Master of Public Health

Integrative Learning Experience Report

OPERATIONALIZING AGRICULTURAL SECURITY: STRENGTHENING NEW MEXICO'S BIOSECURITY AND EMERGENCY READINESS IN ANIMAL AGRICULTURE

by

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Summary

New Mexico's expansive livestock industry, active cross-border trade, and shared border with Mexico heighten its vulnerability to foreign animal disease (FAD) outbreaks and mass mortality incidents—events that pose significant threats to animal health, public safety, and economic continuity. This applied research and planning initiative critically evaluates New Mexico's agricultural preparedness through two key frameworks: the Large Animal Mass Mortality Carcass Management Plan and the Emergency FAD Vaccination Plan. The carcass management plan outlines scalable, environmentally compliant, and biosecure disposal strategies, supported by interagency coordination and clearly defined operational triggers. The vaccination plan guides emergency response through risk-based herd targeting, resource prioritization, practical biosecurity practices, and regulatory integration. These efforts are further contextualized by two commentary articles that expand the discourse on agricultural security: one addressing operational challenges and best practices in carcass disposal, another highlighting biosecurity risks in livestock exhibition settings, and a third advocating for systems-based approaches to agricultural security across both crop and livestock domains. Developed in collaboration with governmental, tribal, industry, and academic stakeholders, this integrated portfolio of planning and scholarship reinforces a systems-thinking approach to agricultural security—advancing proactive risk mitigation, continuity of operations, and resilience in the face of transboundary disease threats.

Subject Keywords: Agriculture Security; Carcass Management; Emergency Vaccination; Foreign Animal Disease (FAD); Biosecurity; Livestock Health

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Chapter 1 – Introduction to Livestock Emergency Response

Typologies of Livestock Emergencies

While the majority of livestock emergency response literature focuses on managing disease outbreaks, it is essential to recognize the broader array of threats that can destabilize livestock systems. Natural, technological, and human-induced incidents—each with the potential for cascading effects—must be systematically accounted for in emergency management frameworks. A typological approach enables more holistic preparedness and response, ensuring that animal health, food systems, and rural economies are protected against a full spectrum of risks.

High-Consequence Animal Diseases

The most prominent category of livestock emergencies involves high-consequence transboundary animal diseases. These are not only biologically aggressive—they are economically and politically disruptive. Outbreaks of foot-and-mouth disease (FMD), African swine fever (ASF), and avian influenza often demand rapid and forceful interventions, including mass depopulation, movement restrictions, quarantine, and emergency vaccination efforts (Werling et al., 2024). Time is critical. These pathogens can spread with alarming speed, crossing national borders and overwhelming local containment efforts. When they do, the fallout is immediate: international trade grinds to a halt, domestic markets destabilize, and national biosecurity systems are put to the test.

Compounding the challenge is the involvement of zoonotic pathogens such as anthrax and brucellosis. These diseases blur the boundaries between veterinary response and public health action. As a result, emergency management must extend beyond the farm gate, requiring synchronized efforts among animal health authorities, human health agencies, and emergency services (Rahman, 2020). The complexity of these events underscores the high stakes of disease-driven emergencies—where rapid coordination, clear communication, and decisive action can mean the difference between containment and catastrophe.

Natural Disasters

Environmental hazards are becoming not only more frequent, but also more intense—posing escalating challenges to livestock operations worldwide. Droughts, for example, often unfold slowly yet relentlessly, draining water sources, reducing forage availability, and placing mounting stress on both animals and producers. Over time, these conditions can lead to herd reductions or forced depopulation, with lasting consequences for productivity and genetic stock.

Floods, by contrast, tend to strike with little warning. They bring swift and devastating impacts: mass drownings, injuries from debris, waterborne disease, and the contamination of feed supplies and carcasses (Crist et al., 2020). Recovery is rarely quick. Inundated pastures and damaged infrastructure may take months, even years, to restore.

Wildfires add another layer of risk. In regions like Australia and California, fast-moving blazes have caused direct mortality in cattle and sheep, while destroying fencing, shelters, water systems, and grazing lands critical to recovery (O'Hara et al., 2021). The destruction of such infrastructure doesn't just impede animal welfare—it delays any return to normal operations.

Together, these climate-driven events lay bare the vulnerability of livestock systems to environmental volatility. As these hazards become more frequent and extreme, adaptive strategies and climate-informed emergency planning are no longer optional—they are essential.

Technological and Industrial Hazards

Emergencies triggered by technological failure or industrial accidents present a significant, though often underappreciated, threat to livestock systems. These incidents may lack the scale of a disease outbreak or natural disaster, but their impacts can be just as severe—especially in concentrated animal feeding operations where systems are tightly coupled and failure cascades quickly. Power outages or ventilation system failures in high-density livestock housing, for instance, have led to the rapid asphyxiation or overheating of hundreds, sometimes thousands, of animals within hours (Reyes-Illg, et al., 2022; Sinel, et al. 2024). In such environments, even brief disruptions can prove catastrophic.

Chemical spills introduce a different set of hazards. When contaminants are released into grazing areas or water sources, they may cause acute poisoning in animals or create long-term land degradation. The consequences ripple outward—jeopardizing herd health, pasture viability, and ecological integrity (Afzal & Mahreen, 2024).

Transportation-related incidents further highlight the fragility of livestock logistics. Truck rollovers and train derailments involving animals demand urgent, coordinated response efforts. On-scene triage, humane handling, containment, and route detours must be rapidly enacted to minimize suffering and prevent further complications (Gimenez, Gimenez, & May, 2009; Miranda-de la Lama et al., 2011). These events are often sudden, localized, and resource-intensive.

Together, these technological and industrial hazards illustrate the necessity of comprehensive emergency preparedness. Infrastructure redundancy, rapid response protocols, and veterinary surge capacity must be integral components of resilience planning—not afterthoughts. Failure to plan for these scenarios can lead to preventable animal losses and extended operational disruptions.

Intentional Threats and Agroterrorism

Though infrequent, intentional threats—particularly those involving agroterrorism—represent some of the most disruptive and high-stakes scenarios facing livestock systems. The deliberate introduction of pathogens or toxins into animal populations is not only a direct assault on agriculture, but a strategic blow to national stability. Such acts could rapidly unravel livestock production, trigger cascading trade bans, and sow panic across food supply chains. The psychological impact—on producers, consumers, and global markets—can be as severe as the biological one.

Nations that depend heavily on livestock exports are especially vulnerable. An attack targeting animal agriculture could cripple economies overnight, eroding public trust in food safety and national preparedness. These risks, while rare, demand serious attention.

Mitigating such threats requires more than routine biosecurity. It demands a posture of vigilance: heightened awareness, rapid detection systems, and robust investigative capabilities. Forensic preparedness—being able to trace, attribute, and respond to malicious biological events—is essential. Equally critical is seamless interagency coordination across agriculture, law enforcement, intelligence, and public health sectors (McElwain & Thumbi, 2019; Monke, 2007). The window for response is narrow. Success depends on speed, clarity, and trust among institutions.

Agroterrorism may reside on the margins of probability—but its potential consequences place it at the center of high-consequence emergency planning.

Public Health Emergencies

Public health crises—though not always directly tied to animal disease—can profoundly disrupt livestock systems. The COVID-19 pandemic offered a stark illustration. As viral outbreaks swept through meat processing facilities, worker shortages and plant closures became widespread. With no way to process market-ready animals, producers were forced into devastating decisions. In 2020 alone, millions of pigs and poultry were euthanized on farms, not due to illness, but because the supply chain had ground to a halt (Marchant-Forde & Boyle, 2020).

The ripple effects were far-reaching. From farm to fork, every link in the production system felt the strain: animal welfare crises, financial losses, food waste, and volatile markets. Consumers witnessed empty shelves. Producers bore the emotional and economic burden of mass depopulation. Meanwhile, policymakers and emergency managers were confronted with the realization that human and animal health systems are deeply interdependent.

These cascading impacts underscored the fragility of livestock systems in the face of labor disruptions and public health emergencies. They also highlighted a critical lesson: contingency planning must extend beyond traditional boundaries. Building resilience requires coordinated strategies that bridge agriculture, public health, labor, and transportation sectors—ensuring that essential operations can continue, even amid human health crises.

Economic and Market Disruptions

Finally, economic pressures—often overlooked in emergency planning—can independently trigger livestock crises, even in the absence of disease or physical hazard. Price collapses, trade embargoes, or extreme market volatility can unravel production systems with startling speed. When feed prices soar or export markets disappear overnight, producers may face untenable choices: reduce herd sizes, halt operations, or cull otherwise healthy animals simply to stay afloat (Grant, 2012).

These are not just economic decisions—they are deeply personal, often made under intense stress and uncertainty. The toll on animal welfare is significant. So, too, is the psychological impact on producers, who may experience financial ruin, moral distress, and diminished mental health.

The long-term consequences ripple across the sector. Sudden market exits erode regional production capacity, disrupt supply chains, and undermine community resilience. These dynamics illustrate that economic triggers must be treated with the same seriousness as biological and environmental threats. Without proactive planning and support systems in place, financial shocks can lead to emergencies that are just as devastating as those caused by disease or disaster.

While the primary focus of this project is on disease response within livestock systems, the analysis presented here underscores the imperative to broaden that lens. Disease outbreaks remain a critical concern, but they exist within a wider landscape of hazards—natural, technological, intentional, public health, and economic—that can independently or synergistically disrupt animal agriculture. This section demonstrates that a disease-centric posture, while essential, is insufficient on its own. Effective emergency preparedness requires an inclusive framework—one that recognizes the diverse typologies of risk and builds resilience across all dimensions of livestock system vulnerability. Integrating this expanded understanding into planning and response efforts will better equip stakeholders to safeguard animal health, ensure continuity of operations, and protect food security in a rapidly evolving threat environment.

Livestock Depopulation

The intensification of livestock production and the globalization of animal trade have magnified the risks posed by transboundary animal diseases (TADs). Events such as the outbreaks of foot-and-mouth disease (FMD), African swine fever (ASF), and avian influenza have demonstrated the devastating impact that such diseases can have on economies, ecosystems, and public trust. In response, governments and international organizations have developed multifaceted strategies centered on three core components: humane depopulation, carcass disposal, and vaccination. They must implement each component with careful consideration for animal welfare, environmental safety, public sentiment, and international trade compliance. This literature review critically examines these pillars of emergency response, integrating emerging themes from the One Health framework, recent empirical findings, and policy guidance from leading institutions.

Livestock Depopulation: Practices, Ethics, and Operational Realities

Depopulation—the rapid, mass culling of animals—is an aggressive containment measure used to halt transmission of high-consequence foreign animal diseases (FADs). It is typically employed as a first-line defense when time-sensitive eradication is necessary and when vaccination or movement controls are insufficient or infeasible. The American Veterinary Medical Association (AVMA) recognizes a variety of depopulation methods, including captive bolt stunning, carbon dioxide (CO_2) asphyxiation, gunshot, and ventilation shutdown (VSD)—each with varying implications for animal welfare, field applicability, and scalability (Thornber et al., 2014). For example, captive bolt devices are commonly used in cattle due to their precision but require skilled operators and are not well-suited to large-scale events. CO_2 is more scalable and is often used in poultry and swine, though it remains controversial due to concerns about animal distress before unconsciousness.

The ethical dimensions of depopulation have gained prominence in recent years. Public concern peaked during the COVID-19 pandemic, when supply chain disruptions forced producers to cull millions of animals, often using VSD in poultry operations. These events sparked widespread ethical backlash due to the perceived inhumanity of the methods employed (Marchant-Forde & Boyle, 2020). Critics argue that expediency often overrides welfare considerations, prompting calls for ethical oversight and transparent decision-making in emergency plans (Rubira, 2007; Thornber et al., 2014).

The psychological toll of depopulation events on responders, producers, and support personnel is increasingly recognized. Galles (2023) reports that involvement in mass culling operations is associated with trauma, moral injury, grief, and burnout, compounded by social stigma and professional isolation. These impacts underscore the need for integrated mental health services and long-term support programs embedded within emergency response frameworks.

From an operational perspective, depopulation presents major logistical challenges. Field exercises and real-world events consistently reveal bottlenecks related to the availability of trained personnel, biosecurity restrictions, animal movement constraints, and equipment shortages. Large-scale facilities such as feedlots may require several days to complete depopulation, during which time the risk of disease transmission persists (DeOtte, 2010; McReynolds & Sanderson, 2014). These delays reduce the effectiveness of response and increase the burden on local responders.

To address these challenges, researchers and practitioners have advocated for the development of mobile euthanasia units, just-in-time training protocols, and simulation-based exercises to strengthen workforce readiness. McReynolds and Sanderson (2014) emphasize the value of pre-event modeling to identify potential bottlenecks, while Rubira (2007) and Thornber et al. (2014) call for advance planning around animal welfare and responder wellbeing. Humane slaughter techniques, ethical review mechanisms, and psychosocial responder care must be integrated into national and regional depopulation strategies to ensure both operational efficiency and moral legitimacy.

Carcass Disposal and Environmental Risk Management

Carcass disposal is an unavoidable consequence of mass depopulation during foreign animal disease (FAD) outbreaks and represents one of the most environmentally and politically sensitive aspects of livestock emergency management. A variety of disposal methods are currently employed—burial, incineration, rendering, and composting—each with distinct logistical requirements and ecological trade-offs. Burial is often the fastest and most accessible method but presents significant groundwater contamination risks if not preceded by rigorous site assessments. Incineration ensures complete pathogen destruction but is energy-intensive, costly, and heavily regulated. Composting has gained traction as a biosecure and sustainable option, particularly for swine and poultry, though it demands space, carbon sources, and close management to achieve pathogen inactivation (Costa & Akdeniz, 2019).

A key challenge in large-scale outbreaks is that disposal infrastructure is often rapidly overwhelmed. Ellis (2001) conducted a retrospective review of multiple disaster scenarios, revealing that capacity limitations frequently lead to unregulated and unsafe practices under emergency pressure. These findings are echoed by Geale et al. (2015), who emphasize that disposal efforts often become a race against time, complicated by permitting delays, weather conditions, and local resistance. Thornber et al. (2014) and Rubira (2007) have therefore advocated for pre-designated disposal sites, geospatial planning, and streamlined permitting processes to enable timely, lawful disposal during crisis events. Their work underscores the need to integrate environmental engineering expertise into veterinary public health systems for proactive response design.

To improve operational flexibility and reduce ecological impact, recent innovation has focused on mobile incinerators, in-vessel composting units, and biosecure grinding-composting systems. These technologies help to minimize bioaerosol generation, leachate contamination, and community exposure risks (Snowden, 2023). Additionally, the use of drones and AI-enabled modeling to track carcass distribution and decomposition status is an emerging field with potential to enhance situational awareness, regulatory oversight, and public transparency in large-scale events.

