ENCLOSURE 1

U.S. Army Corps of Engineers, "Flood-Fighting Structures Demonstration and Evaluation Program: Laboratory and Field Testing in Vicksburg, Mississippi," July 2007

ERDC TR-07-3

US Army Corps of Engineers ®

General Investigation Research and Development Program

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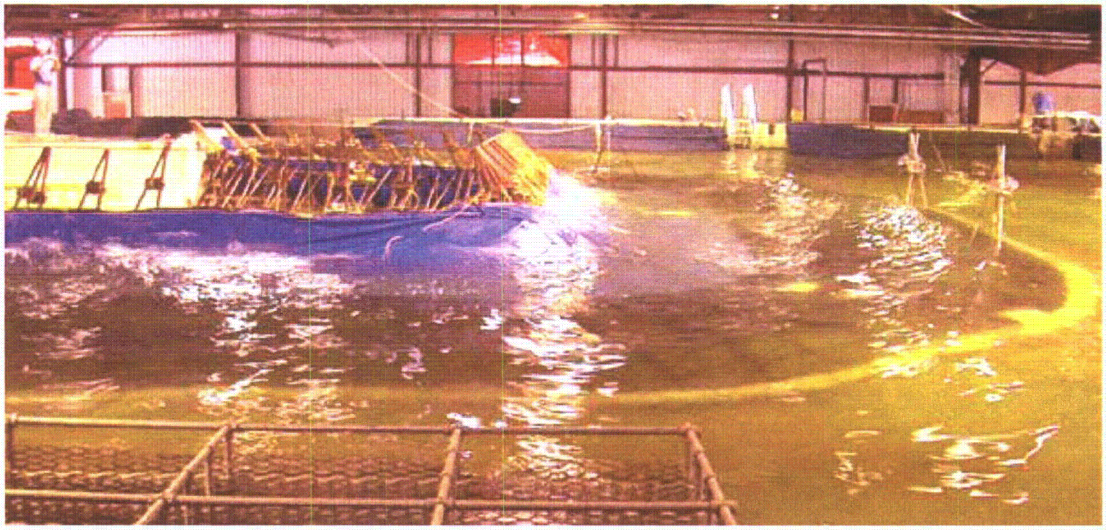
July 2007



Engineer Research and Development Center

General Investigation Research and Development Program

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Flood-Fighting Structures Demonstration and Evaluation Program: Laboratory and Field Testing in Vicksburg, Mississippi

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Final report

Prepared for U. S. Army Corps of Engineers
Washington, DC 20314-1000

ABSTRACT: Within the United States, sandbags have traditionally been the product of choice for temporary, barrier type flood-fighting structures. However, sandbag structures are labor intensive and time consuming to construct. Therefore, a need exists for more expedient, cost effective, temporary barrier type flood-fighting technologies. In 2004, Congress directed the U.S. Army Corps of Engineers to devise real-world testing procedures for Rapid Deployment Flood Wall (RDFW) and other promising alternative flood-fighting technologies. In response to that directive, the U.S. Army Engineer Research and Development Center (ERDC) developed a comprehensive laboratory and field-testing program for RDFW and two other flood-fighting products. Those two products, Portadam and Hesco Bastion, were selected on technical merit from proposals submitted by companies who manufacture temporary, barrier type flood-fight products. A standard sandbag structure was also tested in both the laboratory and field to provide a baseline by which the other products could be evaluated.

During 2004, laboratory and field testing was conducted in Vicksburg, MS, under stringent testing protocols. The lab testing was conducted in a modified wave basin at ERDC. The field testing was conducted at the Vicksburg Harbor. The lab and field protocols included both performance parameters and operational parameters. These tests will provide the flood-fighting community results that will assist in the selection of the product that best fits their temporary, barrier type flood-fighting needs.

