, the virus was first detected in Kinta district and then spread to three other localities, including the largest pig-rearing area in Southeast Asia. Spreading occurred through the trade of infected, live pigs. NiV was contracted by 265 individuals directly associated with the pig industry, and the overall outbreak fatality level was 39.6%[70].

At first, many reports believed humans were dead-end hosts for NiV because the 265 infected individuals were almost all pig farmers or had contact with pigs on a regular basis[71]. However, it was later discovered that some hospital workers ignoring the basic precautions while handling infected patients did contract the disease, indicating NiV can spread from human to human through contact with the infected individual's secretions.

In the West Bengal, India, outbreak of January–February 2001, many more hospital workers and family members of infected patients contracted NiV through human to human contact. In this case, the first wave of infected humans did contract NiV through working amongst infected pigs. Again, through the examples of the case studies, while NiV seems to only be transmissible through direct contact with saliva or excrement of a sick, living animal or human, contact with such substances carries a high rate of infection[72].

The repeated outbreaks in Bangladesh in the winters of 2001, 2003, 2004, and 2005 demonstrate a new case of direct transmittance of NiV from bat to human, without an animal intermediary[73,74]. Through rigorous surveying and animal testing in a retrospective investigation of two outbreaks (2001 and 2003), it was confirmed there was no obvious zoonotic source of NiV in the Bangladesh cases.

Other investigations indicate there may have been a high correlation between consuming fresh date palm sap and contracting NiV. Date palm sap is commonly harvested in the wintertime and used as a cooking ingredient in traditional desserts. Harvesting requires strapping a receptacle to a date tree, and it is not uncommon for the harvesters to find bat droppings or even dead bats in and around the pots. It is hypothesized emerging infectious diseases such as NiV are primarily due to the encroachment of human populations onto wildlife habitats, or even human-imposed changes on the distribution of flora, such as

[68] Luby, Stephen P. (December 2006).
[69] Dimitrov, Dimiter S., Lin-Fa Wang. (2007). In Utero Transmission of Nipah Virus: Role Played by Pregnancy and Vertical Transmission in Henipavirus Epidemiology. *Journal of Infectious Diseases* (196):807-809, 2007.
[70] Lam, Sai-Kit. (March 19, 2002).
[71] Garner, M.G., I.F. Whan, G.P. Gard, D. Phillips. (Feb. 5, 2001).
[72] Chadha, Mandeep S., et al. (Feb. 2006).
[73] Hsu, Vincent P., et al. (December 2004).
[74] Luby, Stephen P. (December 2006).

introducing fruit tree farms to new regions[75]. While it is asserted that most fresh date palm sap is safe to drink, measures should be taken to ensure stricter health standards for the industry.

While morbidity rates are characteristically high in both animals and humans coming into contact with NiV through saliva or urine, case fatality rates vary by outbreak, ranging from 38% to 75% mortality[76]. It still remains to be discovered why some outbreaks have resulted in more deaths than others, yet speculation could point to the fact infected sample sizes vary widely. The largest outbreak in 1998–1999 spread to more than 250 people, of which about 40% died. In a study of 103 patients affected by this outbreak, mortality rates reached 41%, 40% recovered fully, and the other 19% continued to suffer from mild residual neurological signs[77].

Reporting of signs seems to vary widely by individual for each case, although there are some commonalities, such as shown below[78,79].

- Fever
- Severe fatigue
- Headache
- Nausea/vomiting
- Chills/rigors/seizures
- Pneumonia/respiratory failure
- Encephalitis
- Cranial nerve palsies; brain MRI abnormalities; vision loss
- Persistent behavioral/personality changes
- Coma

Recent research based on magnetic resonance imaging tested on 12 patients infected during the Malaysian/Singapore outbreaks showed the affect that NiV has on the brain. Unlike any other viral encephalitis diseases, NiV causes small lesions to form on the brain, which may impair different functions on each individual. For this small sample, two patients died during the study, while another 10 showed signs of recovering, although the residual neurological deficits varied by patient.

A review of 103 patients' hospital records in Malaysia found the average incubation period for NiV was 10 days (ranging from 1 to 32 days), and the first signs of signs were usually fever, headache, and sore throat[80]. Furthermore, for those 42 patients that died, the mean duration of illness, from onset of signs to death, was 16 days. In these fatal cases, the most telling signs before death were tachycardia and an abnormal "doll's-eye reflex," suggesting a severe brainstem involvement. Other autopsy results on 32 fatal human cases of NiV discovered from hospital records that the duration of illness for these patients averaged 9.5 days, ranging from 2 to 32 days[81].

