Flood-Fighting Structures Demonstration and Evaluation Program
Interim Report

Introduction

Executive Notes:

- Sandbags are the most-used flood-fighting product.
- Sandbags are labor intensive and time consuming to construct.
- The USACE is the Nation's emergency flood-fighting leader, and has encouraged development of innovative products and approaches.
- The ERDC is leading a Headquarters (Office of Homeland Security) and field PDT to scientifically evaluate performance of new products and to transfer that information to the Nation's flood-fighting communities.

Within the United States, sandbags have traditionally been the product of choice for temporary, barrier type flood fighting structures. Sandbags are readily available and familiar to the general public. However, sandbag structures are labor-intensive and time consuming to construct. The U.S. Army Corps of Engineers (USACE) has long been aware of the need to develop more expedient, cost effective, temporary flood fighting technologies. Therefore, the USACE continues to encourage the development of innovative products to decrease long-term costs and increase the effectiveness of flood fighting.

USACE Districts are frequently contacted by vendors who market alternative flood-fighting products that they advertise as more efficient than sandbags while being cost competitive. As the nation's leader in flood fighting, the USACE is providing a scientific framework to enable evaluations of these various flood-fighting products. Initial research, testing, and evaluation of some flood-fighting technologies have been conducted at the U.S. Army Research and Development Center (ERDC). This effort provides performance, operational, and economic information on the tested flood fight technologies that will assist the flood fighting community in the selection of appropriate flood fighting products.

Background

Executive Notes:

- Congress has recognized the need for expedient, temporary, barrier type flood fighting technologies.
- Congress has directed the Corps of Engineers to devise real world testing procedures for Rapid Deployment Flood Wall (RDFW) and other promising alternative flood fighting technologies.
- The ERDC developed a comprehensive laboratory and field testing program for the scientific testing of RDFW and two other flood fighting technologies.

Project Authority: Congress has recognized the need for expedient, temporary barrier type flood fighting technologies. Language in House Report 108-357, 2004 Energy and Water Development Conference Report included

"The Nation deserves the best, most reliable, most economical tools which technology can provide for the protection of its citizenry and their property when confronted with natural disaster. The conferees are aware of the preliminary testing of the Rapid Deployment Flood Wall at the Engineering Research and Development Center in Vicksburg, Mississippi. This technology has shown promise in the effort to fight floods. Its proponent's claim, and preliminary tests tend to confirm, that it can be cost-effective, quick to deploy, and superior to traditional sandbags in protecting property from flood damages totaling millions in dollars each year. The conferees therefore direct the Corps of Engineers, within funds available in the Flood Control and Coastal Emergencies account, to act immediately to devise real world testing procedures for this and other promising alternative flood fighting technologies."

In response to this Congressional directive, ERDC developed a comprehensive laboratory and field-testing program for the scientific testing of RDFW and two other alternative flood-fighting technologies. A standard sandbag structure was also tested in both the laboratory and the field to provide a baseline by which the other products could be evaluated.

Product Selection

Executive Notes:

- Three commercially available flood fighting products plus sandbags were lab tested at ERDC and field tested at the Vicksburg, MS Harbor.
- RDFW was tested due to Congressional directive.
- Sandbags were tested since they are the standard temporary, barrier type flood fighting product used in the United States.
- The two "other promising alternative flood fighting technologies" (Portadam and Hesco Bastion concertainers) were selected for testing through a competitive process based on technical merit.

Three commercially available flood fighting products plus sandbags were tested in the laboratory and at the Vicksburg, Mississippi Harbor field site. Rapid Deployment Flood Wall (RDFW) was tested due to the Congressional directive. RDFW is granular filled, plastic grid units that connect together with both horizontal and vertical tabs to form a continuous structure. Each RDFW unit is 4 feet long by 4 feet wide by 8 inches high. Sandbags were tested since they are the standard temporary barrier type flood-fighting product. The two "other promising alternative technologies," were selected through a competitive process based on technical merit. An advertisement was placed on the FedBizOpps webpage requesting technical proposals for temporary, barrier type flood fighting

products. As a result of the advertisement, 9 proposals were received. A 5 member team, consisting of hydraulic, geotechnical, and emergency management disciplines, evaluated the proposals against a set of technical criteria developed prior to issuing the advertisement. Final selection of the alternative technologies was made by the evaluation team and then approved by the study Project Delivery Team (PDT). Based on the technical evaluation, Portadam and Hesco Bastion Concertainers were selected as the products that provided the best overall combination of technical soundness, operational functionality, and economic feasibility. Portadam consists of an impermeable membrane liner that is supported by a steel frame. Hesco Bastion concertainers are granular filled, membrane lined wire baskets that are pinned together to form a continuous structure.

