United States Department of Agriculture

USDA-ARS HERU Embankment Erosion Research: Past, Present, Future

Sherry L. Hunt, PhD., Research Leader and Research Civil Engineer
Darrel M. Temple, P.E., Retired Research Leader
Ron Tejral, P.E., Agricultural Engineer

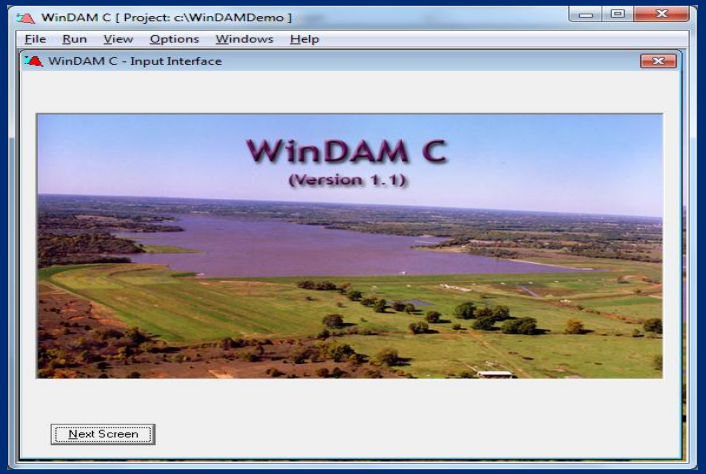
USDA-Agricultural Research Service

Hydraulic Engineering Research Unit

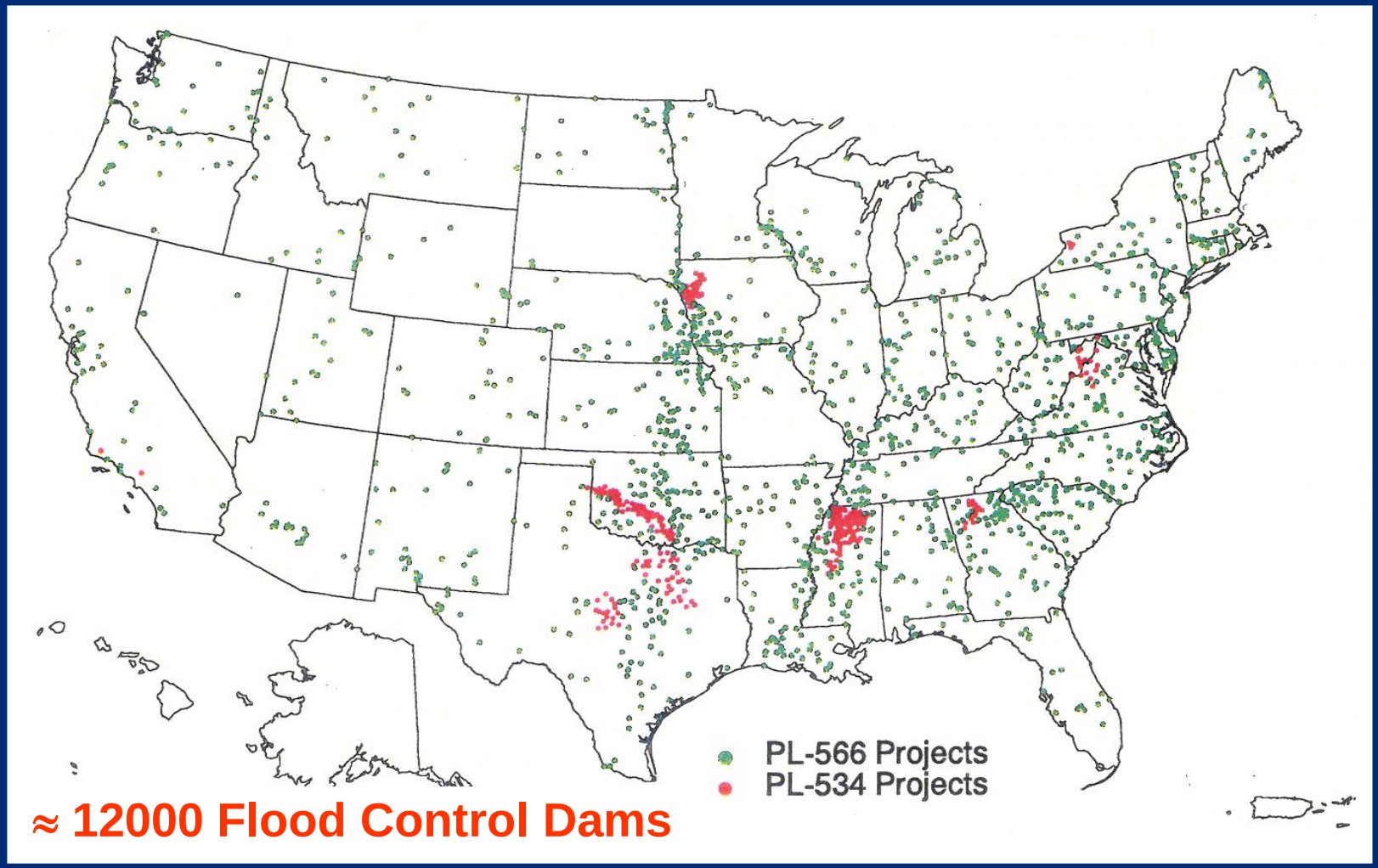
International Workshop on Overflowing Erosion of Dams and Dykes
December 11, 2017