[75] Daszak, P., A.A. Cunningham, A.D. Hyatt. (2001).
[76] Chadha, Mandeep S., et al. (Feb. 2006).
[77] Chong, Heng Thay, et al. (December 2000). Nipah Encephalitis Outbreak in Malaysia, Clinical Features in Patients from Seremban. *Neurol J Southeast Asia* (5):61-67, 2000.
[78] Sejvar, James J., et al.: (2007). Long-Term Neurological and Functional Outcome in Nipah Virus Infection. *American Neurological Association* (62):235-242, 2007.
[79] Lim, Tchoyoson C.C., et al. (January 2002). Nipah Virus Encephalitis: Serial MR Study of an Emerging Disease. *Radiology.* 222 (1):219-226, 2002.
[80] Chong, Heng Thay, et al. (December 2000).
[81] Wong, Kum Thong, et al. (December 2002).

Potential Threat of Nipah Virus to the United States

Generalized Health Threat of Nipah Virus to the United States

The *Pteropus* bat is absent from the Western Hemisphere, and therefore there is no vector to spread NiV outside of the proposed NBAF facility[82]. Even in areas prone to outbreak, the projected reach of a NiV epidemic would be very limited[83]. Improved health standards and practices also greatly curtail the NiV risk of spreading NiV among humans in the United States. Furthermore, the United States has the capacity to disseminate information and effectively quarantine infected farms in a quick, efficient manner.

Generalized Economic Threat of Nipah Virus to the United States

There have been no reported outbreaks of NiV in North America, and the reservoir host, the "Flying Fox" fruit bat of the *Pteropus* genus is not native to the Western Hemisphere. Nevertheless, an outbreak of NiV could potentially occur in North America through a bioterrorism threat, as reports show NiV can easily be produced in large quantities with the potential release to livestock or humans[84]. Another potential threat could be the importation of contaminated date palm sap, processed in developing countries such as Bangladesh[85]. Flying foxes are attracted to this sticky substance, and it is not uncommon for manufacturers to find bat excrement or even dead bats in and around the sap pots. When date palm sap is consumed raw, consumers run the risk of contracting NiV.

Prevention

In the unlikely scenario that NiV would become an endemic threat to North America through possibly the importation of contaminated livestock, in livestock industries, and especially the swine sector, the result could be a restructuring of industry production[86]. High costs due to endemic threats may create significant barriers to entry and crowd out smaller livestock farms so that only those producers best equipped to withstand external shocks will keep producing[87]. Increased costs due to potential threats include occupational health and safety testing, medical expenses for human clinical cases, and prevention programs such as nighttime surveillance for bats on the premises. However, if market shares of livestock industries increase, prices for consumers are predicted to stay relatively the same. There are currently no NiV endemic areas in the world; reported outbreaks have only affected relatively small regions and have been contained within two or three months[88,89,90].

Outbreak Containment

The 1998–1999 outbreaks in Malaysia affected 60% of Malaysian pig farms, which was eventually contained after 35 weeks by the culling of over 1 million pigs. It is estimated that 36,000 jobs were lost in addition to \$120 million (U.S.) in exports[91]. Other job loss estimates cite that 8,500 workers were directly impacted by the outbreaks, while 9,400 workers in supporting industries and 300,000 workers in other related industries incurred costs or lost jobs[92]. This outbreak was exacerbated by the fact that despite government mandates, poor farmers continued to trade infected pigs between farms and on the black market to mitigate economic

[82] Hall, L. & Richards, G. *Flying Foxes: Fruit and Blossom Bats of Australia* (University of New South Wales, Sydney, 2000). [As cited (and illustrated in figure 2) in Eaton BT et al, Hendra and Nipah viruses: different and dangerous. *Nature Reviews Microbiology*. Jan 4(1):23-35, 2006].
[83] Garner, M.G., I.F. Whan, G.P. Gard, D. Phillips. (Feb. 5, 2001).
[84] Lam, Sai-Kit. (March 19, 2002).
[85] Luby, Stephen P. (December 2006).
[86] Note: While all outbreaks have impacted pig industries, it is not possible to rule out potential outbreaks in other livestock industries, as the outbreak is spread from accidental ingestion of fruit fomites via infected bats.
[87] Garner, M.G., I.F. Whan, G.P. Gard, D. Phillips. (Feb. 5, 2001).
[88] Chadha, Mandeep S., et al. (Feb. 2006).
[89] Hsu, Vincent P., et al. (December 2004).
[90] Luby, Stephen P. (December 2006).
[91] Daszak, P., A.A. Cunningham, A.D. Hyatt. (2001).
[92] Lam, Sai-Kit. (March 19, 2002).

ruin. In order to convince farmers to turn over their pigs to the government for slaughter and burial, the Malaysian government and humanitarian fund organizations teamed up to compensate farmers for their full economic loss (this amount was not recorded). Yet many farmers found it difficult to amass the capital necessary to begin investing in livestock again (based on a 2002 account).

