Written Testimony of Dr. Sherry Hunt
Supervisory Civil Engineer
U.S. Department of Agriculture, Agricultural Research Service
Hydraulic Engineering Research Unit

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Chairwoman Sherrill, Ranking Member Bice, and Members of the Committee, thank you for the opportunity to provide testimony on the importance of the topic "From Gray to Green: Advancing the Science of Nature-Based Infrastructure." I am Dr. Sherry Hunt, Supervisory Civil Engineer of the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) Hydraulic Engineering Research Unit (HERU) in Stillwater, Oklahoma. I have served in this leadership role for nearly 10 years. In addition, I serve as the Stillwater, Oklahoma USDA ARS Acting Location Coordinator and our Agency's Dam Safety Officer. I have served on behalf of the public at USDA for nearly 22 years.

My research focuses on the physical modeling of hydraulic structures like dams with a special emphasis in highly air-entrained flow. I conduct research to quantify and predict erosion processes to improve design and analysis tools for conservation hydraulic structures, channels, and embankments. I transfer technology through written publications; development and maintenance of computational models; and presentations at technical and non-technical venues. I collaborate with a diverse group of stakeholders representing action agencies such as the USDA Natural Resources Conservation Service (NRCS), USDA Forest Service (FS), U.S. Army Corps of Engineers (USACE), U.S. Bureau of Reclamation (USBR), United States Geological Survey (USGS), state dam safety offices; private consultants, and national and international scientific peers for developing and implementing evolving technology.

As our Agency's Dam Safety Officer, I review and update the emergency action plan for the USDA ARS Southern Plains Range Research Station dam located in Woodward, Oklahoma and coordinate interagency agreements between USDA ARS and USDA NRCS for the inspection, rehabilitation design, and construction of this USDA ARS owned dam. In addition, I complete the annual reporting requirements on behalf of my Agency for the National Dam Safety Program biennial report to the U.S. Congress. Furthermore, I serve in advisory roles as the federal co-chair of the Federal Emergency Management Agency's (FEMA) National Dam Safety Review Board Research Working Group and as committee member on World Bank-funded dam design and construction projects for the U.S. Departments of State and Treasury.

USDA ARS HERU Scientific Contributions to Natural and Gray Infrastructure

The original mission for USDA ARS HERU scientists was to develop new and improved conservation practices by determining the hydraulic characteristics of vegetations used for waterway lining. Thus, researchers studied the hydraulics of grass-lined channels including terrace outlet channels, farm reservoir emergency spillways, diversions, and meadow strips. The design concepts for vegetated waterways were successfully adopted into design criteria by the USDA NRCS, other federal and state agencies, and consulting firms worldwide. These design concepts are still taught in civil and agricultural engineering collegiate curriculum today. In 1990, USDA ARS HERU scientists were honored when these design concepts were designated an Historic Landmark of Agricultural Engineering by the American Society of Agricultural and Biological Engineers (ASABE).

As the United States (U.S.) emerged from the Dust Bowl of the 1930's, flooding inundated the Midwest along the Missouri and Mississippi River corridors and the Great Plains of Oklahoma and Texas. The monetary damages of agricultural lands and transportation routes along with the loss of human lives led Congress to pass the Flood Control Acts of 1936 and 1944 (Public Law 78-534) and the subsequent Watershed Protection and Flood Prevention Act of 1954 (Public Law 83-566), creating the USDA Small Watershed Program. The Program established the principle of combining conservation practices in the watershed with flood control dams on tributary streams. Implementation of this program required innovations in engineering, hydraulics, hydrology, and soil mechanics by USDA ARS engineers and scientists in partnership with the USDA NRCS. Consequently, the USDA ARS HERU expanded its mission to also develop criteria for the analysis and design of conservation structures and channels for the conveyance, storage, and measurement of runoff waters. USDA ARS HERU scientists in collaboration with USDA NRCS created a signature footprint for these structures that consists most commonly of an earthen dam with a typical height between 25 ft and 100 ft, an inlet tower with a principal spillway pipe through the dam that outlets into an energy dissipator, and a vegetative earthen auxiliary spillway. These Program-funded dams are unlike many of those designed and constructed by USBR and USACE as those are generally larger concrete (e.g., gray) dams, including some very large dams like the Hoover and Grand Coulee dams. Collaboratively, USDA ARS HERU scientists teamed with USDA NRCS engineers and Kansas State University researchers to create computational software for predicting erosion and failure of vegetated earthen auxiliary spillways. These tools, methodologies, and computational model have been adopted into practice by USDA NRCS, USACE, USBR, state dam safety engineers, and consultants worldwide.