Overview

- Background to USDA Small Watershed Program
- Challenges
- Research Drivers
- WinDAM Development and Future Direction
- Impact of the Research and Application

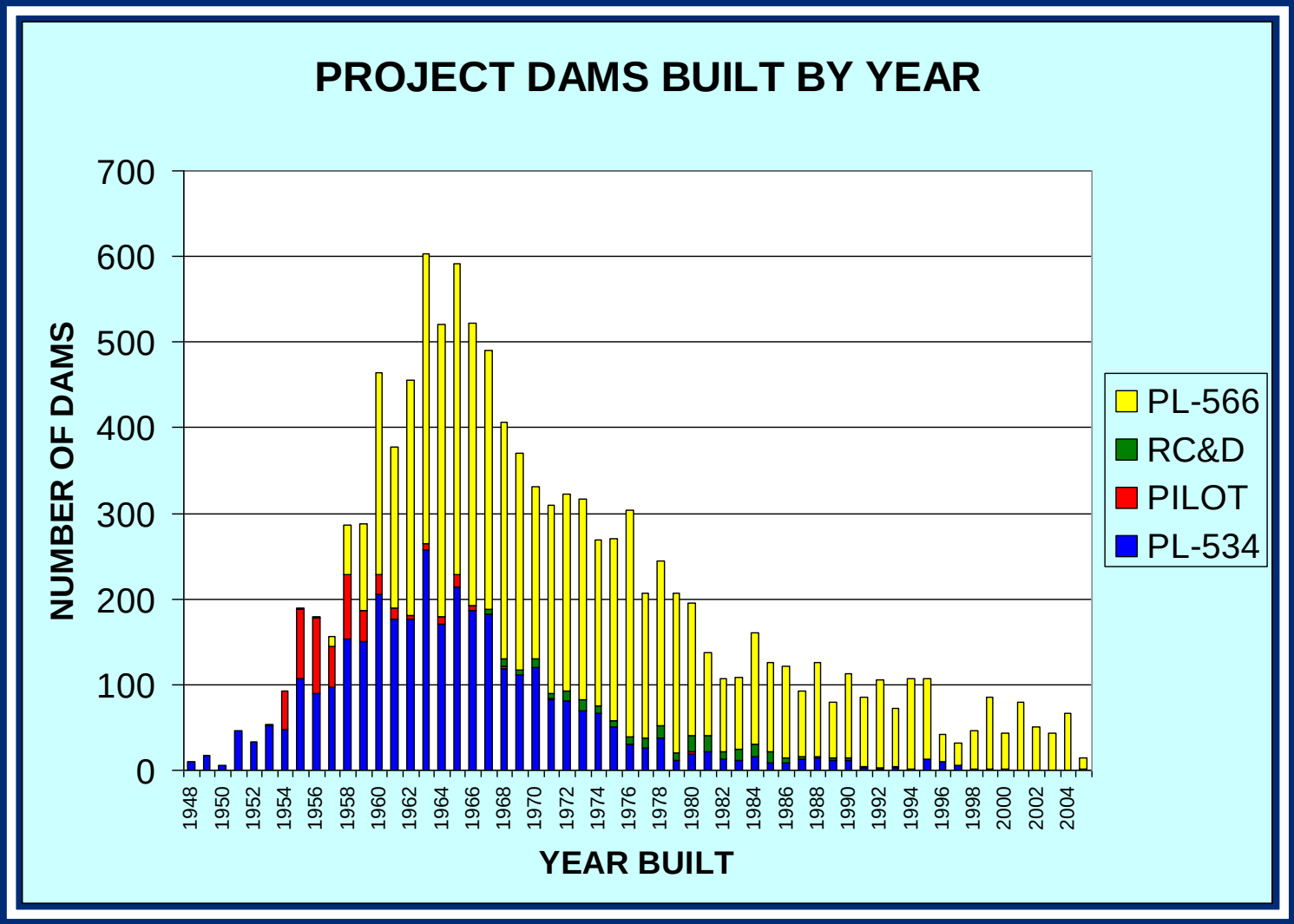


USDA Small Watershed Program



≈ 12000 Flood Control Dams

USDA Small Watershed Program



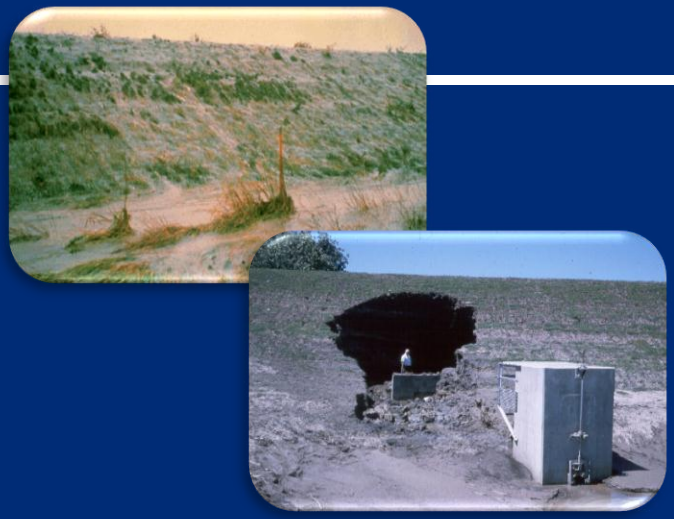
Challenges

- Competition for food, fiber and water
- Climate change
- Aging infrastructure with structural deterioration and/or sedimentation
- Urbanization

Initial Research Drivers

- Increased focus on aging structures and changes in hazard class
- SITES spillway erosion model
  - Field observation of overtopped dams
  - Similarity of embankment and spillway erosion processes
- Soil erosion research
  - High stress detachment
  - Headcut advance

Initial Research Drivers (cont)