While the Malaysian and Singapore governments did not keep sufficient records of the overall direct or indirect economic impacts to their pig industry or human hospitalization costs, a hypothetical cost model was run to determine the impact of a NiV outbreak on the pig industry in the southern regions of Australia[93]. According to the government's AUSVETPLAN strategy, sites of infection would be immediately quarantined and zones requiring authorization for entrance would be established. It is assumed trade outside of the control area would continue as normal; however, public reactions would impact both domestic and international markets. Farms under quarantine would halt production for potentially 1 year, and these farms would also incur the costs of eradicating the disease, which includes managing the quarantine, maintaining movement controls, conducting surveillance, performing mass slaughter and burial, and sanitizing the farm.

Yet compared to other diseases that could affect livestock industries, NiV's limited size epidemics caused lower losses. The main economic impact comes from a loss of export markets, which in turn floods the domestic market, thus lowering the price of the good in local markets. The following table presents the outcomes of one hypothetical mathematical model run 5,000 times.

Table D.4-1 — Expected Gross Income (U.S.$) of the National Pig Industry Following Disease Introductions and Proportional Opportunity Loss (in Parentheses)

Disease	Epidemic[a]	Endemic (per year)
None	590 million	590 million
Nipah Virus	571 million (3%)	589 million (0.1%)
Classical Swine Fever	536 million (9%)	527 million (11%)
Porcine Reproductive and Respiratory syndrome	553 million (6%)	558 million (5%)

[a] Based on the average of two pig industry regions studied: Darling Downs (144 pig farms) and Northern Victoria (77 pig farms). 1 AU$=0.93 U.S.$

Hospitalization Costs

During the time of this study, it was assumed that humans were the end hosts of NiV; however, more recent outbreaks have demonstrated that not only can bats transmit NiV directly to humans, but also that NiV can also be spread human to human through contact with an infected patient's saliva or excretions[94,95,96,97,98]. Cases of nosocomial spread of infection (spread during hospitalization) have occurred as a result of staff members not taking the proper precautions when dealing with disease-infected patients. The potential costs from an outbreak being spread throughout a hospital is very minimal, provided that staff members take the necessary precautions to cover patients' mouths with a mask during transportation around the facility, handle excrement and urine with proper latex glove protection, and educate patients' visitors to avoid contact with bodily fluids.

According to analyses of hospitalized patients, the average hospitalization stay ranged from 2 to 30 days. For those patients who died as a result of contracting NiV, the average duration from the onset of signs to death was 9.5 days according to one report that studied 32 fatalities and 16 days according to another report that

[93] Garner, M.G., I.F. Whan, G.P. Gard, D. Phillips. (Feb. 5, 2001).
[94] Sejvar, James J., et al. (2007).
[95] Lam, Sai-Kit. (March 19, 2002).
[96] Chadha, Mandeep S., et al. (Feb. 2006).
[97] Hsu, Vincent P., et al. (December 2004).
[98] Luby, Stephen P. (December 2006).

studied 103 patients where mortality rates were 41%[99]. There is no treatment as of yet for NiV, and signs seem to vary widely; however, small brain lesions causing neurological damage seem to be a key characteristic[100].

Comparison of Alternative Site's Economic Risks

The risk of an endemic outbreak of NiV in the United States does depend on the proximity of the NBAF facility to livestock. While NiV does not need to be directly transmitted by the *Pteropus* bat, as evidenced by the consumption of fresh palm date sap, only through a gross infraction or negligence on the part of the NBAF would NiV be able to travel from the facility to a farm to be consumed by closely penned livestock.

Of the proposed location sites, only Plum Island has no livestock populations in the vicinity of the proposed site. The other five locations have livestock population densities either between 10 and 20 livestock per kilometer or between 20 and 30 livestock per kilometer[101]. Total livestock populations range from 139,200 in Athens, Georgia, to 542,547 in Manhattan, Kansas. Plum Island's relative isolation from the surrounding environment including its distance to livestock areas renders the site location a lower risk to the regional and national agricultural economy. Yet again, there is a very low risk of the possibility of an release of NiV from the facility and its ingestion by livestock or humans.

[99] Wong, Kum Thong, et al. (December 2002).
[100] Sejvar, James J., et al. (2007).
[101] Department of Homeland Security. (August 6, 2007). "*Biodefense Knowledge Center, Rapid Tasker.*"