Despite these advancements, the pace and scale of high-mortality outbreaks often outstrip available disposal capacity. McReynolds and Sanderson (2014) noted that limited trained personnel, equipment constraints, and coordination breakdowns can extend disposal timelines, increasing the risk of environmental contamination and secondary disease spread. Thornber et al. (2014) recommend the establishment of pre-authorized emergency burial zones and deployment-ready mobile biosecure units to enhance both responsiveness and scalability.

Equally important is public perception and community acceptance, which can significantly influence the success of carcass disposal efforts. Poor communication and lack of transparency have historically led to public protests, litigation, and delays in implementation (Hueston, 2007). Travers et al. (2024) further emphasize that public attitudes toward depopulation and disposal are deeply shaped by the ethical framing, procedural fairness, and visibility of response operations. Building community trust through transparent planning, proactive engagement, and ethical oversight is therefore essential for maintaining operational momentum and social license during FAD responses.

Strategic Vaccination for Foreign Animal Disease Control

Vaccination serves both as a reactive and preventive strategy in the containment of FADs. The strategic implementation of vaccination is influenced by multiple factors, including disease epidemiology, trade implications, vaccine efficacy, and public perception. Three major approaches are recognized: suppressive vaccination within infected zones, protective ring vaccination surrounding outbreaks, and preventive prophylactic vaccination in at-risk populations. Each of these approaches has specific applications based on pathogen behavior and national regulatory contexts.

Trade Implications and the DIVA Challenge

Trade policy plays a central role in shaping national vaccination decisions. Countries that depend heavily on animal product exports often prioritize preserving "disease-free without vaccination" status to maintain market access. As a result, even in severe outbreaks, vaccination may be delayed, minimized, or entirely avoided due to fears of losing international certification.

When vaccination is used, vaccinate-to-kill strategies are frequently employed, where animals are immunized to contain the disease but subsequently culled and disposed of once the outbreak is controlled (Werling et al., 2024). This approach can be effective but raises ethical and logistical challenges and is deeply unpopular with producers and the public.

Advances in DIVA (Differentiating Infected from Vaccinated Animals) vaccines offer a partial solution. DIVA-compatible vaccines, paired with companion diagnostic tests, enable serological surveillance to distinguish between vaccinated and naturally infected animals. This capability supports international confidence in disease freedom and can facilitate earlier re-entry into export markets (Roth et al., 2014; Werling et al., 2024). However, the practical implementation of DIVA strategies requires investment in laboratory capacity, data systems, and internationally harmonized standards.

Modeling Behavior and Economic Incentives

The success of vaccination programs does not rely solely on technical efficacy—it also depends on farmer behavior, economic incentives, and institutional trust. Using game-theoretic modeling, Delabouglise and Boni (2020) explored how smallholder farmers make vaccination decisions during outbreaks. They found that without financial compensation or government guarantees, many farmers opt out of vaccination due to immediate economic losses or perceived risks.

This is especially relevant in regions dominated by small-scale producers who may lack access to credit or risk mitigation tools. Incentive-based models—such as subsidies, indemnities, or guaranteed market access for vaccinated animals—can significantly boost compliance. These findings highlight the need for behaviorally informed policy design, combining economics with communication, education, and trust-building.

Vaccination as an Alternative to Depopulation

In scenarios in which mass depopulation is politically, socially, or logistically untenable, vaccination is increasingly seen as a pragmatic and humane alternative. This includes urban and peri-urban farming systems, heritage livestock populations, and densely populated regions where large-scale carcass disposal is infeasible.

Geale et al. (2015) compared vaccinate-to-die and vaccinate-to-live approaches. While the former supports rapid trade recovery, the latter has the potential to improve public perception, reduce waste, and lower psychological stress on producers and responders. However, vaccinate-to-live strategies require robust surveillance, longer timelines for proving disease freedom, and updated trade agreements.

Ethical considerations are becoming more prominent in disease response policy, particularly in democratic societies where public transparency and animal welfare are highly valued. Vaccine strategies that align with these values can increase legitimacy and reduce resistance to emergency measures.

Wildlife Vaccination and Ecological Integration

Free-ranging wildlife species—such as feral swine, deer, and migratory birds—represent a major biosecurity "blind spot" in many national FAD response plans. These species can sustain disease transmission cycles and repeatedly reintroduce pathogens into domestic animal populations, undermining control efforts.

Despite the risks, wildlife vaccination and control remain underfunded and undercoordinated, often falling outside the mandates of state departments of agriculture. As Wilson et al. (2024) and demonstrated that targeted tools—including aerial bait vaccination, fertility control measures, and geographic information system -guided monitoring—can be effectively operationalized in feral swine populations. While these methods offer scalable solutions, their success depends on coordinated efforts across agricultural, environmental, and wildlife agencies.

Clemmons et al. (2021) highlight the importance of understanding the role of wildlife in the transmission of certain transboundary animal diseases, noting that wildlife reservoirs can complicate eradication efforts and may require targeted strategies for disease control. This perspective aligns with a One Health approach, which emphasizes the interconnectedness of animal, human, and environmental health in addressing complex challenges like transboundary animal diseases and enhancing systemic disease control efforts.

Wildlife, Disease Reservoirs, and the Need for Cross-Species Control

Wildlife species—particularly feral swine, deer, and wild birds—serve as reservoirs for several high-consequence animal diseases, including African swine fever (ASF), foot-and-mouth disease (FMD), and avian influenza. These populations frequently exist outside the purview of structured emergency response plans, which are typically designed around domestic animal systems. Their exclusion from core response activities such as vaccination, depopulation, and movement control creates persistent reinfection risks that can compromise entire eradication campaigns and significantly prolong recovery timelines.

Wobeser (2007) underscores the logistical and ethical challenges of applying livestock-scale depopulation strategies to wildlife. The sheer mobility and population dispersion of wild species, combined with ecological and societal concerns, render broad-scale culling impractical. Nevertheless, targeted wildlife interventions—such as ring vaccination, oral bait delivery, and fertility suppression—have shown promise in containing disease spread at critical transmission interfaces. Long et al. (2010), for instance, demonstrated that combining aerial baiting with geographic information system-guided tracking technologies enabled more precise and cost-effective management of feral swine populations in ASF-prone regions. Such tools enhance operational precision while reducing ecological disruption, and they align with emerging standards for minimally invasive control strategies.

Despite these innovations, wildlife disease control remains severely underfunded and often politically or culturally sensitive. Species such as deer and certain wild bird populations carry ecological and symbolic significance, making aggressive control measures, especially lethal ones, highly controversial. Public resistance, legal constraints, and jurisdictional fragmentation between federal, state, and tribal wildlife authorities further complicate response coordination. As a result, wildlife often occupies a regulatory and operational grey zone during emergency animal health responses—recognized as a risk but rarely integrated into planning, surveillance, or mitigation efforts.

These gaps highlight the critical need for a One Health approach that integrates veterinary science, wildlife ecology, and public health to manage disease across species and landscape boundaries. A One Health framework facilitates cross-sectoral surveillance, enhances early warning systems, and supports the design of scalable, ethical, and ecologically informed control strategies. Importantly, it also enables the inclusion of indigenous and local knowledge in managing culturally significant species, helping to balance disease risk reduction with social acceptability.

To institutionalize this approach, policy frameworks must expand to explicitly include wildlife in national and subnational biosecurity planning. This includes:

- Developing interagency agreements that clarify roles and authorities across wildlife and agriculture sectors;
- Investing in wildlife-specific diagnostics, modeling tools, and vaccine delivery systems;
- Establishing adaptive management protocols that can evolve in response to emerging data and stakeholder feedback; and
- Ensuring transparent public communication to maintain trust and legitimacy, especially when dealing with contentious interventions like culling or fertility control.

Without proactive integration of wildlife into animal disease preparedness and response efforts, eradication efforts will remain vulnerable to reinfection cycles and ecological blind spots. As zoonotic and transboundary diseases continue to emerge, the ability to manage disease risks at the human–animal–environment interface will become an increasingly vital component of agricultural security and national resilience.

Governance, Policy, and Future Directions

At the governance level, global organizations such as the World Organisation for Animal Health (WOAH) and the Food and Agriculture Organization (FAO) provide standardized guidance through the Good Emergency Management Practice (GEMP) framework. This framework emphasizes early detection, transparent reporting, capacity-building, interagency coordination, and simulation-based preparedness (Gary et al., 2021). These elements are essential for building systems capable of responding to transboundary and multisectoral threats, which require whole-of-government and regional coalitions (Levings, 2012).

Animal disease response in the United States is governed by a multi-tiered policy structure that reflects the division of responsibilities across federal, state, local, and tribal jurisdictions. Foundational policies—such as Homeland Security Presidential Directive 9 (HSPD-9), Presidential Policy Directive 21 (PPD-21), and National Security Memorandum 22 (NSM-22)—designate food and agriculture as critical infrastructure and underscore its importance to national security, economic stability, and public health. These directives emphasize risk-based planning, public-private coordination, and cross-sector resilience, given the sector's interdependence with systems like energy, water, and transportation. The National Response Framework (NRF) provides the overarching structure for integrating agriculture into broader emergency operations, while the U.S. Department of Agriculture (USDA), through the Animal and Plant Health Inspection Service (APHIS), leads federal efforts in disease detection, containment, and recovery. Supporting these efforts, the National Animal Health Emergency Management System (NAHEMS) offers operational guidance for actions such as depopulation, carcass disposal, and decontamination. Although these frameworks have supported effective responses to past outbreaks, evolving threats—such as zoonotic spillover, climate-induced disease shifts, and biosecurity risks from global trade—highlight the need for continued policy innovation, enhanced surveillance, and stronger alignment with national biodefense strategies.

Effective emergency response in the livestock sector also depends on cross-sector integration. Coordination among emergency management, environmental protection, and agricultural policy units ensures more coherent and operationally viable responses under real-world constraints. Technical proficiency alone is insufficient—robust responses also require clear governance structures, public trust, and institutional accountability.

A critical component of operational preparedness is contractor accountability. Worsfold (2014) emphasized that clear performance metrics and oversight protocols must be embedded in emergency plans for destruction, disposal, and decontamination (3D) services. Third-party actors involved in depopulation and carcass management must be held to high ethical and procedural standards to maintain public confidence and operational integrity.

The COVID-19 pandemic exposed systemic vulnerabilities in livestock production, particularly the dependence on centralized slaughter facilities and just-in-time logistics (Marchant-Forde & Boyle, 2020). These weaknesses highlight the importance of building more resilient and decentralized systems. Emerging innovations such as AI-powered outbreak modeling, blockchain-based vaccine traceability, and localized composting solutions offer promising avenues for improvement. However, these technologies must be implemented in tandem with community engagement, ethical oversight, and socioeconomic considerations to ensure sustainable and equitable outcomes.

Looking forward, technological innovations such as AI-powered outbreak modeling, blockchain-based vaccine traceability, and decentralized composting systems offer promising solutions. Federal initiatives such as the National Bio and Agro-Defense Facility (NBAF) underscore the U.S. commitment to integrating cutting-edge science into national preparedness. However, technology alone is not a panacea—its deployment must be grounded in community engagement, ethical oversight, and socioeconomic equity to ensure sustainable and just outcomes.

Public perception and social license are also critical. Social license here refers to the informal, ongoing acceptance and approval of an activity or policy by the public and key stakeholders—particularly those outside formal regulatory structures. Travers et al. (2024) found that acceptance of depopulation and vaccination strategies hinges on how policies are framed. Strategies perceived as punitive or opaque often meet resistance, whereas those built on transparency and consultation foster cooperation and compliance. Incorporating public communication planning into emergency protocols is increasingly recognized as a best practice.

Finally, a One Health perspective is essential for modern agricultural biosecurity. The interconnectedness of human, animal, and environmental health necessitates integrated approaches. Mackenzie et al. (2013) and Dixon and Heymann (2013) argue that siloed veterinary models are no longer adequate in the face of zoonotic spillovers, ecological stressors, (e.g., carcass disposal) and public distrust. U.S. policy has begun to reflect this paradigm through interagency collaboration mechanisms and support for multidisciplinary research initiatives, but further institutionalization of One Health principles remains a future imperative.

The complexity of livestock emergency response in the 21st century necessitates a nuanced, interdisciplinary approach that goes beyond traditional veterinary paradigms. Humane depopulation, environmentally responsible carcass disposal, and strategic vaccination must be harmonized with mental health support, community engagement, and cross-sector coordination. Wildlife surveillance and trade policy alignment remain weak points that need urgent investment and research. As One Health gains traction, future emergency preparedness must be designed not only to control disease but to protect the broader integrity of human, animal, and environmental systems.

Chapter 2 – Learning Objectives, Portfolio Products, and Competencies

This chapter provides an overview of key learning objectives and professional competencies demonstrated through the APE. It summarizes and reinforces core themes presented in the APE document while introducing the accompanying portfolio products, which are included as appendices. Together, these materials reflect the integration of academic training with real-world application in the areas of agricultural preparedness, emergency planning, and interagency coordination.

Learning Objectives

The author's APE sought to achieve the following learning objectives:

1. **Assess Agricultural Risk Landscapes**
   Critically examine the evolving biological, environmental, and technological risks impacting livestock and crop systems, with emphasis on the vulnerabilities specific to New Mexico's agricultural sector.
2. **Advance Strategic Emergency Planning**
   Develop and document scalable, evidence-based frameworks for managing large animal mass mortality events and FAD vaccination efforts, tailored to the operational, regulatory, and environmental context of New Mexico.
3. **Integrate Systems-Based Approaches**
   Promote a systems-thinking model in agricultural security that bridges biosecurity, emergency response, and infrastructure protection across pre- and post-harvest domains.
4. **Enhance Stakeholder Coordination and Communication**
   Facilitate interagency, tribal, industry, and academic collaboration to ensure cohesive planning, response capability, and continuity of operations in the face of high-consequence animal health emergencies.
5. **Inform Practice Through Applied Scholarship**
   Contribute to the broader field of agricultural emergency management and One Health preparedness through publication of practitioner-informed commentary on mass mortality operations, livestock biosecurity at exhibitions, and integrated agricultural risk management.
6. **Strengthen Resilience in Animal Agriculture**
   Support long-term resilience in livestock systems through proactive planning, robust biosecurity practices, and adaptive capacity to respond to transboundary disease threats and cascading disruptions.

Project Description

New Mexico, the fifth-largest state in the U.S., supports over 25,000 farms and ranches across 40 million acres (excluding tribal lands), and is home to a diverse and high-value livestock industry—with 1.29 million cattle as of January 2024. [1] The state's agricultural system is geographically and economically complex, shaped by dynamic trade activity, a shared international border with Mexico, the presence of wildlife corridors and migratory herds, and an export-oriented dairy sector concentrated along the southern border. This context intensifies the risk of mass mortality events and FAD outbreaks with transboundary implications for animal health, public safety, and agricultural markets.