Laboratory Testing - Plan

Executive Notes:

- Laboratory testing was conducted in a modified wave research basin at ERDC.
- Each of the four structures was tested consecutively under identical conditions.
- Stringent construction, testing, and removal protocols were developed and followed.
- Protocol included the evaluation of each structure for both performance and operational parameters.

Laboratory testing of Portadam, Hesco Bastion concertainer, RDFW, and sandbag structures was conducted in a wave research basin at ERDC. The products were tested in a controlled laboratory setting but under conditions that emulate real world flood fighting. The structures were tested consecutively under identical conditions. Stringent construction, testing, and removal protocols were developed for the laboratory. The protocol for the laboratory testing included both performance parameters (hydrostatic testing, hydrodynamic testing with waves and overtopping, and structural debris impact testing with a floating log) and laboratory setting operational parameters (time, manpower, and equipment to construct and disassemble, suitability for construction and disassembly by unskilled labor, fill requirements, ability to construct around corners, disposal of fill material, damage, repair, and reusability).

The laboratory testing included the construction of skewed u-shaped structures. Each structure had an approximate length of 85 feet. Due to the restrictive height of the research basin walls, the height of each structure was limited to approximately 3 feet. Laboratory testing of the structures was initiated in March 2004 and completed during August 2004. The sandbag structure was tested first in the laboratory followed in order by the Hesco Bastion concertainer structure, the RDFW structure, and finally, the Portadam structure.

Laboratory Testing – Results

Executive Notes:

- Sandbag structure construction time was significantly longer than that for the other three structures.
- RDFW removal time was significantly longer than that for the other three structures.
- Hesco Bastion concertainer structure seepage rates were significantly higher than those for the other three structures.
- Each structure sustained some damage during testing. The degree of the damage varied from minor to structure failure.

The following three tables present the pertinent laboratory testing results. The results show that as expected, the sandbag structure took much longer (205.1 man-hours) to construct than the other 3 structures. The RDFW structure was the most difficult to remove taking more than 3 times longer (42 man-hours) than any of the other structures. The lab results also show that the RDFW structure had the lowest seepage rates while the Hesco Bastion structure had significantly higher seepage rates than the other 3 three structures. Each structure sustained varying degrees of damage during testing. This damage is summarized in Table L-3.

Table L-1. Effort Required to Construct, Repair, and Remove The Flood-Fighting Structures

Structure	Construction (man-hrs)	Repairs (man-hrs)	Removal (man-hrs)
Sandbags	205.1	6.0	9.0
Hesco Bastion	20.8	1.8	13.4
RDFW	32.8	4.6	42.0
Portadam	24.4	2.0	4.4

Table L-2. Seepage Rates During Static Head Tests

Structure	1 ft Head (gpm / ft)	2 ft Head (gpm / ft)	95% Head (gpm / ft)	Average (gpm / ft)
Sandbags	0.05	0.23	0.54	0.27
Hesco Bastion	0.39	0.94	1.81	1.05
RDFW	0.02	0.08	0.10	0.07
Portadam	0.10	0.14	0.14	0.13

gpm / ft = gallons per minute per linear foot of structure

Table L-3. Structure Damage During Laboratory Testing	
Structure	**Observed Damage**
Sandbags	Repeatedly Damaged By Waves Failed During Overtopping
Hesco Bastion	Minor Sand Settling and Washout Some Bending of Wire During Debris Impact
RDFW	Minor Sand Settling Significant Washout Along Edges and Toe Toe Damaged During Large Waves or Overtopping 10% of Structure Broken
Portadam	Impermeable Liner Torn During Debris Impact

Field Testing - Plan

Executive Notes:

- Field testing was conducted at the Vicksburg, MS Harbor on a site representative of real world flood fight conditions.
- Unlike the laboratory testing, the four structures were tested at the field site concurrently.
- The four structures were constructed, tested, and removed in accordance with developed protocols.
- The field testing allowed the assessment of operational concerns such as ROW requirements, adaptability to varying terrain, ease of construction and removal (time, manpower, equipment) seepage, fill requirements, repair, reusability, and ability to raise.

During May 2004, Portadam, Hesco Bastion concertainer, RDFW, and sandbag structures were constructed at a field site at the Vicksburg, MS Harbor. Each structure was generally u-shaped with an approximately 100-foot riverward face. The structures were originally constructed high enough to hold back 3 feet of water. Each structure was then required to be raised 1-foot to demonstrate that the structures could be raised if used in a situation where flood waters continue to rise. The Vicksburg Harbor site was selected primarily because conditions at that site were expected to be representative of real world flood fight conditions. Also, the site is located on Government property thus requiring no rights of entry or easements and had provided security. The site is also adjacent to the Vicksburg District Mat Sinking Unit that had a large, available labor force and heavy construction equipment. The Vicksburg Harbor site is within the backwater area of the Mississippi River which insures relatively reliable, predictable water levels. Soil conditions indicated that the Vicksburg Harbor site contained suitable substrate which was consistent over a sufficiently large area to construct the four test structures. The structures were constructed on

individually prepared sites. The specific site on which each structure was constructed was determined by a random drawing.