Earthen dams make up more than 85% of the more than 90,000 dams on the U.S. National Inventory of Dams (NID). USDA is the engineer of record for the design and construction of approximately one-third of dams in the NID. Through the USDA Small Watershed Program, nearly 12,000 dams and associated conservation practices in more than 2,000 watershed projects encompassing 160 million acres in 47 states have been constructed based on design standards developed by USDA ARS HERU scientists and engineers since 1948. My home state of Oklahoma leads the nation with over 2,100 of these dams, and ninety percent of Oklahoma residents live within 20 miles of one of them. These dams are federally assisted not federally owned. Project sponsors, who are generally local conservation districts, special use conservancy districts, or municipalities, own, operate, and maintain these dams. In 2011, the USDA Small Watershed Program was selected by ASABE as a Historic Landmark of Agricultural Engineering. This tribute was the first of its kind with its recognition of a Program that was instituted through the successful partnership between USDA ARS HERU engineers and scientists; USDA NRCS staffs; and project sponsors. Today, the USDA Small Watershed Program provides the U.S. an estimated $2.3 billion in annual benefits including flood control, municipal water supplies, water-based recreation, protection of homes and businesses, controlling soil erosion, improving water quality, managing agricultural water, and creating or enhancing wildlife habitat.[1]

Recently, USDA ARS HERU scientists focus on developing new innovative solutions with the release of new design standards, engineering tools, and a computational model to address the needs of these aging dams. Specifically, the USDA ARS HERU scientists have developed new advancements in routing flood waters safely and economically around or over dams impacted by changing land use (e.g., rural to urban). Take, for example, Big Haynes Creek Watershed Dam No. 3, located in the Atlanta, Georgia greater metropolitan area of Gwinnett County, Georgia and Tongue River Watershed Dam Site No. M-4 (also known as Renwick Dam) located near the city of Cavalier, North Dakota. Both dams were constructed in the 1960s to reduce the flood risk to downstream farms, croplands, roads, and bridges. In the early 2000s, both dams were reclassified as high hazard potential dams. Hazard potential classification categorizes dams based on the adverse consequences of a dam failure or mis-operation, and it has nothing to do with the condition of the dam. In this case, the consequences of a failure or mis-operation of the high hazard potential dams are loss of human life as the downstream land use changed from agricultural to residential and commercial. With these reclassifications, it was determined that neither dam met state and federal dam safety regulations as both had inadequate spillway capacity to pass the required flood flow. Altering existing spillway dimensions to increase spillway capacity is often limited by topography and unobtainable land rights due to encroaching residential and commercial properties, which was the case in these two situations. Consequently, I collaborated with USDA NRCS to perform site-specific physical model studies for these two dams to support the design of stepped spillways to route flood waters over the dams in a safe manner. Since USDA NRCS expects ten percent of the Program funded dams to need similar design solutions, the USDA ARS HERU research program was expanded to develop generalized stepped spillway design guidance to any earthen dam. USDA ARS HERU scientists successfully developed standardized stepped spillway design criteria that were adopted by USDA NRCS, USDA Forest Service (FS), USACE, USBR, and architectural and engineering (A&E) consulting firms. USDA NRCS indicates the criteria when applied to an anticipated 1,200 Program-funded dams will provide a construction cost-savings ranging from $600 million to $1.2 billion when compared to other traditional spillway options. In addition, this design criterion is now an industry standard among A&E consultants across the U.S. This research and technology are assisting dam safety engineers in preserving the $2.3 billion in annual benefits provided by these Program funded dams.

While most dams remain safe, dam incidents and failures do occur. The two most common types of earthen dam failures are water spilling over the top of dam and water passing through an internal opening of the dam. Because of the sheer number of Program funded dams reaching the end of their planned service life, USDA ARS scientists recognized a need for computational models to assist in prioritizing Program funded dams for rehabilitation as well as predicting the erosion rates and failure time should water spill over the dam or pass through an opening within the dam. USDA ARS HERU scientists conducted large-scale overtopping and internal embankment erosion and failure tests to develop and validate algorithms that quantifies erosion processes of earthen dams subjected to water spilling over the top of the dam or flowing through an opening within the dam. Algorithms can simulate anticipated embankment performance by estimating the time of failure of