The author undertook the creation of various portfolio products to advance New Mexico's agricultural emergency preparedness posture. He accomplished this through two primary planning frameworks and two commentary articles, offering a systems-based, interdisciplinary approach to safeguarding animal agriculture and food security.

Large Animal Mass Mortality Carcass Management Plan

The Large Animal Mass Mortality Carcass Management Plan for New Mexico serves as a foundational component of the state's agricultural emergency preparedness framework. Designed to be both scalable and adaptable, the plan outlines comprehensive operational strategies for the timely, biosecure, and environmentally sound disposal of large animal carcasses resulting from high-consequence events. These include foreign animal disease (FAD) outbreaks, catastrophic natural disasters, toxicity exposures, and failures in production systems, each of which can result in large-scale mortality requiring swift and coordinated action across local, state, tribal, and federal levels.

At the heart of the plan are clearly defined activation criteria, which guide when and how the plan is initiated. These criteria include localized events exceeding a facility's normal disposal capacity, confirmed or suspected FADs (such as foot-and-mouth disease), and natural disasters that warrant a Governor's disaster declaration. The plan also allows for proactive activation based on routine surveillance data, such as detection of internationally notifiable diseases or high-risk migration pathways involving wildlife or bison that cross the U.S.–Mexico border.

[1] New Mexico Department of Agriculture. 2023 New Mexico Agricultural Statistics. Retrieved from https://data.nass.usda.gov/Statistics_by_State/New_Mexico/Publications/Annual_Statistical_Bulletin/2023-2024/2023-2024-NM-Ag-Statistics.pdf

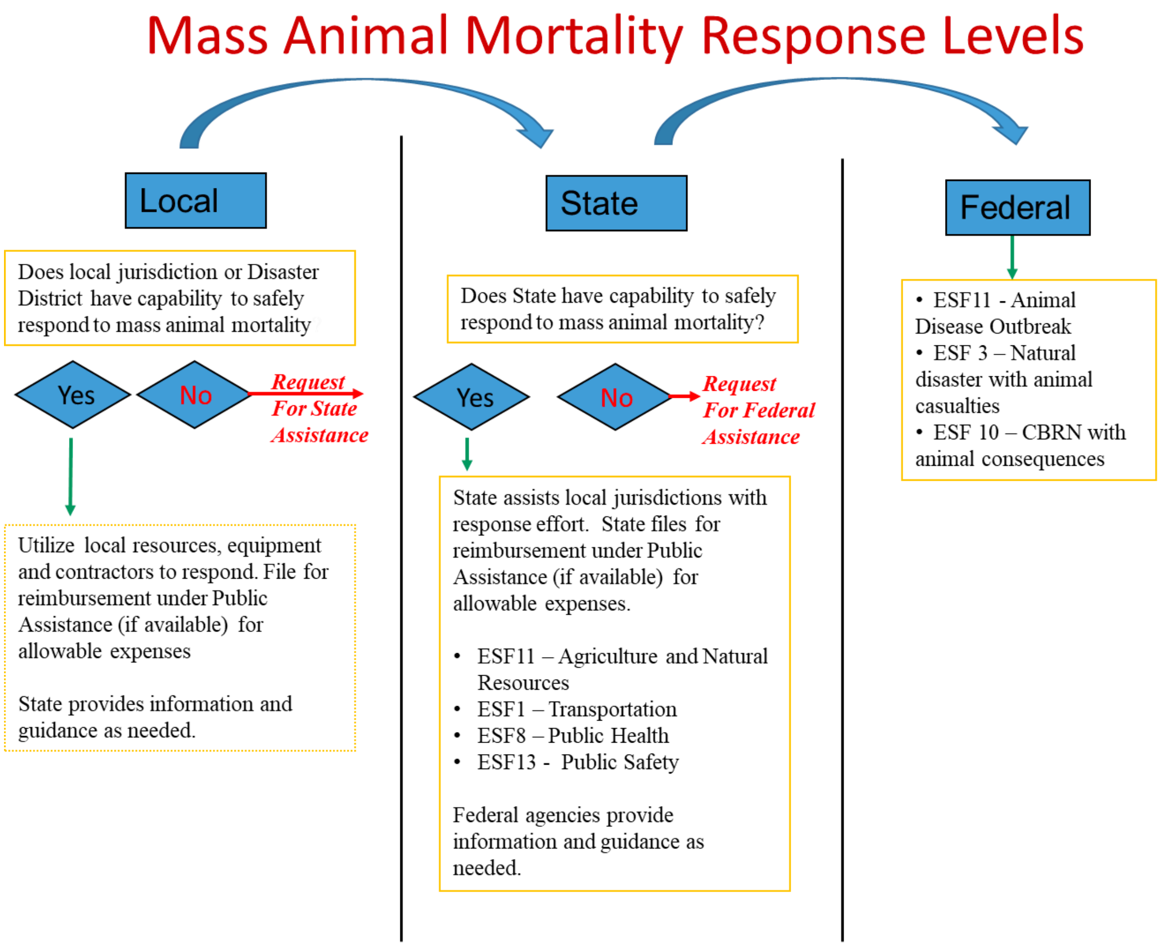

Figure 2.1: Mass Animal Mortality Response Levels (Source: NM Large Animal Mass Mortality Carcass Management Plan)

A critical component of the plan is its detailed evaluation of disposal methodologies, offering a spectrum of site-appropriate and disease-sensitive options. These include the following:

- Alternative use of livestock for food systems when animals are not diseased but no longer serve their intended production function.
- Rendering, with noted capacity limitations confined to eastern New Mexico and subject to biosecurity restrictions.
- Burial, including deep and above-ground techniques, with strict environmental criteria to prevent groundwater contamination and comply with federal and state regulations.
- Landfilling, where pre-arranged agreements and regulatory permissions must be in place, especially if infectious waste classification is applicable.

- Composting, a method familiar to many New Mexico producers, particularly dairies, which is effective for pathogen inactivation but requires large volumes of carbon material and ongoing management.
- Incineration, including air curtain and fixed-unit technologies, considered a method of last resort due to capacity constraints, air quality concerns, and regulatory barriers.

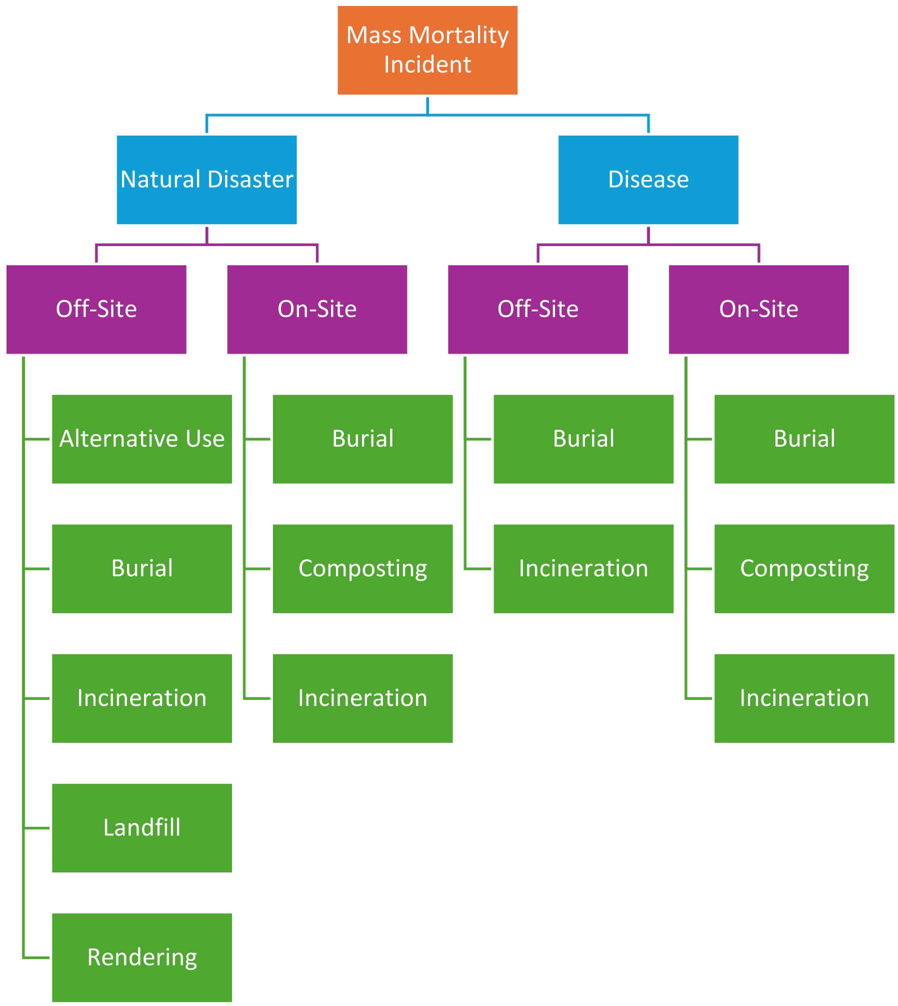

Figure 1.2: Carcass Management Methods (Source: NM Large Animal Mas Mortality Carcass Management Plan)

The plan outlines clear command and coordination structures, in alignment with the National Incident Management System (NIMS). It anticipates integration into Emergency Operations Center (EOC) functions when activated, ensuring streamlined operations between the New Mexico Department of Agriculture (NMDA), the New Mexico Livestock Board (NMLB), the New Mexico Environment Department (NMED), and federal partners such as USDA APHIS. Unified command and clear delineation of agency roles are emphasized to reduce duplication, enhance situational awareness, and enable timely decision-making.

Given the potential environmental and public health consequences of mass carcass disposal, the plan is grounded in regulatory compliance, offering detailed guidance on permitting, waste classification, and site selection. It accounts for parameters such as proximity to water sources, groundwater depth, floodplain presence, and soil suitability—factors critical to protecting New Mexico's diverse and often fragile ecosystems. Coordination with NMED ensures that all disposal methods, including emergency burning or on-farm burial, comply with air quality, solid waste, and water protection rules.

To support implementation, the plan details a broad range of support functions, from equipment mobilization and biosecurity enforcement to public information coordination and transportation logistics. It anticipates the need for specialty equipment, trained personnel, carbon materials, and PPE, especially in hazardous or post-disaster environments. It also addresses access challenges, such as floodwaters, frozen ground, or damage to roads and infrastructure, that may delay site entry or alter disposal feasibility.

Perhaps most importantly, the plan is built with strategic flexibility. It is intended to be a living document that evolves with scientific advancement, operational lessons learned, and emerging threats. Its structure allows it to be scaled from localized single-jurisdiction incidents to multi-county, state-coordinated disease responses, with provisions for integration into federal incident response in cases of TAD incursion.

Positioning NMDA as the lead coordinating agency, the plan empowers county and local responders, tribal authorities, and private sector stakeholders with accessible, actionable guidance. By ensuring preparedness across multiple disposal scenarios and response tiers, the plan reinforces New Mexico's capacity to respond rapidly and responsibly to large-scale animal mortality events—protecting animal health, environmental integrity, and agricultural continuity across the state.

Emergency Foreign Animal Disease Vaccination Plan

The Emergency Foreign Animal Disease (FAD) Vaccination Plan developed for New Mexico provides a comprehensive operational and strategic framework for deploying emergency vaccination during an animal disease outbreak. Designed to align with USDA's Foreign Animal Disease Preparedness and Response Plan (FAD PReP) and National Animal Health Emergency Management System (NAHEMS) guidelines, the plan addresses the complexity of implementing vaccination in real-time outbreak conditions while navigating regulatory, logistical, and industry-specific constraints.

To enhance response coordination and consistency, the plan includes a Decision Support Tool that outlines the state's strategic framework for prioritizing livestock for vaccination (See Appendix 1A and 1B). This tool is designed to guide incident command decision-making following the initial stamping-out of livestock within a 10-kilometer (6.2-mile) buffer zone around the index case. It integrates both science-based criteria and practical field considerations to help ensure vaccine deployment is targeted, effective, and efficient.

The Decision Support Tool incorporated into the Emergency FAD Vaccination Plan is designed to guide incident command teams through a structured and transparent prioritization process during vaccine deployment. By evaluating multiple operational, epidemiological, and logistical factors, the tool helps ensure that limited vaccine resources are directed where they will have the greatest impact in terms of containment, continuity, and recovery. Each characteristic reflects a nuanced understanding of disease dynamics, production realities, and infrastructure readiness across diverse livestock operations:

- **Proximity to the Index Case**: Prioritizing animals located within or near the 10-kilometer (6.2-mile) buffer zone surrounding the initial outbreak site is a foundational principle of disease containment. Animals in close proximity to the index case are at highest risk of exposure through direct or indirect contact. Early vaccination in these zones can significantly reduce the pathogen's ability to spread and create new infection foci, forming an immunological firewall around the epicenter of the outbreak.
- **Herd Density**: In densely populated livestock areas, disease transmission can occur more rapidly due to closer contact between animals and increased shared use of personnel, equipment, and infrastructure. Prioritizing vaccination in high-density zones—particularly in concentrated dairy or feedlot operations—can reduce the speed and scale of an outbreak, limiting both economic losses and operational disruptions across entire production regions.
- **Calves and Young Stock**: Young animals have immature immune systems and are more susceptible to disease morbidity and mortality. Prioritizing their vaccination protects animal welfare, reduces viral shedding within herds, and helps maintain future herd viability. In dairy systems, protecting heifer replacements is critical to sustaining production capacity over the long term.
- **Time-to-Slaughter**: Animals that are within six months of market weight are prioritized under a vaccinate-to-slaughter strategy. A single vaccine dose generally provides protection for this duration, eliminating the need for costly or logistically complex booster doses. This approach minimizes economic loss by preserving animals already near processing and stabilizes supply chains by maintaining throughput to packing plants.
- **Reproductive Status**: Pregnant and lactating cows represent high-value animals in both economic and genetic terms. Protecting these animals supports reproductive continuity, milk production, and overall herd stability. Prioritizing their vaccination helps producers avoid long-term losses in productivity and reduces the potential for severe disruption to both dairy and breeding operations.
- **Biosecurity Planning**: Producers who have developed and implemented formal biosecurity plans are given prioritization to incentivize system-wide compliance with best practices. These operations are more likely to maintain effective disease prevention and containment protocols, making vaccination campaigns more successful and reducing the likelihood of post-vaccination transmission events.