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Conversion Factors, Non-SI to SI Units of Measurement

Multiply	By	To Obtain
feet	0.3048	meters
inches	0.0254	meters
ounces (mass)	0.02834952	kilograms
pounds (mass)	0.45359237	kilograms

Preface

This report describes research conducted by the U. S. Army Engineer Research and Development Center (ERDC) through the General Investigation Research and Development (GI R&D) Program for prototype testing of temporary barrier-type flood-fighting structures. The project was funded by the U.S. Army Corps of Engineers (USACE) Flood Control and Coastal Emergency (FCCE) Program and leveraged with the GI R&D technical programs.

In the 2004 Energy and Water Development Bill, Congress directed USACE to develop a comprehensive laboratory and field testing program for the scientific assessment of Rapid Deployment Flood Wall® (RDFW) and "other promising alternative flood-fighting technologies." This report describes the congressionally mandated testing and evaluation program for three commercial flood-fighting products and sandbags.

Laboratory and field testing were conducted from March to August 2004. The laboratory testing was completed in a wave research basin at ERDC, Vicksburg, MS, and included construction, testing, and removal protocols. Field testing was accomplished at a site north of Vicksburg, on the southern bank of the turning basin of the Vicksburg Harbor.

A Project Delivery Team (PDT) was established to serve for both laboratory and field testing and included a Technical Director, Program Manager, co-Principal Investigators (PI's), and engineering support staff. In addition, the PDT included advisors from the USACE Districts including the GI R&D Program Product Selection Committee, Emergency Management personnel assigned by Headquarters, USACE (HQUSACE), and local sponsor representatives as recommended by District PDT participants. A complete listing of the Team and their responsibilities can be found in Appendix B within the Project Management Plan.

The ERDC representation on the project development team (PDT) combined the wide range of expertise of the Coastal and Hydraulics Laboratory (CHL) and the Geotechnical and Structures Laboratory (GSL). Dr. Donald Ward (CHL) and Dr. Johannes Wibowo (GSL) led the laboratory testing. Fred Pinkard (CHL) and George Sills (GSL) led the field testing. Other ERDC team members included Perry (Pat) Taylor, Tina Holmes, Landris (Tommy) Lee, Nalini Torres, Eric Smith, Terry Jobe, Lester Flowers, Julie Kelley, Cheri Loden, and Dr. Lillian Wakeley from GSL; Thad Pratt, Thomas Murphy, Calvin Buie, Terry Waller, Christopher Callegan, Mike Kirklin, and Charlie Little from CHL; David Daily from ITL; and Jackie Brown, Kel Shurden, Eddie Stewart, Bill Waldrop, Carl Warner, Paul Williams, and Howard Zeigler from the U.S. Army Engineer District, Vicksburg.

The following authors listed alphabetically wrote sections of the report; Ms. Holmes, Ms. Kelley; Messrs Lee, Pinkard, Pratt, Sills, Smith, and Taylor; Ms. Torres; and

Drs. Wakeley, Ward, and Wibowo. The overall report was assembled and prepared by Messrs. Sills, Taylor, and Pinkard, with assistance from Ms. Kelley. Dr. Wakeley was principal technical reviewer and report coordinator. J. Holley Messing, Coastal Engineering Branch, CHL, formatted this report. Dr. Jack Davis, ERDC Technical Director for Flood and Coastal Storm Damage Reduction, provided a detailed review of the draft report.

Joan Pope, Office Chief of Engineers Program Director for Civil Works and formerly ERDC Technical Director for Flood and Coastal Storm Damage Reduction, provided overall guidance for the project, beginning with the congressional mandate and continuing through PDT selection, planning, technical accomplishment, and reporting. The PDT is grateful to Ms. Pope for providing vision and continuity throughout this many-faceted project.

From CHL, general supervision for this project was provided by James R. Leech, Chief, River Engineering Branch; Dennis Markle, former Chief, Harbors, Entrances, and Structures Branch; Dr. Rose Kress, Chief, Navigation Division; Dr. William D. Martin, Deputy Director, CHL; and Thomas W. Richardson, Director, CHL. From GSL, Dr. Joseph Koester, Chief, Geotechnical and Earthquake Engineering Branch; Dr. Lillian Wakeley, Chief, Engineering Geology and Geophysics Branch; Dr. Robert L. Hall, Chief, Geosciences and Structures Division; and Dr. David Pittman, Director, GSL, provided general supervision.