By the first week of June 2004, water levels were sufficient to begin testing. Unlike the laboratory testing, the four structures were tested at the field site concurrently. As the water levels rose, seepage was determined for each structure by collecting the seepage water in a concrete tank on the protected side of each structure. The seepage rates were calculated by determining the change in volume in the collection tank over time. By July 2004, the water levels had receded enough that the structures were removed. The structures in the field were constructed, tested, and removed in accordance with established protocols.

The field-testing allowed a complete assessment of operational concerns such as construction right-a-way requirements, adaptability to varying terrain, ease of construction and removal (time, manpower, equipment) seepage, fill requirements, repair, reusability, and ability to raise.

Field Testing - Results

Executive Notes:

- Sandbag structure construction time was significantly longer than that for the other three structures.
- RDFW removal time was significantly longer than that for the other three structures.
- Hesco Bastion concertainer structure seepage rates were significantly higher than those for the other three structures.
- None of the four structures sustained significant damage during the field testing. All three of the vendor products had a high rate of reusability.

The following three tables present the pertinent field-testing results. The results show as expected, that the sandbag structure was very time consuming to construct, requiring much longer than the other 3 structures. As occurred in the lab testing, the RDFW structure took significantly longer to remove and the Hesco Bastion structure had significantly higher seepage rates. All three of the vendor products performed well during the field-testing with all three having high rates of reusability.

Table F-1. Effort Required To Construct, Raise One Foot, and Remove The Flood Fighting Structures

Structure	Construction (man-hours)	Raise 1-ft (man-hours)	Removal (man-hours)
Sandbags	419.8	33.3	3.5
Hesco Bastion	34.7	22.8	36.3
RDFW	39.4	9.0	113.4
Portadam	25.6	0.6	12.6

Table F-2. Seepage Rates				
Wetted Area of Structure square feet)	**Seepage Rate (Gallons / Hour)**			
	Sandbags	**Hesco Bastion**	**RDFW**	**Portadam**
100	0	300	50	200
200	0	2300	200	300
300	50	3900	700	500
400	300	6000	900	550
500	800	---	1500	600
600	3200	---	---	600

Table F-3. Structure Damage During Field Testing	
Structure	**Observed Damage**
Sandbags	Began to Deteriorate (not to specs) All Disposed
Hesco Bastion	Bent Some Panels and Coils During Removal Over 95% Reusable
RDFW	Broke Some Pieces During Testing and Removal 95% of Pieces Reusable
Portadam	None – 100% Reusable

Product Summaries.

The lab and field-testing conducted during 2004 revealed several product strengths and weaknesses. These are presented in Table S-1.

Table S-1. Observed Product Strengths and Weaknesses		
Product	**Strengths**	**Weaknesses**
Sandbags	1. Low Cost – generally constructed by volunteer labor 2. Conforms well to varying terrain 3. Low seepage rates 4. Can be raised if needed	1. Very labor intensive and time consuming to construct 2. Not reusable
Hesco Bastion	1. Ease of Construction and Removal (time & manpower) 2. Low Cost 3. High degree of reusability 4. Can be raised if needed	1. Significant ROW required due to granular fill 2. High seepage rates

Table S-1 (Continued). Observed Product Strengths and Weaknesses		
Product	**Strengths**	**Weaknesses**
RDFW	1. Ease of Construction (time & manpower) 2. Low seepage rates 3. High degree of reusability 4. Can be raised if needed 5. Most height flexibility due to eight inch high units	1. Significant ROW required due to granular fill 2. High cost 3. Difficult to remove
Portadam	1. Ease of Construction and Removal (time, manpower, equipment) 2. Low seepage rates 3. No required fill 4. High degree of reusability 5. Limited ROW required	1. Punctured during laboratory debris impact test 2. Can't be raised in a typical application 3. Not applicable for high wind use

Pilot Testing

Executive Notes:

- A pilot testing plan has been developed.
- Vendor products were purchased during FY05 and distributed to 3 host Corps Districts.
- Vendor products are being tested at pre-selected locations during FY 05 and FY 06. Remaining product quantities will be made available for use during real world flood events by all Districts located within each host Division's geographic region.