- **Relevant Infrastructure**: Vaccine administration requires specialized handling facilities to ensure animal and personnel safety. Operations with functioning chutes, pens, and restraining equipment are better positioned to facilitate timely and efficient vaccination. Prioritizing such sites ensures that doses can be administered quickly, minimizing stress on animals and responders alike.
- **External Exposure Risk**: Operations located near major transportation corridors, railways, or other infrastructure that may facilitate the spread of disease via fomites (e.g., contaminated vehicles or equipment) are assessed for elevated risk. Conversely, natural barriers such as mountains or forests may offer a degree of protection. Prioritization takes into account both the likelihood of exposure and the operation's role in potential disease dissemination.
- **Genetic Significance**: While more subjective than other factors, the genetic value of certain animals or herds—such as elite breeding stock or heritage lines—must be considered. Preserving these animals supports long-term industry resilience and genetic diversity. Prioritizing their protection reflects a forward-thinking approach that balances immediate containment with future sustainability.

Vaccination during a FAD outbreak, such as foot-and-mouth disease (FMD), requires the incident command team to rapidly evaluate a wide range of epidemiological, operational, and economic factors to determine the most appropriate strategy—or combination of strategies—for disease control. These vaccination strategy factors include the specific strain of the disease detected and vaccine match, the density and geographic distribution of susceptible livestock, the segment of the livestock industry affected (e.g., dairy vs. beef), and the purpose of vaccination, whether suppressive (aimed at stopping disease spread) or protective (to shield at-risk populations). Additional considerations include the rate of disease transmission, presence of genetically or economically valuable herds, resource availability for vaccine delivery, tracing capability for vaccinates, and the level of acceptance from trading partners regarding the movement and processing of vaccinated animals. As seen in table 2.1, these strategic decisions are dynamic and may evolve as the outbreak progresses.

The plan also emphasizes critical command and coordination measures, including the potential for implementing and enforcing a standstill order of 72 to 168 hours to limit animal movement during the early phase of the outbreak. It accounts for the complex cold chain logistics required to receive, store, and distribute vaccines across New Mexico's broad and often remote geography. The framework outlines key protocols for vaccination traceability, movement permitting, and integration with existing Secure Food Supply plans to maintain continuity of commerce and food production wherever feasible.

Table 2.1: Overview of Emergency Vaccination (Source: USDA FAD PreP Ready Reference Guide)

Strategy or Strategies	Definition of Strategy	Likelihood of Use	Example of Application
Stamping-Out (No Emergency Vaccination)	Depopulation of clinically affected and in-contact susceptible animals.	Possible (if outbreak is contained in jurisdictional areas in which FMD can be readily contained and further dissemination of the virus is unlikely).	Stamping-out Infected Premises.
Stamping-Out Modified with Emergency Vaccination to Kill	Depopulation of clinically affected and in-contact susceptible animals and vaccination of at-risk animals, with subsequent depopulation and disposal of vaccinated animals. Depopulation and disposal of vaccinated animals may be delayed until logistically feasible, as determined by Incident Command and the VS Deputy Administrator (U.S. CVO).	Possible (if outbreak is contained in jurisdictional areas in which FMD can be readily contained and further dissemination of the virus is unlikely).	Stamping-out Infected Premises, emergency vaccination to kill within the selected areas of the Buffer Zone in Containment Vaccination Zones.
Stamping-Out Modified with Emergency Vaccination to Slaughter	Depopulation of clinically affected and in-contact susceptible animals and vaccination of at-risk animals, with subsequent slaughter of vaccinated animals if animals are eligible for slaughter under USDA Food Safety and Inspection Service authority and rules and/or State and Tribal authority and rules.	Highly likely (depending on the type of the FMD outbreak).	Stamping-out Infected Premises; emergency vaccination to slaughter within the Control Area in Containment Vaccination Zones.
Stamping-Out Modified with Emergency Vaccination to Live	Depopulation of clinically affected and in-contact susceptible animals and vaccination of at-risk animals, without subsequent depopulation of vaccinated animals. Vaccinated animals intended for breeding, slaughter, or other purposes live out their useful lives.	Highly likely (depending on the type of the FMD outbreak).	Stamping-out Infected Premises; emergency vaccination to live outside of the Control Area in Protection Vaccination Zones.
Combination of Stamping-Out Modified with Emergency Vaccination to Kill, Slaughter, and Live	Combination of emergency vaccination to kill, slaughter, and live.	Highly likely (depending on the type of the FMD outbreak).	Stamping-out Infected Premises; emergency vaccination to slaughter within the Control Area in Containment Vaccination Zones and emergency vaccination to live outside of the Control Area in Protection Vaccination Zones.
Vaccination to Live (without Stamping-Out)	Vaccination used without depopulation of infected animals or subsequent depopulation or slaughter of vaccinated animals.	Less likely (unlikely to be implemented at start of outbreak).	No stamping-out Infected Premises; Vaccination to live outside of the Control Area in Protection Vaccination Zones.
No Action	FMD would take its course in the affected population; other measures may be implemented to control and contain FMD spread.	Unlikely.	Quarantine and movement control measures; biosecurity measures; cleaning and disinfection measures implemented. No stamping-out and no vaccination.

Operationally, the plan is structured to support the full vaccination lifecycle, including receiving, storage, and handling of vaccine doses, proper administration by trained personnel, and safe disposal of related waste and carcasses, if necessary. It outlines essential practices for biosecurity enforcement, surveillance of vaccinated herds, and documentation and data management to ensure regulatory compliance and situational awareness across incident command structures.

The plan is particularly relevant to New Mexico's high-risk geographic and trade profile. With six major dairy-producing counties situated near the international border, and significant cross-border livestock movement through two international livestock ports of entry—Santa Teresa and Columbus—the state plays a pivotal role in national animal agriculture infrastructure. More than 640,000 head of cattle and over 1,400 horses enter the United States through these ports each year, destined for multiple states. These dynamics necessitate robust vaccine deployment readiness, particularly in response to diseases that may originate or spread across the U.S.–Mexico border.

Further, the framework incorporates economic and logistical tradeoff analyses to assist incident commanders in choosing between vaccination, stamping-out, or hybrid control strategies. It recognizes that while stamping-out may provide epidemiological advantages in certain circumstances, it can be socially and politically contentious, resource-intensive, and economically disruptive—especially when genetically valuable or breeding stock are involved. Therefore, the plan supports scenario-based modeling and stakeholder input to guide decisions that protect both animal health and market stability.

Overall, the Emergency FAD Vaccination Plan enhances New Mexico's ability to deploy rapid, risk-based vaccination strategies grounded in national response doctrine. It strengthens decision-making capabilities, ensures logistical and regulatory preparedness, and provides a blueprint for maintaining continuity in animal agriculture operations during disease emergencies. The plan's emphasis on flexibility, coordination, and operational realism makes it a critical component of the state's broader agricultural security strategy.

Applied Scholarship: Commentary Publications

To complement and contextualize the applied planning frameworks, this portfolio includes a series of two commentary articles that contribute to the public-facing operational discourse on agricultural emergency preparedness and biosecurity. Together, these articles explore sector-specific vulnerabilities, cross-cutting systemic risks, and targeted response strategies, offering both conceptual insight and practical guidance for agricultural security stakeholders.

Beyond the Showcase: Strengthening Biosecurity at Livestock Exhibitions

The first article, "Beyond the Showcase: Strengthening Biosecurity at Livestock Exhibitions" (see Appendix 2), published in the *Domestic Preparedness Journal* in March 2025, examines the often-overlooked risks of animal disease transmission at fairs, shows, rodeos, and livestock exhibitions—settings that draw together thousands of animals and people for education, competition, and public outreach. While emergency management professionals are accustomed to planning for hazards such as crowd safety, medical incidents, or mass casualty scenarios at high-attendance events, this article highlights a distinct and significant threat specific to agricultural venues: the introduction and spread of infectious animal diseases.

Drawing on historical event data and recent outbreaks, the article situates livestock exhibitions within the broader national disease risk landscape, where the movement of animals—both interstate and international—can unintentionally facilitate the transmission of contagious agents like FMD, APAI, African swine fever, equine herpesvirus, and rabbit hemorrhagic disease. Despite the existence of Certificates of Veterinary Inspection (CVIs) and other state-mandated controls, the article identifies limitations in current screening and certification protocols, especially when issued up to 30 days before travel. These limitations create windows of vulnerability in which subclinical disease or emerging infections may go undetected, particularly among non-commercial producers and hobbyists unfamiliar with stringent biosecurity practices.

The article chronicles a growing number of event cancelations in the U.S. and abroad resulting from disease outbreaks—from the World Pork Expo to California's Mid-State Fair and international events in Canada, Australia, and Europe—underscoring the potential for even isolated outbreaks to disrupt large-scale events, trade flows, and animal welfare. The ongoing HPAI outbreak in both poultry and dairy herds, for instance, has prompted widespread exhibition bans and highlights the interconnectedness of disease risk across sectors.

In response, the article offers a detailed framework of biosecurity planning considerations, structured across three operational phases: before, during, and after the event. Recommendations include access control, facility disinfection, quarantining protocols, dedicated equipment zones, real-time communication strategies, and participant education. It also calls for greater integration of exclusion, segregation, and hygiene principles—aligned with World Organisation for Animal Health (WOAH) guidance—into planning efforts. Notably, it recognizes the need for ongoing surveillance, feed safety, movement permitting, and veterinary staffing to be incorporated into biosecurity planning at the event level.

Beyond technical recommendations, the article makes a compelling case for protecting not only animal health and food security, but also the developmental and economic opportunities these events provide to youth and agricultural communities. High-profile events like the Houston Livestock Show and Rodeo, which has distributed over $630 million in scholarships and youth support since its inception, are critical to cultivating the next generation of agricultural professionals. Cancelations or disease-related disruptions jeopardize not only the animals and exhibitors but also the broader public understanding of animal agriculture and its societal value.

Ultimately, the article frames livestock exhibition biosecurity as a shared responsibility that requires alignment between emergency managers, animal health officials, producers, event organizers, and educational institutions. Through proactive planning, stakeholder collaboration, and investment in local-level preparedness, it argues that these culturally and economically significant events can be preserved—even in the face of growing global animal health threats.

Agriculture Security: Systems-Based Preparedness

The second commentary, "Agriculture Security: Systems-Based Preparedness" (see Appendix 3), also published in the *Domestic Preparedness Journal* in March 2025, addresses the urgent need for a systems-based approach to protecting agricultural production in a rapidly changing global landscape. Against the backdrop of United Nations projections estimating a global population nearing 10 billion by 2050—and a corresponding 50% increase in global food demand—the article examines how traditional frameworks of food security, which largely focus on post-harvest safety and defense, are insufficient for addressing the complex risks that threaten the pre-harvest environment. These include threats to critical agricultural inputs such as seeds, feed, water, veterinary supplies, and energy systems, all of which are foundational to global food production.

The article reframes agricultural security as a critical infrastructure issue, one that underpins national food security, economic stability, and public health. It outlines the convergence of natural, biological, and technological hazards that pose significant risks to both crop and livestock systems—including extreme weather, plant and animal disease outbreaks, invasive species, and cyberattacks on precision agriculture systems. The growing interdependence of global supply chains, geopolitical volatility, and labor shortages further amplify these risks, creating conditions for cascading failures that threaten the continuity of food systems at multiple levels.

Rejecting siloed preparedness strategies that treat agricultural risks as isolated incidents, the piece advocates for a systems-thinking approach that integrates biological, environmental, technological, and economic factors into holistic planning frameworks. It calls for improved interjurisdictional coordination, expanded surveillance and early warning systems, and cross-sector risk governance that includes stakeholders from emergency management, public health, trade, and environmental sectors. Specific attention is given to the need for coordinated action across both the crop and livestock sectors, recognizing their shared vulnerabilities and the potential for cross-domain disruptions during major agricultural emergencies.

By emphasizing the pre-harvest environment and the protection of agricultural inputs, the article fills a critical gap in mainstream food security discourse. It offers practical pathways for enhancing resilience through biosecurity planning, technological safeguards, and supply chain hardening. Ultimately, the piece positions agricultural security as not only essential to the four dimensions of food security—availability, access, utilization, and stability—but also as a pillar of national security in an era marked by compounding and unpredictable global threats.

Impact and Societal Contribution

These commentary articles deepen both academic and practitioner conversations around agricultural emergency management by examining real-world challenges through multiple lenses—from biosecurity at livestock exhibitions to strategic frameworks for disease response and infrastructure protection. They reinforce the core themes of this portfolio by translating field-based planning efforts into peer-informed thought leadership, effectively bridging operational practice and strategic policy development. Each article contributes to a broader understanding of how risks across animal health, public safety, food systems, and the economy are interconnected—and why integrated approaches are essential. Their inclusion underscores the growing urgency for systems-based, forward-looking strategies that address the complex and converging risks facing modern agriculture.

Collectively, the portfolio's applied planning frameworks and published analyses exemplify how emergency preparedness, stakeholder collaboration, and strategic foresight can be operationalized to confront today's agricultural security challenges. By aligning academic inquiry with practical application, the portfolio strengthens interdisciplinary dialogue across emergency management, public health, and One Health preparedness. It demonstrates the critical role of adaptive planning, cross-sector coordination, and public-private engagement in building agricultural resilience and protecting critical infrastructure in an increasingly uncertain risk landscape.

Chapter 3 – Reflection and Lessons Learned

The author produced several key portfolio products that contributed to enhanced agricultural emergency preparedness and biosecurity planning at the state level, with broader implications for national response systems. The project yielded two comprehensive, operationally focused planning frameworks, a structured decision support tool for vaccine prioritization, and two commentary articles that expand discourse at the intersection of agriculture, public health, and emergency management.

Project Reflection

Bridging Doctrine and Practice in Agricultural Emergency Planning

This portfolio contributes a multidimensional body of work to the field of agricultural emergency preparedness, including operational plans, applied tools, and commentary articles. While the risks associated with foreign animal diseases (FADs), mass mortality events, and systemic agricultural vulnerabilities are well established in both federal doctrine and academic literature, this project narrows the gap between policy and practice. The materials translate high-level frameworks into practical strategies tailored for state-level implementation, specifically addressing the complexities unique to New Mexico's geography, livestock trade dynamics, and environmental conditions.

The development of the Large Animal Mass Mortality Carcass Management Plan and the Emergency FAD Vaccination Plan marks a shift from hazard-specific, reactive responses to scalable and integrated preparedness models. These plans address the operational demands of mass mortality events and transboundary disease outbreaks through detailed guidance on logistics, regulatory compliance, stakeholder engagement, and environmental stewardship. They offer a rare, jurisdictionally flexible blueprint for states seeking to operationalize preparedness in settings marked by limited infrastructure or high-risk livestock concentrations.