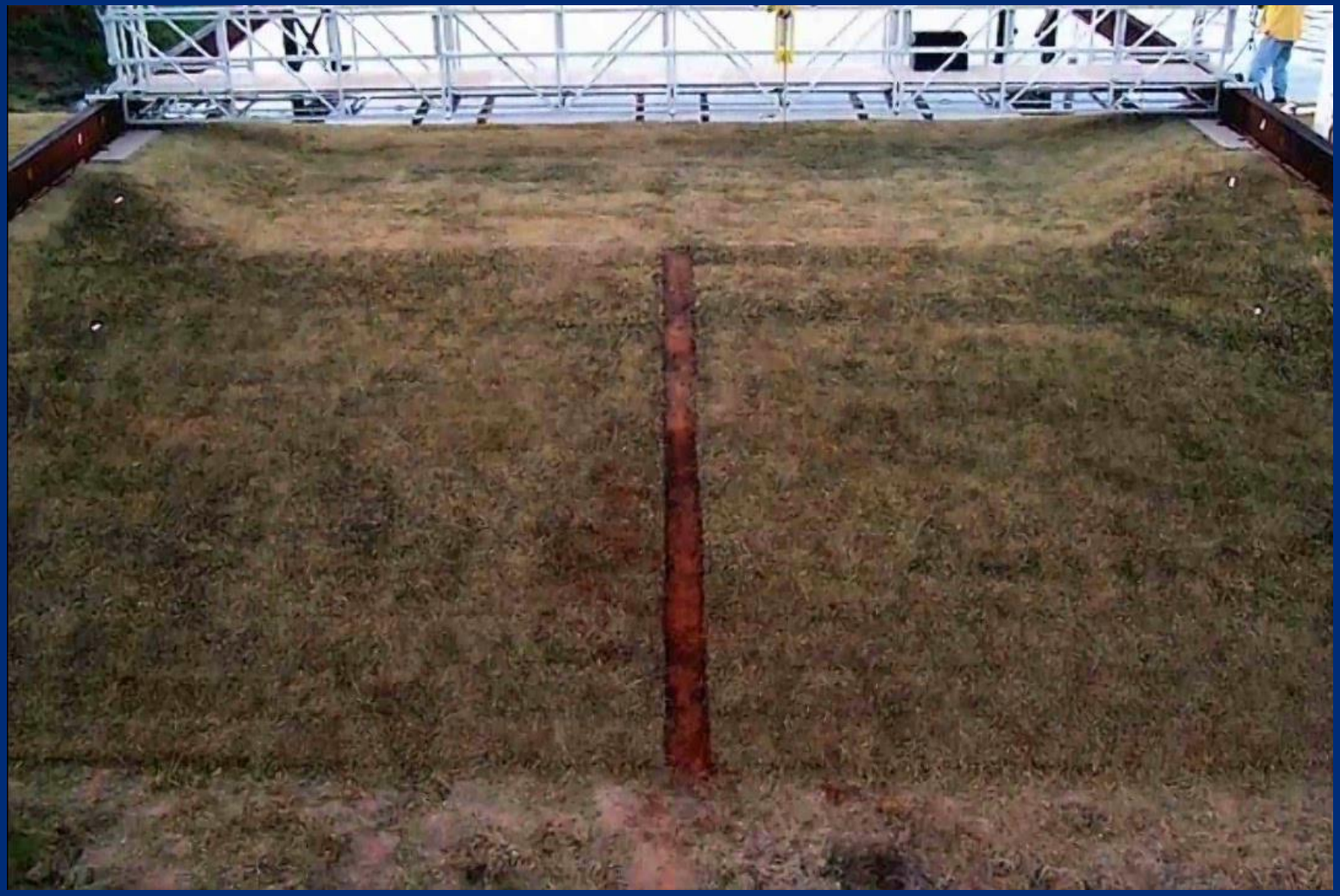
- Two primary ways embankments fail
  - Overtopping
  - Internal erosion
- Need for process based model to evaluate what if scenarios of dam overtopping and failure
  - Prioritization of Rehabilitation
  - More in-depth development of inundation mapping of specific sites
  - More in-depth evaluation of EAPs in some cases
    - Extent of flooding
    - Breach Timing
  - Evaluation of single sites and sites in series

Embankment Overtopping/WinDAM A Development

Vegetal Protection

Riprap Protection

Embankment Overtopping/WinDAM B Development



Embankment Overtopping/WinDAM B Development

Overtopping Breach

- **Homogeneous embankment dam**
  - Stage 1: Formation of headcut on downstream face
    - Failure of surface protection (if any)
    - Downward erosion to form headcut
  - Stage 2: Breach initiation – headcut advance through crest
  - Stage 3: Breach formation – local removal of embankment
  - Stage 4: Breach widening and stored water release