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[1] Watershed and Flood Prevention Operations Program | NRCS (usda.gov)

vegetal or rock protection materials on the downstream face of the dam, the erosion rates of the underlying soil materials, and the timing of when an earthen dam failure is expected to occur. Through the collaboration between USDA ARS HERU, USDA NRCS, and Kansas State University, algorithms were used to develop a physically based, simplified earthen dam erosion and failure model, WinDAM (Windows Dam Analysis Modules) as an analysis tool for conducting what-if scenarios and to assist with prioritizing dams for rehabilitation. The software does not calculate the risk or probability of a dam failure. This software has been successfully adopted by USDA NRCS, USDA FS, USACE, USBR, Tennessee Valley Authority (TVA), state dam safety offices, and consulting engineers worldwide. USDA ARS HERU scientists expect to expand the software prediction capabilities as research continues to examine earthen dam erosion processes and failures. Specifically, scientists will conduct studies on concentrated overtopping water flow along the intersection of the dam and the natural landscape (e.g., abutments), disruptions in overtopping flow caused by stability berms sometimes constructed in dams, and embankments constructed of multiple soil material types.

Research Drivers in Natural and Gray Infrastructure Today

Climate and Environmental Change

Climate and environmental change and human activities are threatening water and land resources and economic growth across America. Increasing occurrences of extreme weather exacerbate vulnerability of water infrastructure and threaten public health and safety. While more intense precipitation events increase the pressure on our nation’s dams, droughts are also detrimental to dam integrity. Drought and wildfires are also increasing in intensity in some regions due to climate change. Drought can make dams more susceptible to erosion, and wildfires can alter the vegetation in the area around a dam.

Hazard Potential Classification Changes due to Rural to Urban Cross-over

Growing residential communities and commercial development are creating changes in the hazard potential classification of dams. Hazard potential classification categorizes dams based on the adverse consequences of a dam failure or mis-operation. For instance, the consequences expected from the failure or mis-operation of a high hazard potential dam are loss of human life whereas failure or mis-operation of a low hazard potential classified dam would result in no probable loss of human life and low economic and/or environmental loss. The benefits of a dam can change based on changing land use. Research, including new data collection and assessment methods for dynamic systems, is needed to better informed decisions on the economic feasibility of water resource development, rehabilitation, and management.

Development of Holistic Water Resources Infrastructure Monitoring and Inspection Networks with New and/or Improved Cloud-Based Technology

With 85 percent of the dams on the U.S. NID identified as earthen, it shouldn’t be a surprise that most dam failures across the U.S. are associated with this type of dam. Real-time data for rainfall, snowmelt, stream flow, and seismic activity are accessible from publicly available sources, but much of these data are missing the meta-data or not reported in a standardize format. Additionally, valuable historic data like that released in soil mechanic reports for dam design and construction are locked away in filing cabinets because the technology did not exist to input and store the information like you can in today's modern computing and cloud-based systems. These data are very relevant today as they provide insight for input parameters in earthen dam and spillway failure prediction models. Web-based applications for dam monitoring do exist and allow users to access critical legacy documents including as-built drawings, operation and maintenance agreements, emergency action plans, inspection reports, photos, video, and assessment reports. Dam monitoring systems currently available have drawbacks as they often don't provide data on water quality nor do they account for changes in the available detention storage caused by withdrawal of water from the reservoir for irrigation or for municipal and rural water supply, reservoir evaporation, principal spillway discharge, or storm events over multiple days. Additionally, there is no accurate accountability as to the economic benefits for Program-funded dams during extreme weather events as the benefit analyses based on reduction in flood damages and non-flood benefits that USDA NRCS computed during the original planning process rather than on current conditions. To get a more accurate account of flood risks, reservoir response time, and economic benefits, research is needed on real-time dam monitoring and their impounded reservoirs with an intent to develop a holistic decision support informatics platform that includes a database management system using ArcGIS as an integrated graphical interface, decision support tools, standardize operating procedures, historic data, and legacy software and documents. This platform coupled with artificial intelligence could produce high resolution frequently updated land use and flood routing maps that could inform policy makers; decision support tools for dam operation, irrigation scheduling, and municipal and rural water supply use; standard operating procedures for monitoring dam performance; and alert systems for informing emergency managers and the public of dam safety related emergencies.