Advancing Decision-Making Through Operational Tools

One of the portfolio's most significant contributions is a Decision Support Tool designed to assist incident commanders in vaccine prioritization during FAD responses. Building on prior federal guidance, the tool introduces a transparent, multi-criteria framework that integrates epidemiological data with operational constraints. Unlike previous models that rely on expert judgment, this tool formalizes prioritization using a weighted matrix, making decision-making more defensible and adaptable under pressure. By linking vaccination access to preparedness indicators such as biosecurity planning and infrastructure readiness, it also fosters proactive risk mitigation within the producer community.

The tool's design reflects both analytical rigor and practical usability, with strategic secondary benefits that extend beyond incident response. To aid implementation, an attached addendum deconstructs the decision matrix into discrete components, enabling long-term adaptability and clearer training applications across stakeholder groups.

Commentary Publications and Scholarly Integration

To complement the operational tools, a set of commentary articles was developed to extend the project's insights into broader professional and academic discourse. These articles address challenges and emerging considerations in livestock exhibition biosecurity, systems-based agricultural risk, and carcass disposal operations. Each publication situates technical challenges within a larger socio-political and ecological context, aligning with the growing body of One Health literature. In doing so, they underscore the interconnected nature of agricultural security, public health, and environmental resilience.

The portfolio also contributed to academic instruction. As part of a new module on agricultural security in DMP 816: Trade and Agricultural Health, the author collaborated with a faculty advisor to design a guest lecture and assignment that engaged students in assessing threats and vulnerabilities in the agricultural sector. This classroom integration helped translate practical tools into pedagogical content, reinforcing the project's educational value.

Acknowledging Contextual Limitations

Although the tools are grounded in national doctrine such as USDA's FAD PReP and NAHEMS guidelines, their applicability beyond New Mexico has not yet been fully tested. The state's specific risk profile—including cross-border cattle movement and limited carcass disposal infrastructure—may not mirror conditions in other jurisdictions. Likewise, while the Decision Support Tool reflects real-world constraints and stakeholder feedback, it remains unvalidated in an actual outbreak. Iterative testing and refinement will be essential to ensure its effectiveness, usability, and alignment with regulatory expectations.

Furthermore, the emphasis on biosecurity readiness as a prerequisite for vaccination prioritization introduces implementation challenges, particularly for smaller or resource-limited producers. Future iterations should consider tiered benchmarks and embedded technical assistance mechanisms to ensure equity in access and avoid unintentionally penalizing willing but under-resourced stakeholders.

Personal Reflection

Operationalizing Preparedness: Navigating Real-World Constraints

The process of developing this portfolio reinforced a critical truth: successful emergency planning must reconcile strategic vision with operational feasibility. In working with state agencies and private stakeholders, the author encountered logistical, regulatory, and behavioral constraints that can impede even the most technically sound plans. These constraints were not merely technical; they reflected competing priorities, limited resources, and organizational inertia—all of which must be accounted for in any realistic planning effort. The experience highlighted the importance of building frameworks that are both adaptable and grounded in the everyday realities of those expected to implement them.

The development of the carcass management and vaccination plans revealed the necessity of designing for flexibility, especially in jurisdictions marked by workforce limitations, infrastructural gaps, and geographically dispersed operations. Each planning element—from cold chain logistics to regulatory compliance—had to be stress-tested against not only ideal conditions but also suboptimal scenarios in which capacity was strained or uncertain. These lessons reaffirm the value of planning models that are modular, scalable, and rooted in stakeholder-informed assumptions, capable of being activated in stages or adjusted in real time to meet emerging needs.

Designing Tools That Inspire Trust

In designing the Decision Support Tool, the author grappled with a central challenge of emergency management: decision-making under uncertainty. Developing a prioritization matrix that was scientifically rigorous, operationally feasible, and broadly acceptable required more than analytical accuracy—it demanded legitimacy. The tool's credibility rested on its ability to align expert guidance with field constraints, and to clearly communicate why certain decisions might be prioritized under pressure. This necessitated iterative refinement through feedback loops with operational users, including animal health officials, emergency managers, and producers.

The process demonstrated that effective tools must be more than technically accurate—they must be transparent, trusted, and adaptable to shifting field conditions. The author found that trust is built through clarity of criteria, inclusiveness in development, and the ability to explain decisions after the fact. In this way, decision support tools become more than instruments of efficiency—they function as governance tools, supporting consistency, accountability, and stakeholder buy-in during high-stakes response operations.

Systems Thinking and Relationship-Centered Preparedness

A key realization from this work was the importance of stakeholder-centered design. Engaging producers, veterinarians, and state officials clarified that operational success hinges as much on relationships and communication as on protocols and procedures. The author found that effective preparedness planning must account for stakeholder values, operational culture, and levels of resource access—not just technical risk metrics. In practice, this meant ensuring plans were not only scientifically sound but also understandable, actionable, and sensitive to the social and economic contexts in which they would be used.

Moreover, the cascading nature of agricultural risks—spanning zoonotic disease, extreme weather, and supply chain fragility—reinforced the need for systems thinking. No single discipline or agency can own the solution set for modern agricultural emergencies. Emergency management in the agricultural domain increasingly serves as a convening function, requiring interdisciplinary coordination among agriculture, public health, environmental regulation, and economic resilience actors. This project illustrated how preparedness is not simply about response readiness—it is about creating a shared understanding of interconnected vulnerabilities and building the relational infrastructure needed to act on that understanding across sectors.

Future Research and Integrated Impacts

This project invites a number of pressing questions that will shape the future of agricultural emergency preparedness. As state and national agencies contend with shifting leadership, uneven resources, and increasing risk complexity, how can planning tools remain adaptive and relevant? What mechanisms can be implemented to ensure equitable access to preparedness resources—especially for small-scale or historically underserved producers who may lack the capacity to meet formal biosecurity benchmarks but remain vulnerable to the same threats? Moreover, as technology evolves, how might AI-enabled disease modeling, drone-assisted surveillance, and blockchain-based traceability reshape not only detection and response, but also the broader architecture of agricultural security?

These questions, while complex, reinforce the importance of designing systems that do more than manage crises. The author leaves this body of work with a renewed commitment to advancing integrative, risk-informed approaches that invest in the systems, relationships, and foresight necessary to build enduring resilience. This portfolio represents a foundational step in that direction—an effort that acknowledges the layered, interdependent nature of modern agricultural risk and responds with tools that are as multidimensional as the challenges they are meant to address.

Collectively, the projects comprising this portfolio have significantly strengthened New Mexico's agricultural preparedness infrastructure. They provide both operational capacity and strategic foresight to navigate high-consequence animal disease scenarios and other disruptive events. Through the development of planning frameworks, decision support tools, and accompanying scholarly publications, the portfolio presents a comprehensive and scalable model for agricultural emergency management—one that is grounded in state-specific realities but adaptable across jurisdictions and hazard types.

The integration of interdisciplinary coordination, stakeholder engagement, and evidence-based planning into these tools reflects a deliberate effort to operationalize both rapid response capabilities and long-term recovery strategies. From carcass disposal and vaccine deployment to cold chain logistics and regulatory alignment, the portfolio addresses technical imperatives while simultaneously attending to organizational needs, such as interagency coordination, public trust, and risk communication. The result is a holistic approach that balances tactical responsiveness with strategic vision.

Importantly, while developed in response to New Mexico's unique risk profile—marked by expansive geography, international livestock movement, and sectoral diversity—the frameworks presented are highly transferable. They offer replicable methodologies for other states and regions seeking to modernize foreign animal disease preparedness. The Decision Support Tool, detailed in Appendix 1A and 1B, fills a longstanding operational gap by formalizing vaccine prioritization through a transparent, science-informed, and context-sensitive framework. Its emphasis on preparedness-linked eligibility criteria represents a novel means of aligning producer incentives with public health goals, and the tool is positioned for national adaptation.

Beyond its direct application at the state level, this work contributes to national discourse at the intersection of agricultural security, public health preparedness, emergency management, and One Health. By pairing technical planning products with systems-level analysis, the project demonstrates how data, infrastructure, and policy considerations can be synthesized into functional tools for real-world use. The accompanying commentary articles serve as a bridge between practice and scholarship, making applied insights accessible to researchers, policymakers, and practitioners alike.

Taken together, this portfolio affirms the urgent need for adaptive, forward-looking preparedness strategies that reflect the evolving complexity of agricultural systems and the convergence of risks they face. It underscores that proactive investment in planning, coordination, and knowledge dissemination is not only essential for effective emergency response—it is fundamental to the resilience, sustainability, and security of the nation's food and agriculture systems.

Chapter 4 – Competencies

Student Attainment of MPH Foundational Competencies

Table 4.1: Summary of MPH foundational Competencies

Number and Competency		Description
7	**Planning and Management to Promote Health**	Assess population needs, assets and capacities that affect communities' health.
9	**Planning and Management to Promote Health**	Design a population-based policy, program, project or intervention.
13	**Policy in Public Health**	Propose strategies to identify stakeholders and build coalitions and partnerships for influencing public health outcomes.
21	**Interprofessional and/or Intersectoral Practice**	Perform effectively on interprofessional teams.
22	**Systems Thinking**	Apply systems thinking tools to a public health issue.

This portfolio represents an intentional, practice-based application of public health competencies in a non-traditional but critically important setting: agricultural security and animal health emergency preparedness. It showcases how the core tenets of population health—prevention, planning, equity, systems thinking, and stakeholder engagement—can be translated into meaningful tools and strategies that address risks at the nexus of food security, zoonotic disease prevention, environmental health, and community resilience. Through this interdisciplinary, cross-sectoral effort, I engaged with complex problems that demanded not only subject matter expertise, but also strategic foresight, adaptive leadership, and interprofessional collaboration.

Competency 7: Integrative Assessment of Risk and Capacity

"Assess population needs, assets, and capacities that affect communities' health."

The planning products developed in this portfolio are rooted in a deep, integrative assessment of New Mexico's agricultural landscape. This included quantitative and qualitative evaluation of risk factors such as livestock density, geographic proximity to Mexico, cross-border animal movement, infrastructure gaps, producer readiness, and jurisdictional complexity. The Emergency FAD Vaccination Plan and Mass Mortality Carcass Management Plan reflect this assessment by aligning population-specific vulnerabilities—such as high herd density in border counties and limited carcass disposal options—with tailored interventions that mitigate both animal and human health risks.

Importantly, this competency was not applied in isolation. The assessment process also laid the foundation for competency 9 (designing interventions), competency 13 (stakeholder engagement), and competency 22 (systems thinking), demonstrating how a robust understanding of population needs enables more nuanced and sustainable policy design.

Competency 9: Designing Population-Based Emergency Interventions

"Design a population-based policy, program, project, or intervention."

The development of two major planning frameworks—the New Mexico Large Animal Mass Mortality Carcass Management Plan and the Emergency FAD Vaccination Plan—represents applied, population-based public health interventions designed to protect the health and continuity of agricultural communities. These plans were not created in a vacuum; rather, they were built through iterative, interagency consultation and grounded in USDA FAD PReP and NAHEMS doctrine while being adapted to the realities of New Mexico's terrain, agricultural economy, and regulatory environment.

Both interventions are systems-aware and equity-informed, incorporating considerations like accessibility, producer resources, and community engagement. For example, the Decision Support Tool embedded in the vaccination plan not only supports real-time epidemiological decision-making but also prioritizes producers who maintain formal biosecurity plans—thereby incentivizing preparedness and reinforcing equitable resource distribution.

These efforts represent more than compliance with a public health planning exercise—they are functional, deployable tools that align with national health security objectives and directly impact the state's capacity to respond to agricultural emergencies with public health consequences.

Competency 13: Building Coalitions and Fostering Trust

"Propose strategies to identify stakeholders and build coalitions and partnerships for influencing public health outcomes."

Agricultural emergency preparedness cannot be executed in silos. Recognizing this, I worked across multiple state agencies, industry associations, tribal entities, and academic institutions to ensure that planning products were both technically sound and culturally and operationally appropriate. In particular, stakeholder engagement informed not just content, but implementation pathways—who would activate plans, under what conditions, and how roles would be coordinated in real time.

This coalition-building was not limited to formal planning documents. The commentary articles served as a mechanism to extend knowledge, facilitate professional dialogue, and influence policy and practice by framing agricultural emergencies as shared public health concerns—not just sectoral disruptions. This outward-facing work aligns with broader health promotion goals and creates a platform for broader stakeholder buy-in.

In this way, stakeholder engagement efforts also intersect with Competency 21 (interprofessional teamwork) and Competency 22 (systems thinking) by translating shared goals into practical, collaborative strategies for preparedness and response.

Competency 21: Working Across Boundaries: Interprofessional and Intersectoral Collaboration

"Perform effectively on interprofessional teams."

Throughout the portfolio, I operated within diverse interprofessional environments—including veterinarians, public health officials, emergency managers, environmental scientists, livestock producers, communications professionals, and policy advisors. This required navigating different vocabularies, timelines, and decision-making frameworks while maintaining a shared vision of risk mitigation and public protection.

The Decision Support Tool's development process, for example, involved extensive cross-sectoral consultation to ensure alignment with both scientific validity (e.g., disease transmission dynamics) and field feasibility (e.g., availability of chutes, cold chain logistics). My role as facilitator and planner was not only to integrate these inputs but also to translate them into usable, defensible, and scalable frameworks that diverse end-users could trust and apply under pressure.

This collaboration strengthened my ability to lead and contribute meaningfully to complex, high-stakes planning processes—a critical skill set for any public health professional navigating today's interdependent preparedness landscape.

Competency 22: Applying Systems Thinking in Real-World Contexts

"Apply systems thinking tools to a public health issue."

Agricultural emergencies are inherently systemic. They are not defined by single events, but by the interdependencies between biological threats, environmental degradation, global trade networks, community trust, and infrastructure resilience. This portfolio applied systems thinking throughout: from the cascading impact analysis in the carcass management plan, to the weighted, multi-factor decision model used in the vaccination tool, to the commentary article reframing agricultural security as a critical infrastructure and national security concern.

Rather than isolate problems (e.g., disposal logistics, vaccine scarcity), I treated each challenge as part of a larger, interwoven system. This allowed for the design of tools and frameworks that could adapt to uncertainty, accommodate jurisdictional variation, and evolve over time as new risks or technologies emerged.

The systems perspective also informed stakeholder strategies—acknowledging that no one agency or actor can independently control an FAD response, and that preparedness must be built on networked relationships, shared situational awareness, and mutual trust.

Translating Competency into Preparedness Action

This portfolio operationalizes foundational public health competencies through a systems-based, stakeholder-informed, and action-oriented approach. It moves beyond theoretical understanding to demonstrate how public health knowledge can be applied across complex, real-world domains—particularly those involving high-consequence risks to food systems, animal health, and community resilience. By synthesizing planning doctrine, scientific evidence, regulatory frameworks, and stakeholder priorities, this work bridges the persistent gap between federal-level strategy and state- and local-level implementation. In doing so, it transforms academic preparation into practical tools that are usable, scalable, and grounded in operational realities.