Dr. James R. Houston was Director of ERDC. COL Richard B. Jenkins was Commander and Executive Director.

Executive Summary

Introduction

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.

In the 2004 Energy and Water Development bill, Congress recognized the need for expedient, temporary barrier type flood-fighting technology. The U. S. Army Engineer Research and Development Center (ERDC) was directed to develop real-world testing procedures for Rapid Deployment Flood Wall (RDFW) and other promising alternative flood-fighting technologies. In response to that directive, ERDC developed a comprehensive laboratory and field testing program for the scientific evaluation of the products.

Three commercially available flood-fighting products plus sandbags were tested in the laboratory and at the Vicksburg Harbor field site in Vicksburg, MS. 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 ft long by 4 ft wide by 8 in. high. Sandbags were tested since they are the standard temporary barrier type flood-fighting product used by the Corps of Engineers. The two "other promising alternative technologies" were selected through a competitive process based on technical merit. An advertisement was placed on the FedBizOpps Web page requesting technical proposals for temporary, barrier type flood-fighting products. As a result of the advertisement, nine proposals were received. A five-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

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. The length of the structures varied from approximately 69 ft to about 81 ft. Due to the restrictive height of the research basin walls, the height of each structure was limited to approximately 3 ft. 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

Tables ES-1 through ES-3 present the pertinent laboratory testing results. The results show that the sandbag structure took much longer (205.1 man-hours) to construct than the other three structures. The RDFW structure was the most difficult to remove taking more than three times longer (42 man-hours) than any of the other structures. The laboratory results also show that the RDFW structure had the lowest seepage rates while the Hesco Bastion structure had much higher seepage rates than the other three structures. Table ES-2 includes seepage rates for 1 ft, 2 ft, and 95 percent head. The 1-ft head means that a 1-ft-deep static pool was against the structure during testing. The 2-ft head included a 2-ft-deep static pool against the structure while the 95 percent head included a static pool depth that was equal to 95 percent of the structure height. Each structure sustained varying degrees of damage during testing. This damage is summarized in Table ES-3.

Table ES-1
Effort Required to Construct, Repair, and Remove the Flood-Fighting Structures

Structure	Construction (man-hours)	Repairs (man-hours)	Removal (man-hours)
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 ES-2 Seepage Rates During Static Head Tests				
Structure	**1-ft Head (gpm/ft)**	**2-ft Head (gpm/ft)**	**95 Percent 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
Note: gpm/ft = gallons per minute per linear foot of structure.				

Table ES-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 percent of structure broken
Portadam	Impermeable liner torn during debris impact

Field Testing

During May 2004, Portadam, Hesco Bastion Concertainer, RDFW, and sandbag structures were constructed at a field site at the Vicksburg Harbor. Each structure was generally u-shaped with an approximately 100-ft riverward face. The structures were originally constructed high enough to hold back 3 ft of water. Each structure was then required to be raised high enough to hold back 4 ft of water to demonstrate that the structures could be raised if used in a situation where floodwaters continue to rise.

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 that was consistent over a sufficiently large area. The field test site is located on Government property, requiring no rights of entry or easements and security was already provided. The site is also adjacent to the U. S. Army Engineer District, Vicksburg Mat Sinking Unit where a large, available labor force and heavy construction equipment were available 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. Testing continued until the structures overtopped. 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 of 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

Tables ES-4 through ES-6 present the pertinent field testing results. The results show that the sandbag structure was time consuming to construct, requiring much longer time than the other three structures. Table ES-4 includes the time to construct each structure to its initial height to hold back 3 ft of water. The effort to raise included the time to increase the height of each structure to hold back 4 ft of water. As occurred in the lab testing, the RDFW structure took much longer to remove and the Hesco Bastion structure had much higher seepage rates. The seepage rates in Table ES-5 are based on a wetted area of the structure. Wetted area was used since the ground elevations at the base of the structures varied. Therefore, for a given river stage, each structure would have a different height of water against it. All three of the vendor products performed well during the field testing with all three having high rates of reusability (Table ES-6).