Emergency managers need reliable data to make decisions for public safety (e.g., road closures, evacuations) during flood events. Irrigation districts and American farmers need water availability data coupled with decision support tools, so they can properly apply the right amount of water to their croplands or store away water for future use if needed. Having this data along with "smart" tools will improve the sustainability of agricultural production (e.g., crops and livestock) for a growing population in the U.S. Additionally, lending institutions need to know their investment is protected. It is these reasons that USDA ARS scientists are committed to addressing these challenges.

USDA ARS Partnerships for Data Innovations and USDA ARS HERU's Role

USDA ARS is already taking a holistic approach at engaging collaborators from other federal and state agencies, academic institutions, national and international scientific peers, and private partners through our Partnerships for Data Innovations (PDI). PDI is a field-engaged effort to innovate the way we collect, handle, store, use, and serve data. PDI works strategically and collaboratively with public and private partners with multi-disciplinary backgrounds (e.g., engineering, environmental scientists, biologist, plant pathologists, geographical information systems) to find new innovative and affordable ways for high-quality standardized data collection and to develop cloud-based technologies, artificial intelligence (AI), and integrated systems that will make data more accessible and shareable. The goals of the PDI program include 1) innovation by improving the way data is collected, processed, analyzed, stored, and distributed; 2) standardization by ensuring data are of the highest quality for maximum usefulness and impact; 3) automation by decreasing the number of times one handles samples or interact with their data; and 4) integration by expanding the power of data and opportunities for scientific collaboration. Leveraging public and private partnerships will create customized solutions to reduce the time researchers spend on data management, so they can focus more time on their science. Achieving these goals will result in 1) new ways for scientists to interact with their data in a living, working data environment, 2) tools and data that are not islands, but linked and updated within the research data environment, 3) a "network of networks" where researchers can interact virtually across locations and disciplines, and 4) increased impact for our scientists, collaborators, customers, and stakeholders.

USDA ARS plays an integral role in water resources management and availability across America and is equipped to meet the challenges through scientific discovery and engineering know-how. USDA ARS HERU is a PDI technical team where scientists will be key players in the success of this well-rounded approach of scientific discovery. Specifically, USDA-ARS HERU scientists will focus on five research objectives: 1) developing new and/or improved cloud-based technologies and engineering tools for data acquisition for water resources infrastructure monitoring and reservoir management, which will allow data to be used in off-site decision support systems and integrated into watershed modeling tools, 2) expanding hydrologic and hydraulic prediction models through real-time monitoring and/or physical modeling of water resources infrastructure through the implementation of a dam monitoring and inspection network, 3) developing new and/or enhancing designs, engineering tools, models, and best management practice standards to monitor and assess the performance of water resources infrastructure, 4) engaging stakeholders through extension and outreach activities to assess the economic benefits of new and/or rehabilitated water resources infrastructure and conservation practices, and 5) developing stochastic optimization models and risk assessments to improve sustainable agriculture production and water management practices, while enhancing long-term landscape health in temperate environments.

Scientists will accomplish these objectives through strong collaborations and the utilization of the USDA ARS HERU, a one-of-a kind facility with a water siphon system consisting of five 18-inch diameter pipes that draw gravity flow water from the adjacent Lake Carl Blackwell. These siphons provide water that is delivered through a network of channels for testing small to prototype scale physical models of natural (earthen) and gray (concrete) infrastructure. In addition, two siphons convey gravity water flow through pipelines to two indoor facilities for small and intermediate scale physical model testing of hydraulic structures. The capabilities of this siphon, channel, and pipe network system are unmatched by any other hydraulic laboratory worldwide. Because of the uniqueness of the USDA ARS HERU, our facilities have been made available to other USDA ARS scientists from across the U.S., other federal agencies, public universities, and international scientists from the European Union. The siphon system along with modeling facilities will soon be impacted as OSU has received funding through FEMA's Rehabilitation of High Hazard Potential Dams (HHPD) grant program for the rehabilitation design of Lake Carl Blackwell Dam, and it is anticipated that OSU will apply for additional monetary assistance for rehabilitation construction of the dam once the design is complete.

Conclusion

In closing, the question that comes before us today is how do we address the challenges that affect the sustainability of our agricultural production, water resources, and our economic growth that these dams provide? The answer is simple. Through collaborative partnerships and a holistic science-based approach to develop cloud-based technologies and engineering tools for standardized data acquisition and management, dissemination of data and information for aiding sustainable resource management and precision agriculture, and decision support tools for assessing the social and economic benefits of our water and land resources. USDA ARS scientists and engineers are committed and poised to lead the charge in these efforts.