Intentional design and inclusive engagement were central to this effort. Whether developing vaccination decision frameworks or carcass disposal strategies, every product emphasized equity, adaptability, and accessibility—ensuring that those responsible for implementing plans and policies are equipped with tools that reflect their constraints, values, and capacities. This approach not only strengthens technical outcomes but also promotes trust, transparency, and sustained collaboration—critical elements of effective public health systems.

Engaging directly with the intertwined challenges of agriculture, public health, and emergency management has expanded my perspective on what public health leadership demands. This work sharpened my planning and policy development skills, deepened my understanding of complex systems, and underscored the importance of integrating scientific, social, and logistical considerations in decision-making. More broadly, it contributes to the field's evolving understanding of how public health principles can protect and sustain essential systems—such as food and agriculture—that underpin population health and national security.

Ultimately, this portfolio stands as a model for interdisciplinary public health practice, real-world problem solving, and the type of adaptive, systems-aware leadership increasingly required in today's interconnected risk environment. It reflects a commitment not only to technical excellence but to public service—and to building preparedness capacity that endures beyond the next emergency.

Student Attainment of MPH Emphasis Area Competencies

Table 4.1: MPH Emphasis Area Competencies

MPH Emphasis Area: Food Safety & Biosecurity		
Number and Competency		**Description**
1	**Food Safety & Biosecurity**	Evaluate solutions appropriate for different food safety, biosecurity, and defense issues in the food production continuum.

2	**Threats to the Food System**	Examine specific threats to the food system and scientifically investigate how each can be prevented, controlled, and/or mitigated in the food production system.
3	**Food Safety Laws & Regulations**	Differentiate key U.S. food safety regulatory bodies and their unique legislative authorities, missions, and jurisdictions.
4	**Food Safety Policy and the Global Food System**	Analyze and distinguish how food safety and governmental biosecurity policies, globalization, and international trade cooperation influence public health.
5	**Multidisciplinary Leaderships**	Contrast the food safety and biosecurity technical needs of different stakeholders and make judgements as to the appropriate methods of collaboration.

This portfolio exemplifies applied public health leadership in the domains of food safety, agricultural biosecurity, and systems-level preparedness. Developed within the high-risk and high-stakes context of New Mexico's livestock industry, the tools, plans, and publications included in this body of work reflect a rigorous application of food safety and biosecurity principles to protect public health, animal health, and environmental integrity across the pre-harvest and emergency response stages of the food production continuum.

The portfolio not only demonstrates compliance with foundational theory but also addresses the dynamic realities of food system protection in an era marked by globalized trade, zoonotic disease emergence, environmental disruption, and complex regulatory landscapes. The five emphasis area competencies were engaged holistically and iteratively throughout the planning, stakeholder engagement, and strategic writing phases of the project, often reinforcing one another in practice.

Competency 1: Food Safety & Biosecurity

"Evaluate solutions appropriate for different food safety, biosecurity, and defense issues in the food production continuum."

Across the portfolio, I critically evaluated and designed context-sensitive solutions to a range of food safety and biosecurity challenges that emerge across the animal agriculture continuum. The Emergency FAD Vaccination Plan and Mass Mortality Carcass Management Plan directly addressed pre-harvest biosecurity and continuity concerns, while the Decision Support Tool helped operationalize vaccine prioritization in a way that accounts for production timelines (e.g., time-to-slaughter), infrastructure readiness, and herd structure—all of which influence downstream food system outcomes.

Similarly, the commentary articles—particularly the one focused on livestock exhibitions—highlighted event-specific vulnerabilities where animal intermingling presents a high risk for pathogen introduction. These environments represent early points in the production system where failure to control disease can lead to cascading effects on supply chain integrity, food safety, and public trust. The proposed solutions—biosecurity zoning, improved exhibitor guidance, coordinated surveillance—were evaluated for their practicality, scalability, and relevance to producers, regulators, and public health officials alike.

This competency was exercised not in theoretical isolation but as a cross-cutting consideration embedded into all preparedness planning efforts, ensuring that proposed interventions strengthened not just emergency response, but also long-term food system safety and resilience.

Competency 2: Threats to the Food System

"Examine specific threats to the food system and scientifically investigate how each can be prevented, controlled, and/or mitigated in the food production system."

The entire portfolio is organized around identifying and mitigating high-consequence threats to the food system, particularly those involving zoonotic or transboundary animal diseases. Through risk characterization and systems modeling, I examined how events like FMD outbreaks or mass animal mortalities could threaten food availability, economic stability, public confidence, and export market continuity.

Mitigation strategies embedded in the planning documents include vaccine ring deployment, traceability integration, movement permitting, disposal option analysis (e.g., composting, burial, rendering), and regulatory harmonization across jurisdictions. The Decision Support Tool further operationalized scientific principles of disease transmission and control—such as prioritizing dense herd areas or animals near known exposure routes—into real-time resource allocation decisions.

Additionally, in examining mass mortality management, I incorporated soil science, environmental health, and pathogen inactivation research to compare disposal methods. The plan critically assessed tradeoffs between speed, environmental risk, regulatory compliance, and operational feasibility—supporting informed mitigation decisions under emergency conditions.

Competency 3: Food Safety Laws & Regulations

"Differentiate key U.S. food safety regulatory bodies and their unique legislative authorities, missions, and jurisdictions."

Throughout this work, I differentiated and aligned planning strategies with the unique missions and authorities of key regulatory bodies, including USDA APHIS and FSIS, FDA, EPA, and relevant New Mexico state agencies such as the NM Department of Agriculture, the Environment Department, and the Livestock Board. This was critical in ensuring that both the vaccination and carcass disposal plans reflected real-world regulatory boundaries, reporting protocols, permitting processes, and incident command structures.

For example, the carcass disposal plan included operational guidance for compliance with solid waste and water protection rules under EPA and state environmental authorities, as well as movement control under APHIS Veterinary Services during foreign animal disease outbreaks. Understanding these distinctions was essential to drafting activation criteria, legal triggers, and interagency coordination strategies that were both legally sound and operationally executable.

Furthermore, the commentary articles often explained these distinctions for a broader audience, helping practitioners and decision-makers navigate the jurisdictional complexities of agricultural emergencies—a critical but often overlooked component of public health education.

Competency 4: Food Safety Policy and the Global Food System

"Analyze and distinguish how food safety and governmental biosecurity policies, globalization, and international trade cooperation influence public health."

New Mexico's geopolitical and agricultural context—with international ports of livestock entry and proximity to Mexico—offered an opportunity to deeply engage with this competency. The portfolio explicitly addressed the transboundary nature of FAD threats, including how cross-border cattle movement, international disease reporting, and trading partner acceptance of vaccinated animals influence both national policy and local decision-making.

The vaccination plan analyzed the impact of suppressive vs. protective vaccination strategies not only on disease containment but on trade continuity, international animal health code compliance (OIE/WOAH), and market perception. I incorporated scenarios where political and economic concerns might override epidemiological best practices, further complicating vaccination decision-making during an outbreak.

This competency was especially relevant to the systems-based agricultural security article, which argued for a reconceptualization of biosecurity as part of critical infrastructure protection—bridging public health, economic stability, and national security. This framing mirrors current One Health and global health security dialogues around the need for international cooperation on biosecurity and trade to protect both food systems and human populations.

Competency 5: Multidisciplinary Leadership

"Contrast the food safety and biosecurity technical needs of different stakeholders and make judgments as to the appropriate methods of collaboration."

Finally, this portfolio reflects a deep understanding of the varying technical needs, capacities, and risk perceptions of different stakeholder groups, including commercial livestock producers, state regulators, emergency managers, environmental scientists, veterinarians, and public information officers. Throughout the planning and tool development process, I made careful distinctions in communication, expectations, and guidance depending on each group's role and operational context.

For example, the vaccination plan distinguishes between producers with robust infrastructure and formal biosecurity plans versus smaller operators who may lack resources but remain vulnerable. It embeds flexibility in delivery models, training requirements, and eligibility criteria to ensure collaboration without exclusion.

The mass mortality plan accounts for the divergent roles of the NMDA, NM Livestock Board, NM Environment Department, and local emergency managers, coordinating their regulatory and technical inputs around disposal site permitting, environmental monitoring, and public messaging. The plans and tools reflect deliberate decision-making about how to mobilize these groups collaboratively without duplication, contradiction, or delay.

These collaborative judgments were not just theoretical but directly informed plan structure, tool usability, and stakeholder education materials, reflecting an ability to lead multi-sector preparedness efforts with technical and interpersonal precision.

Strengthening Agriculture and Food Security Through Applied Systems Thinking

This portfolio translates the MPH Food Safety & Biosecurity emphasis area into applied public health leadership—advancing from academic competency to operational capacity. Rather than viewing food safety and biosecurity as isolated technical concerns, this body of work treats them as integral components of a complex, interdependent system that underpins public health, economic stability, environmental protection, and national security. By developing field-ready tools, scalable planning frameworks, and peer-informed commentary, the portfolio bridges the gap between conceptual learning and real-world preparedness action.

In doing so, it integrates critical threat analysis, regulatory navigation, scientific mitigation strategies, and inclusive stakeholder collaboration into a systems-informed, forward-looking framework for emergency response and agricultural resilience. The solutions proposed—ranging from mass mortality management to emergency vaccination prioritization—are rooted in scientific evidence, yet tailored to the operational realities of producers, state agencies, and emergency planners. This emphasis on practical utility, coupled with systems awareness, ensures that the outputs are not only technically sound but also implementable and enduring.

As the global food system contends with mounting risks from zoonotic disease emergence, climate volatility, invasive species, antimicrobial resistance, and geopolitical trade disruptions, the need for interdisciplinary, anticipatory public health leadership has never been more urgent. Public health professionals must be equipped to operate across sectors, disciplines, and jurisdictions—engaging diverse partners while advocating for scalable, equitable, and sustainable approaches to risk reduction.

This work contributes meaningfully to that effort. It demonstrates how academic preparation, stakeholder engagement, and strategic foresight can converge to build resilience into the systems that sustain human and animal populations alike. Moreover, it serves as a replicable model for how food safety and biosecurity competencies can be leveraged to address evolving challenges at the intersection of agriculture, health, and security. By centering public health principles in the protection of the food system, this portfolio affirms that biosecurity is not only a technical priority, but a foundational public health imperative for the future.

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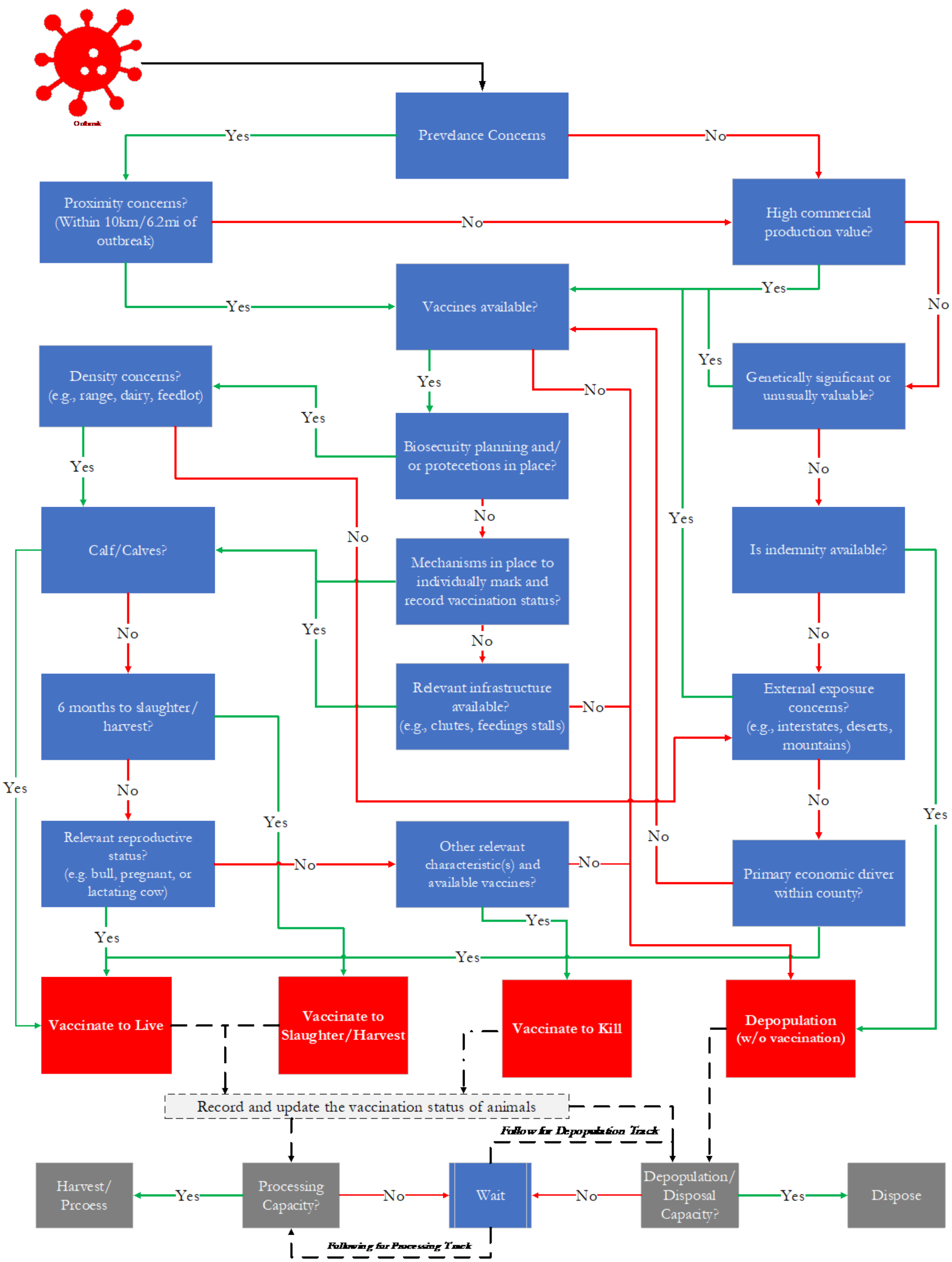
Appendix 1A: NM Livestock Vaccination Decision Support Tool



Appendix 1B: NM Livestock Vaccination Decision Support Tool Addendum

The timely implementation of a comprehensive animal vaccination strategy following a foreign animal disease (FAD) outbreak in New Mexico is critical to effectively manage both the disease spread and subsequent economic damage that may result from such an outbreak. Given the national implications of an outbreak and the anticipated scarcity of resources available to support response efforts, a strategic approach to vaccination distribution and herd prioritization is critical to limiting disease spread and safeguarding the well-being of the impacted industry. This decision support tool and flowchart outlines the state's strategic framework for prioritizing animal vaccinations. It serves as an addendum to the New Mexico Emergency FAD Vaccination Plan and may be used as a tool to inform and guide decision-making following the initial stamping out of livestock within the 10km (6.2mi) buffer of the State's index case. It should be used by relevant officials in evaluating how to distribute the FAD/FMD vaccinations most effectively, once received by USDA.