Stage I
$0 < t_1 < 16$ min

Stage II
$16 < t_2 < 31$ min

Stage III
$31 < t_3 < 51$ min

Stage IV
$t_4 > 51$ min

t_i, initiation time

t_f, formation time

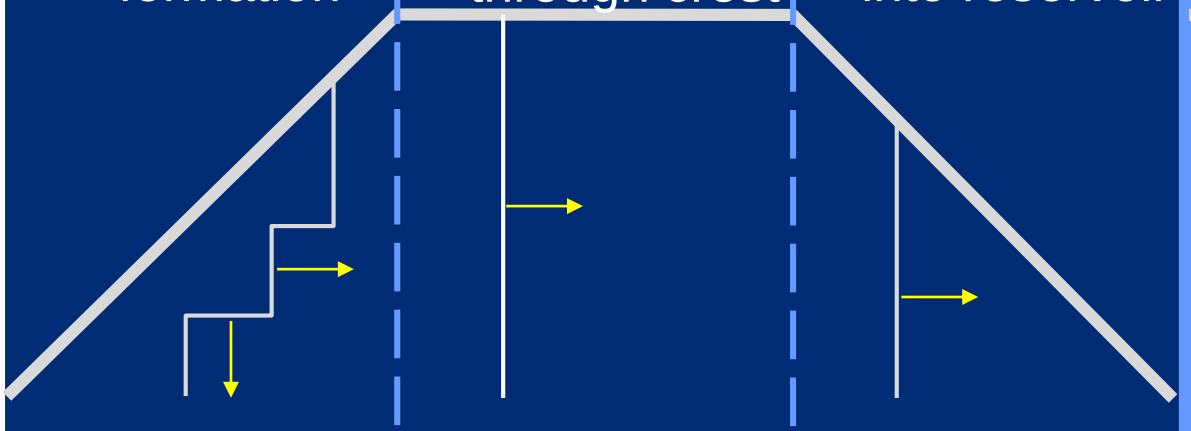



1) Headcut formation

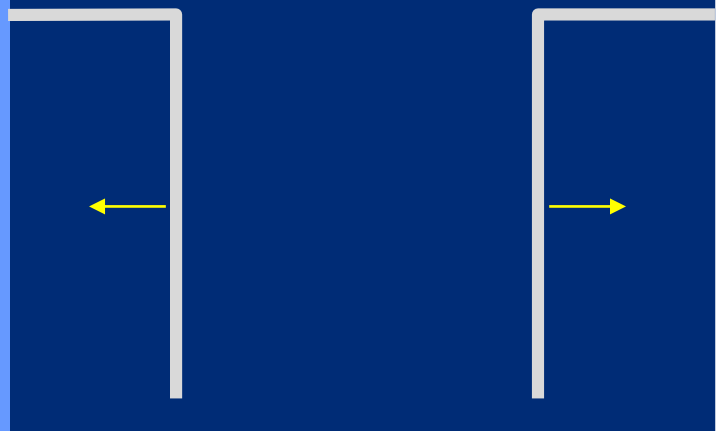
2) HC advance through crest

3) HC advance into reservoir

4) Breach widening



X-SECTION



PROFILE

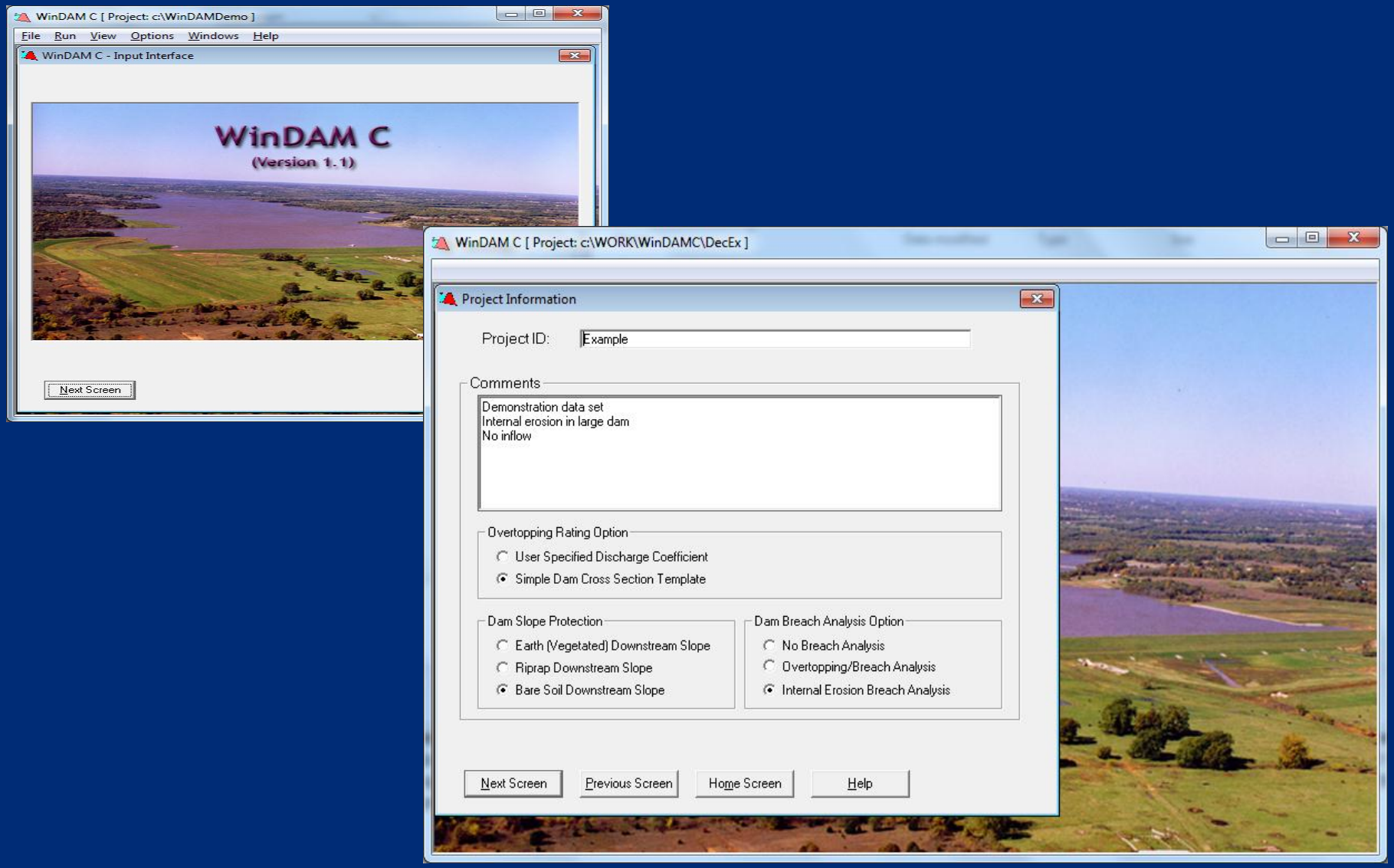

Tube
Lid
Deflection
Plate
Sample
Tank

Internal Erosion/WinDAM C Development

Internal Erosion/WinDAM C Development

Internal Erosion Breach

- **Homogeneous embankment dam**
  - Initiated by horizontal flow path through embankment
  - Headcut may form at exit to slope
  - Conduit expansion and headcut advance may take place simultaneously
  - Conduit may flow full or have free surface over a portion or entire length
    - Conduit expansion based on average boundary stress