During FY 05, 5000 linear feet (4 feet high) of each of the 3 vendors' temporary, barrier style flood fighting products (Portadam, Hesco Bastion, and Rapid Deployment Floodwall) were purchased. These products will be used for pilot testing at selected locations. This testing will provide an opportunity to evaluate the products' performance under conditions different from those at the Vicksburg field tests. Host Districts for the pilot testing were selected and the products were distributed to those Districts. The host Districts include Omaha, Baltimore / Philadelphia, and Sacramento. The products not used for pilot testing are being made available to all Corps Districts within each geographic region for use in real world flood events if those Districts and local sponsors choose to use the products in place of sandbags or other flood fight techniques.

Pilot testing sites were selected on the Missouri River in the Omaha District and on the Susquehanna River in the Baltimore District. The Omaha District is excavating low water benches into the banks of the Missouri River to create shallow water habitat. During July 2005, 400-foot long, u-shaped structures were constructed near Brownville, Nebraska on one of these low water benches. The structures are awaiting high water for testing. During November 2005, pilot testing was conducted on the Susquehanna River in the Baltimore District. This pilot test was a joint effort between the Baltimore and Philadelphia Districts. For this test, 500-foot long u-shaped structures were constructed. The Susquehanna River rose high enough for testing on 30 November. ERDC researchers are currently evaluating the test data.

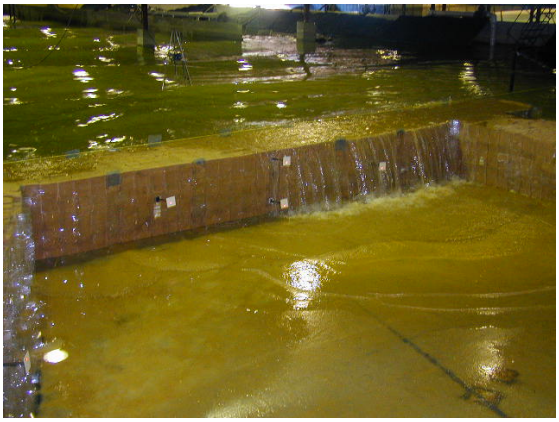
During May 2005, southwest Utah experienced snowmelt flooding. In response, 1000 feet of the Hesco Bastion product were shipped to Cedar City and 1000 feet of the RDFW product were shipped to Iron County. Cedar City chose not to deploy any of the Hesco Bastion product. Iron County constructed a 465-foot long, 16-inch high structure along a county road. This structure was constructed to prevent the road from overtopping and flooding a subdivision. During September 2005, 1680 feet of the Hesco Bastion product and 855 feet of the RDFW product were shipped to New Orleans in advance of Hurricane Rita. Approximately 1,200 feet of the Hesco Bastion product were deployed at 3 locations as part of temporary repairs to levees/floodwalls that were damaged during Hurricane Katrina. The temporary repairs provided a level of protection for the remainder of the 2005 hurricane season. Permanent repairs are now under construction.

Laboratory Testing Photos

Sandbags – Static Loading Test

Sandbags - Overtopping

RDFW – Under Construction



RDFW – Wave Test

Hesco Bastion – Construction Complete

Hesco Bastion – Overtopping Test

Portadam – Construction Complete

Portadam – Overtopping Test

Field Testing Photos

Sandbags – Construction

Sandbags – Construction Complete

Sandbags – Prior To Overtopping

Sandbags – Removal

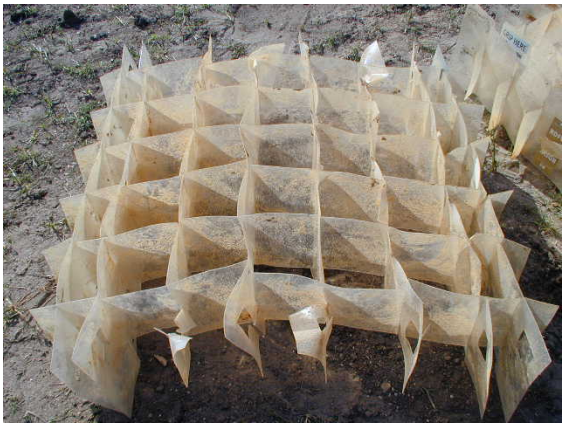
RDFW – Construction

RDFW – Construction

RDFW – Prior To Overtopping

RDFW – Overtopping

RDFW – Removal



RDFW – Removed 4’x4’x8” Unit

Hesco Bastion – Construction

Hesco Bastion – Construction

Hesco Bastion – Testing

Hesco Bastion – Seepage

Hesco Bastion – Removal

Hesco Bastion - Removal

Portadam – Construction

Portadam – Construction

Portadam – Prior To Overtopping

Portadam – Overtopping

Portadam – Disassembly

Portadam – Removal of Liner