Framework Assumptions:

- **Initial Stamp-Out:** Animals within or near (e.g., 10km buffer) the index case/herd have been stamped-out and NMDA has transitioned to the modified response strategies (See Response Strategies).
- **Vaccine Scarcity:** Depending on the severity of the outbreak (i.e., regional versus national outbreak), sufficient vaccine may not be available to vaccinate designated or at-risk animal populations.
- **Unified Command:** Use of emergency vaccination will be determined by the Unified Incident Command, the State Animal Health Official(s), and the relevant USDA officers (e.g., Regional Emergency Coordinator, Veterinary Services Deputy Administrator/U.S. Chief Veterinary Officer).
- **Distribution:** The State and responding agencies maintain the ability to efficiently transport vaccines (once received) throughout the state, preserving the cold chain (e.g., maintaining appropriate storage temperatures) and vaccine efficacy.
- **Participating Agencies:** Roles and responsibilities of responding agencies may change depending on the severity/scale of the outbreak. Non-traditional partners/agencies may be leveraged to surge resource and support operational needs (e.g., transportation, distribution, administration, depopulation).

Response Strategies

- **Vaccinate to Live:** Depopulation of clinically affected and in-contact susceptible animals and vaccination of at-risk animals, without subsequent depopulation of vaccinated animals. Vaccinated animals intended for breeding, slaughter, or other purposes live out their lives.
- **Vaccinate to Slaughter/Harvest:** Depopulation of clinically affected and in-contact susceptible animals and vaccination of at-risk animals, with slaughter and processing of vaccinated animal, if animals are eligible for slaughter under USDA FSIS and/or State/Tribal authority and rules.
- **Vaccinate to Kill:** Depopulation of clinically affected and in-contact susceptible animals and vaccination of at-risk animals, with subsequent depopulation and disposal of

vaccinated animals. Depopulation and disposal of vaccinated animals may be delayed until logistically feasible, as determined by Incident Command and VS Deputy Administrator.

- **Depopulation (No Vaccination):** The rapid destruction of affected and in-contact susceptible animals and vaccinated at-risk animals (assuming no slaughter capacity), via gunshot, penetrating captive bolt, and/or IV administration of a lethal dose of barbiturate acid derivative in accordance with AVMA guidance.

Decision Characteristics/Factors:

- **Proximity:** The proximity of animals to one another and to potential disease sources greatly influences the risk of disease transmission. Animals in proximity, such as those in crowded feedlots or shared pastures, have an increased risk of exposure to infectious agents. Therefore, prioritizing vaccination for animals near others can help contain disease spread more effectively.
- **Density Concerns:** Herd density refers to the number of animals within a given space. High herd density can facilitate the rapid spread of diseases in crowded conditions. Vaccinating animals in high-density populations is crucial to prevent disease outbreaks and minimize transmission. In accordance with USDA APHIS guidance, dairies may be given priority over other high-density operations given both the challenges associated with milk disposal and narrow profit margins. Feedlots and cow-calf operations are said to recover more efficiently when compared to other forms of cattle farming.
- **Calves:** Calves are often more susceptible to diseases than adult animals due to their developing immune systems. Prioritizing vaccination for calves can help reduce disease-related morbidity and mortality in this age group, ensuring the future health and productivity of the herd.
- **Time-to-Slaughter:** The time an animal spends in a specific location before slaughter is important. According to USDA, cattle should be protected for 6 months with one dose before a booster is required. It is for this reason that animals within 6 months of being slaughtered should be prioritized under the vaccinate-to-slaughter/harvest response strategy.
- **Reproductive Status (Bull, Pregnant, or Lactating):** The reproductive status of animals, such as bulls, pregnant females, or lactating mothers, can affect their susceptibility to diseases and the transmission of diseases to offspring. Pregnant or lactating animals may have altered immune responses, making them more vulnerable. Bulls may have a different risk profile due to isolation or breeding practices. Adjusting vaccination priorities based on reproductive status is essential to protect vulnerable individuals and ensure the health of the next generation. Vaccine prioritization based on reproductive status is function of business continuity and herd composition: pregnant cows, lactating cows, and bulls. When evaluating the reproductive status of a herd, pregnant females should be given priority to ensure the health of both the cow and the developing fetus and the assumed vaccination status of the lactating female most found on dairies (See Density Concerns). Bulls on the other hand are often isolated from the main herd and thus have a reduced risk of disease exposure during an outbreak. Depending on the genetic significance of the animal, bulls are likely to be the last vaccinated during a FAD response for these reasons (See Genetic Significance).
- **Biosecurity Planning:** Biosecurity planning involves implementing strategies and protocols to prevent the introduction and spread of diseases within a herd or agricultural

setting. It is a critical component to maintaining a herd's health by minimizing the risk of infectious diseases, enhancing animal welfare, and preserving productivity. Incentivizing biosecurity planning among individual producers strengthens the entire system by creating a network of controls. Each operation's commitment to stringent biosecurity planning and procedures acts as a crucial link in safeguarding the collective health and resilience of the industry.

- **Tracking and Traceability:** To ensure effective disease management and strategic decision-making during a Foreign Animal Disease (FAD) outbreak, robust mechanisms are in place to individually mark and record vaccination status. These include the use of unique animal identification tags (e.g., RFID or visual ear tags), centralized digital record systems, and standardized paper documentation for operations without digital infrastructure. Temporary visual markings (e.g., paint or chalk) provide immediate identification of vaccinated animals, while cold chain compliance logs ensure vaccine efficacy. Routine audits and inspections verify adherence to protocols and address discrepancies. Together, these measures enable traceability, accountability, and efficient prioritization of vaccination efforts, enhancing overall outbreak response.
- **Relevant Infrastructure:** Having suitable facilities, like chutes or handling equipment, is crucial for efficient and safe vaccine administration. These infrastructure elements are necessary for proper vaccination procedures and ensure the safety of both animals and handlers. Prioritizing vaccination where such infrastructure is available and accessible can streamline the vaccination process.
- **External Exposure Concerns:** While natural topographical obstructions (e.g., mountains, forests, plateaus) may limit the aerosol transmission of a FAD, built infrastructure (e.g., interstates) have the potential to spread a FAD through fomites. As such it is important to understand the geographical context of a facility in relation to the index case/herd with some facilities being more susceptible to disease transmissions compared to others (e.g., intensive livestock production facility near an interstate or neighboring facility versus a remote, range-based operation).
- **Genetic Significance:** Genetic significance can be a subjective component of livestock productions and therefore challenging, yet necessary to consider during FAD outbreaks to achieve long-term resilience. It can refer to individuals or breeding lines that possess exception genetic traits, superior performance characteristics, or rare genetic markers crucial for enhancing the breed's overall quality. These individuals or breeding lines often exhibit traits like high growth rates, disease resistance, superior meat or milk production, or specific desirable phenotypes. Preserving, breeding, and incorporating these animals into breeding programs can significantly improve the genetic diversity, health, producibility, and economic value of livestock herds, contributing to the overall advancement, sustainability, and resilience for the industry.

Appendix 2: Beyond the Showcase: Strengthening Biosecurity at Livestock Exhibitions (Final Proof)

For emergency management professionals, the hazards and risk associated with local, county, and state fairs mirror those of other high-attendance events—medical emergencies, mass casualty incidents, and other public safety risks. However, those familiar with the food and agriculture sector recognize an additional risk: the introduction and spread of animal diseases, which can have potentially catastrophic consequences for state, regional, and national economies.

Animal Movement and Risk Landscape

County and state fairs, rodeos, horse shows, races, and livestock shows are long-standing agricultural traditions that promote youth development and public education in the agricultural sciences. To facilitate these gatherings, hundreds or even thousands of animals are transported across states for purposes of entertainment, genetic showcasing, and athletic performance. For instance, major livestock events like the Houston Livestock Show and Rodeo, the National Western Stock Show in Denver, and the Calgary Stampede in Canada, and the American Royal in Kansas City, bring together large numbers of animals—approximately 30,000 at Houston, 12,000 at Denver, 7,500 at Calgary, and 6,000 in Kansas City. These multi-day events feature a wide array of animals and attract audiences numbering in the millions. However, the movement of these animals is independent of the millions of animals transported annually within the United States for the commercial agricultural purposes of breeding, grazing, auction, export, and processing.

States regulate transports to exhibitions through their departments of agriculture or related agencies tasked with animal health oversight. Animals destined for shows or other recreational events are often required to obtain a Certificate of Veterinary Inspection (CVI), or health certificate, before moving within or between states. CVIs provide information on the number of animals inspected, the purpose of movement, the points of origin and destination, and a statement by a USDA-accredited veterinarian confirming that the animals show no clinical signs of illness or parasites that would pose a risk at their destination.

Despite these health assessments, risks remain. Errors on health certificates are common and the requirement for certificates to be issued up to 30 days before movement may not account for changes to an animal's health status post-inspection, for incubation periods of certain infectious diseases, or for the potential for subclinical signs of illness within a herd or specific animal. While most livestock producers and handlers are familiar with the health status of their animals, those raising livestock for exhibition purposes—at times outside traditional agricultural production—may have different priorities and risk tolerances, highlighting the critical need for strong biosecurity awareness, education, and practices at event sites.

A Look Back

Stringent biosecurity practices minimize the impact of animal disease spread, enabling future events to continue. Consider these recent event cancellations due to animal disease outbreaks:

- *2015:* A Colorado horse show canceled due to Vesicular Stomatitis Virus (VSV).
- *2018:* The Vancouver Island Rabbit Breeder Association show canceled following an outbreak of Rabbit Hemorrhagic Disease (RHD).
- 2019:
    - The Salinas Valley Fair's poultry exhibit was canceled due to Virulent Newcastle Disease.
    - The World Pork Expo was canceled over African Swine Fever concerns—and again in 2020 for the same cause and the then emerging COVID-19 pandemic.
    - Several high school rodeos in Utah were canceled over the concerns of equine herpes spread.
- *2021:* The California Mid-State Fair postponed its rabbit show due to RHD.
- *2023:* The Rancho Mission Viejo Rodeo canceled due to VSV concerns.
- *2024:* The cancelation of dairy exhibits at both the Big Fresno Fair and the Iowa State Fair due to the transmission of highly pathogenic avian influenza (HPAI) in dairy herds.

The ongoing response to HPAI, a type of bird flu that spreads rapidly between and within both commercial and backyard flocks, began in March 2022 and has affected over 156 million birds to date. Its continued transmission not only within domestic flocks but also within dairy herds continues to raise concerns. Since its first identification in dairy cattle in March 2024, 959 cases have been reported across 16 states as of February 2025—California having the highest number of confirmed cases. This has resulted in the recent banning of poultry and dairy exhibitions this year at all county fairs and shows within the state. With ongoing transmission within both dairy and poultry production facilities, it is likely that cancelations will continue in 2025. It is worth noting, however, that these incidents are not unique to the United States.

In 2022, the National Poultry Show in Ontario, Canada, was canceled due to HPAI. More recently, in 2024, poultry exhibits in South Australia were also canceled in response to the HPAI outbreak. Additionally, the English Winter Fair in Staffordshire, England, and an annual sheep herding event in Madrid, Spain, were both canceled over bluetongue virus concerns. These are just a few examples highlighting the widespread impact of animal disease outbreaks on agricultural and livestock exhibition events across the world.

Understanding Disease Response: Why It Matters

A robust disease response involves detection, containment, eradication or control, and recovery. Delays or inadequacies in these stages can lead to widespread consequences that affect the economy, public health, and the food supply chain.

- Livestock losses alone result in billions of dollars in damages, while canceled events and trade restrictions result in lost revenue and marketing opportunities. Zoonotic diseases like

Salmonella, E. coli, HPAI, and others can originate in domestic animals and wildlife and pose direct threats to human health. These outbreaks can rapidly spread between animals, to humans, and vice versa, creating a cycle of transmission that disrupts food production and shpply chain. As a result the availability and affordability of food products domestically and abroad, exacerbating economic and public health challenges.

Collaboration and integration among stakeholders—including government agencies, producers and trade associations—with both the authority and expertise to manage these intersectoral risks are crucial for effectively reducing consequences within and across affected sectors.

The Stakes for Future Agricultural Leaders and Professionals

Independent of the severe consequences associated with an animal disease outbreak—estimated in the tens of billions of dollars for animal diseases like foot-and-mouth and ASF—the cancellation or modification of these events across the United States may also disrupt vital opportunities for the next generation of agricultural leaders. Exhibition events provide valuable hands-on experience, education, and career development for youth, as well as opportunities to expose the general public to animal agriculture. For example, the Houston Livestock Show and Rodeo, one of the world's largest livestock events, has awarded over $630 million in scholarships and support to youth since 1932, including nearly $25 million planned for 2025.

Exhibition Biosecurity Planning Considerations

According to the World Organization for Animal Health, biosecurity is the collection of management practices and physical measures aimed at minimizing the risk of introducing, establishing, or spreading animal diseases, infections, or infestations within, into, or out of an animal population. The risk of an animal disease outbreak and the subsequent biosecurity planning and infrastructure required at an event involving livestock are influenced by factors such as the species involved, the event size and scope, the season or time of year, and the effectiveness of preventive measures in place.

Effective biosecurity practices are essential to safeguarding the health of livestock, protecting public safety, and ensuring the success and continuation of exhibition events. By implementing robust biosecurity measures—such as exclusion, dedication (or segregation), and hygiene—event organizers, agricultural professionals, and exhibitors can minimize risks to both humans and animals and preserve the integrity of an event and the broader domestic livestock system. This section offers several biosecurity planning considerations for event planners at each stage.

Before the Event

- Restrict non-essential personnel, vehicles, and equipment; require health certifications, advanced screenings, and designated entry points for animals and materials.

- Assign separate zones for different species, quarantine areas for high-risk animals, and dedicated storage for feed, bedding, and equipment.
- Clean and disinfect facilities, equipment, and transport vehicles; install and maintain handwashing and boot-washing stations; train staff and exhibitors on biosecurity practices; and plan for proper disposal of contaminated materials.