WinDAM C [Project: c:\WinDAMDemo]
File Run View Options Windows Help
WinDAM C - Input Interface
WinDAM C
(Version 1.1)
Next Screen
WinDAM C [Project: c:\WORK\WinDAMC\DecEx]
Project Information
Project ID: Example
Comments
Demonstration data set
Internal erosion in large dam
No inflow
Overtopping Rating Option
User Specified Discharge Coefficient
Simple Dam Cross Section Template
Dam Slope Protection
Earth (Vegetated) Downstream Slope
Riprap Downstream Slope
Bare Soil Downstream Slope
Dam Breach Analysis Option
No Breach Analysis
Overtopping/Breach Analysis
Internal Erosion Breach Analysis
Next Screen
Previous Screen
Home Screen
Help

WinDAM Reservoir Routing

- Inflow hydrograph as input from “other software”
- Outflow hydrograph exported to “other software”
- Level surface routing with stepwise steady state computations
- Principal and up to three ungated auxiliary spillways
  - Earth auxiliary spillway integrity analysis may be performed
- Dam overtopping
  - Dam crest elevation varied along length of dam
  - Vegetated or nonvegetated crest conditions
- Breach outflow with progressive breach erosion
- Tailwater influences on discharge included

WinDAM Breach Prediction

- Simplified dominant process erosion model(s)
- Attempt to simulate behavior observed in large scale laboratory tests
- Homogeneous earthen embankment with simple cross section
- Breach initiated by overtopping or horizontal flow path through embankment

HERU Project Plan – 2017-2022

Project Title: Development of Engineering Tools for the Design and Rehabilitation of Safe, Efficient Embankment Protection Alternatives, Hydraulic Structures, and Channels.

- **Objective 1:** Improve the WinDAM model to predict the erosion of complex embankment geometries and composite materials, and the allowable overtopping flows for alternative materials, including articulated concrete blocks or riprap integrated with vegetation

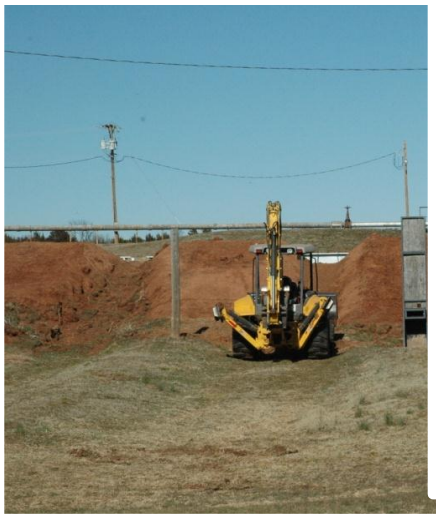
HERU Project Plan – 2017-2022

Subobjective 1A: Quantify the impact of complex vegetated embankment geometries on erosion process during overtopping including: convergence zones at the intersection of the earthen embankment and valley walls and embankment berms and toes. (Vacant SY and Hunt)

- **Subobjective 1B:** Quantify the impact of changes in soil materials (specifically zoned vs. homogenous) on erosion processes and rates of earthen embankment erosion and breach. (Vacant SY and Hunt)

United States Department of Agriculture

WinDAM D Development



Impact of the Research and Application

- Prioritization of Rehabilitation
- Improvement of Flood Warning Systems
- Development of Emergency Action Plans
- Zoning Regulations


$2 BILLION
IN ANNUAL
BENEFITS

Summary

- WinDAM is an implementation of research conducted by the USDA Agricultural Research Service.
- The ongoing research is driven by the needs of the USDA Natural Resources Conservation Service and others in the dam safety community.
- WinDAM is being developed through the joint efforts of the ARS, NRCS, and KSU.
- WinDAM C is the current CCE approved version of the program.

Summary (Continued)

- WinDAM C Breach Model
  - SIMPLIFIED dominant process model
    - Attempts to simulate observed breach processes
  - Applicable to homogeneous embankments
  - Overtopping and internal erosion components
  - Testing for code verification is ongoing.
  - Additional validation testing is needed.
  - Research in the area is ongoing to refine the model(s).

Questions…….