Table ES-4
Effort Required to Construct, Raise, and Remove the Flood-Fighting Structures

Structure	Construction (man-hours)	Raise (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 ES-5
Seepage Rates

Wetted Area of Structure (sq ft)	Seepage Rate (gal/hr)			
	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 ES-6 Structure Damage / Reusability During Field Testing	
Structure	**Observed Damage**
Sandbags	Began to deteriorate (bags not to specs) All disposed
Hesco Bastion	Bent some panels and coils during removal Over 95 percent reusable
RDFW	Broke some pieces during testing and removal Over 90 percent of pieces reusable
Portadam	None – 100 percent reusable

Product Costs

Even if a product performs well, the flood-fighting community is not likely to use the product unless it is cost-effective. In order to make a fair comparison of costs, each product vendor was asked to provide the cost of constructing and removing 1,000 linear ft of their product, 3 ft high in Vicksburg. These costs include purchase of the product, fill material, labor, and equipment rental. The furnished costs show that the cost of the products, especially for the RDFW and Portadam products far outweigh the combined cost of the fill material, labor, and equipment rental. Table ES-7 provides a summary of the vendor furnished product cost. During January 2005, the Corps purchased approximately 5,000 lft, 4 ft high of each of the products. These products were purchased for pilot testing and to be stored and made available during real-world floods to any Corps District that chooses to use them. Table ES-8 provides a summary of the cost of those products.

Table ES-7
Summary of Vendor Furnished Products Cost (March 2004)

Product	Product Description	Product Cost	Product Cost Per Linear Foot
Hesco Bastion	67 3'x3'x15' units at $394/unit (1005 feet)	$26,398	$26.27
RDFW	1,450 4'x4'x8" units at $95/unit (1015 feet)	$137,750	$135.71
Portadam	3' high frames, liner, hardware	$71,300	$71.30

Table ES-8
Summary of USACE Purchased Products Cost (January 2005)

Product	Product Description	Product Cost	Product Cost Per Linear Foot
Hesco Bastion	336 4'x3'x15' units at $488/unit (5,040 ft)	$163,968	$32.53
RDFW	8,700 4'x4'x8" units at $95/unit (5,075 ft)	$826,500	$162.86
Portadam	4' high frames, liner, hardware	$473,595	$94.72

Product Summaries

The lab and field testing conducted during 2004 revealed several product strengths and weaknesses. These are presented in Table ES-9.

Table ES-9
Observed Product Strengths and Weaknesses

Product	Strengths	Weaknesses
Sandbags	1. Low product cost 2. Conforms well to varying terrain 3. Low seepage rates 4. Can be raised if needed	1. Labor intensive and time consuming to construct 2. Not reusable
Hesco Bastion	1. Ease of construction / removal (time and manpower) 2. Low product cost 3. Reusable 4. Can be raised if needed	1. Significant right of way required due to granular fill placed with machinery perpendicular to the structure 2. High seepage rates
RDFW	1. Ease of construction (time and manpower) 2. Low seepage rates 3. Reusable 4. Can be raised if needed 5. Height flexibility (8-in units)	1. Significant right of way required due to granular fill placed with machinery perpendicular to the structure 2. High product cost 3. Labor intensive and time consuming to remove
Portadam	1. Ease of construction / removal (time, manpower, and equipment) 2. Low seepage rates 3. No required fill 4. Reusable 5. Limited total ROW required (footprint + construction work area)	1. Punctured during laboratory debris impact test 2. Cannot be raised in a typical application 3. Not applicable for high wind use without anchoring

The laboratory and field testing pertinent information has been placed on a publicly accessible Web page to assist locals in the selection of products that best meet their temporary, barrier style flood-fighting needs. The Web site address is http://chl.erdc.usace.army.mil/ffs.