During the Event

- Control access points with physical barriers, inspect animals for illness, and prohibit unauthorized equipment or feed without inspection.
- Segregate animal populations, provide dedicated tools and equipment, clearly label “clean” and “dirty” zones, and limit equipment sharing.
- Regularly disinfect high-contact areas, provide personal protective equipment, enforce handwashing and boot-washing protocols, and ensure adequate cleaning supplies are available.
- Establish clean communication channels among event organizers, participants, and relevant animal health personnel to report concerns, share biosecurity updates, and ensure compliance with protocols.

After the Event

- Conduct exit health checks, clean and disinfect vehicles leaving the premises, and properly dispose of contaminated materials like bedding and manure.
- Use dedicated tools and supplies for post-event cleanup and inspect equipment before returning it to general use.
- Thoroughly clean and disinfect all areas, vehicles, and equipment, and provide participants with guidelines for post-event animal health monitoring.

Additional considerations may include ongoing surveillance and access to veterinary staff throughout the event, feed safety and contamination prevention, waste management, dead stock removal, notification protocols, and movement permitting if illness or disease is identified. By offering biosecurity guidance before and after the event, along with clear instructions for reporting issues, and by integrating exclusion, dedication, and hygiene at every stage of the event cycle, planners can create effective biosecurity systems that minimize disease risks and ensure safety for all.

Looking Forward: A Shared Responsibility

As Western sport fans welcome the 2025 season and students and families everywhere eagerly anticipate upcoming exhibition events, it is imperative that agricultural and emergency management professionals and event planners are familiar with and remain vigilant regarding the ever-present risk and threat of animal disease introduction and transmission. By fostering cross-sector collaboration, implementing rigorous biosecurity protocols, and remaining watchful, exhibition planners can ensure the continued success of these events while safeguarding the opportunities they provide for future generations of agricultural leaders throughout the United States.

Additional contributions to this article were made by Adrian Self (Operations Research Analyst, National Agricultural Biosecurity Center at Kansas State University), David Hogg (Research Associate, Cooperative Institute for Server and High Impact Weather Research and Operations at the University of Oklahoma), and Marshal Wilson (Co-Director, Southwest Border Food Protection and Emergency Preparedness Center at New Mexico State University).

Appendix 3: Agriculture Security: Systems Based Preparedness (Final Proof) By Joshua Dise and Adrian Self

The United Nations' Food and Agriculture Organization projects that the global population will reach nearly 10 billion by 2050. Although estimates vary across academia, such population growth is expected to result in an approximately 50% increase in global food demand. As economies grow and dietary preferences change, food security is of increasing concern.

Food security is defined as the state in which everyone, at all times, has reliable physical, social, and economic access to sufficient, safe, and nutritious food. Food security achieved by policies and mechanisms at the state, national, and international levels ensure that food is protected from intentional adulteration or tampering (food defense) and accidental contamination (food safety) by biological, chemical, or physical contaminants in the post-harvest processing environment, all of which pose risks to public health and economic stability.

Food systems are inherently complex and sustained by global trade networks of inputs and outputs that support agriculture production and food consumption. However, food safety and defense (as an implementation of food security) address only half the supply chain—from post-harvest to consumption—when using the traditional farm-to-table model.

In the cultivation, rearing, and pre-harvest environment, food security can best be achieved by protecting necessary inputs (e.g., seeds, feed, water, energy, fertilizers, pesticides, reproductive resources, and veterinary medicine) used for the primary production of food from crops, livestock, forestry, fisheries, and aquaculture resources. The protection of these inputs from threats, hazards, and vulnerabilities—similar to those in post-harvest and production environments, along with many unique risks—is a key aspect of agricultural security. Additionally, preparedness activities associated with these risks, as well as the enabling of agricultural production, further contribute to the overall concept of agricultural security. Put more simply, agriculture security is the safeguarding of crops, livestock, and associated input supply chains against natural, intentional, or accidental disruption.

Agriculture Under Threat: The Modern Risk Landscape

Agricultural security ensures the protection of essential inputs used in food production, including crops, livestock, forestry, fisheries, and aquaculture. Global agriculture employs 1.23 billion people and spans production, processing, packaging, transportation, and distribution. The U.S. food and agriculture sector comprises nearly 2 million farms, over 700,000 restaurants, and 220,000 food-related facilities, contributing 5.6% to the gross domestic product (GDP) and employs more than 10% of the workforce. Safeguarding these elements and the sector as critical infrastructure is crucial to maintaining food security across the four dimensions of availability, accessibility, utilization, and stability.

Agricultural security encompasses a range of risks—including hazards (e.g., extreme weather events), threats (e.g., agroterrorism, cyberattacks), and vulnerabilities (e.g., reliance on fragile supply chains)—that directly influence food security outcomes. Understanding these distinctions is essential for developing effective mitigation strategies. These risks fall into three broad categories: natural, biological, and technological, each posing significant challenges to food production, distribution, and producer livelihoods. Compounding these challenges are external pressures such as economic instability, geopolitical conflicts, and regulatory shifts, highlighting the need for a comprehensive, adaptive approach to safeguarding agricultural systems.

Extreme Weather and Natural Disasters

Agriculture is among the most exposed and vulnerable sectors to extreme weather and natural disaster given its reliance on natural resources and environmental conditions. Such disasters have resulted in an estimated $3.8 trillion in global losses across crop and livestock production, or 5% of global agricultural GDP.

Extreme temperatures, drought, floods, storms, and wildfires can devastate crops and livestock, disrupt supply chains, and threaten rural economies. Following are examples of how such events may impact agricultural security.

- ***Extreme Heat & Drought***—Prolonged heat and drought conditions can reduce soil moisture, hinder plant growth, lower crop yields, stress and kill livestock, decrease pasture availability, and increase the risk of pest outbreaks.
- ***Floods***—Excessive rainfall and flooding can erode soil, waterlog crops, spread plant diseases, disrupt planting and harvesting schedules, damage infrastructure, and contaminate water and food supplies.
- ***Storms***—High winds and heavy rain from hurricanes, cyclones, and severe thunderstorms can physically damage crops, uproot trees, and destroy greenhouses, barns, irrigation systems, and other agricultural infrastructure.
- ***Wildfires***—Fires destroy crops, scorch grazing lands, kill livestock, and damage agricultural infrastructure, while indirectly impairing plant respiration, growth, and subsequent yield.

Pests, Pathogens, and Disease

Animal and plant diseases threaten agricultural systems. Outbreaks of livestock diseases like foot-and-mouth disease, African swine fever, or avian influenza can have catastrophic economic and social consequences. Similarly, crop diseases such as wheat rust or citrus greening threaten food supplies.

Following are examples of how pests, pathogens, and disease may impact agricultural production.

- ***Crop Losses***—Plant diseases and pests destroy crops, reducing yields and affecting food availability.

- ***Livestock Mortality***—Disease outbreaks in livestock production lead to a variety of impacts, which could include mass culling, reduced domestic herd populations, severe economic losses, supply chain disruptions, and food shortages.
- ***Trade Disruptions***—Plant and animal disease outbreaks not only result in site quarantines and other movement restrictions, but also disrupt international trade and agricultural market continuity.
- ***Soil & Ecosystem Damage***—Pathogens may persist in soil, reducing long-term land productivity and resulting in costly plant disease management and control operations.

Invasive Species

Invasive species disrupt ecosystems and agricultural productivity. Competition against native species damage crops, dispersing novel pathogens. The economic impact of invasive species has escalated from $2 billion annually in North America in the 1960s to over $20 billion yearly since 2010. Globally, the cost has exceeded $1.2 trillion over the past five decades.

Below are a few examples of how invasive species may impact agricultural production.

- *Crop Damage*—Invasive pests and pathogens consume and infect crops, spreading diseases and reducing harvest quality and quantity.
- *Soil & Water Disruption*—Invasive plants out-compete native vegetation, deplete soil nutrients, alter root structures, and alter water availability.
- *Livestock Impacts*—Toxic invasive plants reduce grazing land quality, while invasive pests and wildlife may contribute to disease spread, negatively impacting livestock health.
- *Increased Costs*—Invasive pests and pathogens may compel producers to allocate resources to disease or pest management, control efforts, and enhanced biosecurity measures, which all increase operational expenses.

Technological

The integration of digital technologies in agriculture has improved efficiency but has also introduced vulnerabilities that threaten crop and livestock production. Cyberattacks on automated and smart farming systems, IoT-connected devices, and cloud-based data platforms can disrupt agricultural production, leading to economic losses and food security risks. Malicious actors, including agroterrorists, cybercriminals, and other malicious actors, may exploit these vulnerabilities to manipulate critical agricultural processes, causing large-scale disruptions.

Below are examples of the risks associated with agricultural reliance on technology and potential impacts to agricultural security.

- *IoT Device Disruptions*—Hacking IoT sensors and devices can alter data on soils, weather conditions, and livestock health, leading to incorrect irrigation, fertilization, and health interventions, potentially causing crop failures and livestock health issues.
- *Automated Machinery Disruptions*—Cyberattacks on automated machinery and robotics such as drones, autonomous tractors, and robotic harvesters can disrupt planting, spraying,

and harvesting operations, resulting in operational delays, crop damage, and reduced productivity.

- *Cloud-Based Data Platform Disruptions*—Breaches in cloud-based data platforms can lead to unauthorized access and manipulation of agricultural data, compromising decision-making processes and exposing sensitive information, which can result in financial losses and competitive disadvantages.
- *Artificial Intelligence and Machine Learning Disruptions*—Manipulated AI algorithms and machine learning models can result in incorrect forecasting and recommendations for crop management, which may lead to poor crop health, reduced yields, and increased vulnerability to pests and diseases.
- *Supply Chain Management Disruptions*—Cyberattacks on supply chain management systems can delay the delivery of essential inputs like seeds, feed, and fertilizers, disrupting crop planting and livestock feeding practices, which leads to lower yields, compromised animal health, and financial losses.
- *Wireless Sensor Network (WSN) Disruptions*—Attacks on WSNs can lead to data tampering and denial of service attacks, compromising the accuracy and availability of environmental monitoring data, which is critical for precision agriculture.

Agriculture's security challenges extend beyond environmental and biological hazards, encompassing intentional sabotage or compromise of agricultural systems by malicious actors, geopolitical instability, market volatility, labor shortages, and resource competition. These broader pressures exacerbate existing vulnerabilities. Weak data integration and fragmented oversight and awareness hinder threat detection. Trade disruptions and workforce shortages further weaken the capacity of a food system to absorb, adapt to, and recover from disruptions while maintaining stable access to sufficient, safe, and nutritious food for all. Biosecurity threats like agroterrorism and food fraud compromise supply chain integrity, and land conversion—the transformation of agricultural land for urban, industrial, or other non-agricultural uses—alters ecosystems in ways that facilitate the spread of pests and disease. Water scarcity also increases that susceptibility, weakens natural pest control mechanisms, and diminishes overall agricultural productivity. These evolving threats, hazards, and vulnerabilities continue to reshape the agricultural landscape, amplifying risks to global food production and distribution.

Meeting the Challenge: A Systems Approach to Agriculture Security

The multifaceted threats and challenges to agricultural security necessitate a systems-based approach, recognizing the interconnected nature of food production, trade, biosecurity, and the interdependencies with other critical infrastructure (e.g., water, transportation, chemical, and energy). A systems-based approach in pre-harvest and production environments is a holistic framework that integrates biological, environmental, and operational factors to enhance both security and resilience in agricultural systems in order to withstand, adapt to, and recover from disruptions. At the same time, agricultural systems can maintain productivity and long-term stability. This approach moves beyond linear problem-solving to account for complex interactions between inputs, production practices, external threats and hazards, and the broader regulatory and economic landscape. Unlike isolated interventions that focus on individual hazards, a comprehensive framework requires coordinated efforts across stakeholders, including emergency management and other government agencies (e.g., public health, agriculture, environment) agencies, producers, veterinarians, scientists, and global trade partners—each operating within unique regulatory and operational frameworks, making harmonization a significant challenge. A systems-based approach must address unpredictable factors like pests, pathogens, regulations, geopolitics, and market volatility, all of which can disrupt security countermeasures. For example, while biosecurity is critical to preventing and controlling livestock disease, outbreaks will always be a risk that can disrupt supply chains, weaken consumer confidence, and destabilize markets. Even small vulnerabilities in any of these areas can create cascading effects that compromise both agricultural and food security.

Below are some examples of how a **systems-based approach** may strengthen **agricultural security efforts.**

- *Interjurisdictional Coordination*—Agricultural emergencies often involve multiple agencies within a state, leading to fragmented communication, lack of coordination, and possible response delays. A systems-based approach fosters coordinated policies, integrated surveillance, and unified emergency planning, ensuring seamless collaboration across state departments, local governments, and industry stakeholders for rapid risk mitigation and hazard control.
- *Interconnected Risk and Cascading Impact*—Traditional agricultural risk management often focuses on isolated threats and hazards (e.g., a specific livestock disease or natural disaster). However, food and agriculture emergencies are multifaceted, interconnected, and create cascading failures across supply chains, affecting production, processing, trade, and consumer access. A systems-based approach ensures cross-sector collaboration and adaptive risk mitigation to prevent single-point vulnerabilities from escalating into broader crises.
- *Integrated Biosecurity*—Whether driven by emerging pathogens, invasive pests, or environmental disruptions, biosecurity challenges in crop and livestock systems transcend farm boundaries and production systems. Integrated surveillance, cross-sector disease management, and coordinated mitigation strategies are essential to prevent transmission pathways, protect agricultural assets, and strengthen food systems.

Agricultural security is fundamental to global food security, yet it faces an evolving array of risks—from extreme weather and biological hazards to cyber vulnerabilities. Addressing these challenges requires a systems-based approach that recognizes the interconnectivity of food production, supply chains, and technological infrastructure. Traditional linear models of food security are insufficient. Agricultural security efforts must integrate measures across pre- and post-harvest environments to incorporate advanced biosecurity, long-term agroecosystem security strategies, and robust cybersecurity frameworks.

However, implementing such a comprehensive approach is not without challenges. The costs of integrating advanced security measures—such as enhanced awareness, secure digital infrastructure, and comprehensive biosecurity planning—can be prohibitive, particularly for small-scale producers. Additionally, systemic coordination among diverse stakeholders requires overcoming regulatory, logistic, and financial barriers. Together, stakeholders can develop adaptive, forward-thinking solutions that safeguard agricultural systems against disruptions by fostering collaboration among emergency managers, veterinarians, producers, and other relevant preparedness partners.

Despite these challenges, the long-term benefits of agricultural security—ensuring food supply stability, minimizing economic losses, and reducing crisis response expenditures—underscore the necessity of proactive investment in resilience measures. In an increasingly complex and uncertain world, securing the foundations of food production demands a comprehensive, systems-driven approach—one that ensures the stability, safety, and sustainability of global food supplies for future generations.

The views expressed in this article are solely those of the authors and do not represent the views or positions of their respective institutions.

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