Acronyms and Abbreviations

A/D	Analog to Digital
AR-Number	Army Regulation Number
ASCII	American Standard Code for Information Interchange
AVI	Audio Video Interleave
CHL	Coastal and Hydraulics Laboratory
cu yd	cubic yards
deg	degrees
diam	diameter
DPW	Directorate of Public Works
DVR	Digital Video Recording
EM	Emergency Management
EM-Number	Engineering Manual Number
ERDC	U. S. Army Engineer Research and Development Center
ERDC-WES	U. S. Army Engineer Research and Development Center – Waterways Experiment Station
FCCE	Flood Control and Coastal Emergencies
FedBizOpps	Federal Business Opportunities
FHSS	Frequency-Hopping Spread System
ft	feet
GI R&D	General Investigation Research and Development
gph	gallons per hour
gpm	gallons per minute
gpm/lft	gallons per minute per linear foot
GSL	Geotechnical and Structural Laboratory
GUI	Graphic User Interface

HQ USACE	Headquarters, U.S. Army Corps of Engineers
Hr	hours
Hz	cycles
IEEE	Institute of Electrical and Electronic Engineers
in.	inches
JPEG	Joint Photographic Experts Group
LAN	Local Area Network
lft	Linear feet
lin.	Linear inches
MB	Mega-Bits
MC	Micro Controller
MHz	Mega-Cycles
min	minutes
mpbs	Megabits per second
mph	miles per hour
mW	milli-Watt
NGVD	National Geodetic Vertical Datum
PDT	Project Delivery Team
PI	Principal Investigator
PI's	Principal Investigators
PMP	Project Management Plan
lb/ft^2	pounds per square foot
PVC	Polyvinyl Chloride
RDFW	Rapid Deployment Flood Wall
rpm	revolutions per minute
RS232	Recommended Standard Number 232
sec	seconds
SP (Sand)	Uniformly Graded
STP	Standard Testing Protocol
Towns	Technologies and Innovations for Urban Watershed Networks
USACE	U.S. Army Corps of Engineers
V	volts

VDC	Volts Direct Current
WDAT	Wireless Data Acquisition Transmitter

1 Introduction

Introduction

Sandbag barriers traditionally have been the method of choice to raise the height of levees and to protect infrastructure from rising floodwaters. Sandbag structures are labor intensive and time consuming to construct. However, sandbags are readily available and are familiar, and therefore acceptable, to the general public. The U.S. Army Corps of Engineers (USACE) has used sandbags routinely in flood fights for decades, during which time the USACE has been aware of the need to find more rapid and still cost-effective methods of constructing temporary flood barriers.

Early in 2004, Congress tasked the U. S. Army Engineer Research and Development Center (ERDC) to "devise real-world testing procedures for … promising alternative flood-fighting technologies…." This report describes the selection and testing of a temporary, barrier style flood-fighting products in laboratory and field conditions and at prototype scale. The products tested included standard sandbags as well as three commercially available flood-fighting products.

Background

Project authority

ERDC conducted research and developed a laboratory procedure for the prototype testing of temporary barrier-type flood-fighting structures intended to increase levels of protection during floods. The Rapid Deployment Flood Wall (RDFW) is one commercial product example of this type of structure. Per direction from Congress in the Energy and Water Development Bill for 2004:

> *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 floodfighting technologies, and to provide a status report to the Committees on Appropriations within 180 days of enactment of this legislation.
(See Appendix A)

To address this congressional directive, ERDC has tested the RDFW and two other flood-fighting technologies using previously developed laboratory test protocol to compare the effectiveness of each product under carefully controlled laboratory test conditions. In addition, controlled field tests were conducted. In both the laboratory and field, a standard sandbag levee was constructed to provide a baseline by which the other products could be compared. This report describes the facilities, test procedures, and results for both the laboratory and field tests.

Report format

This report is divided into four chapters plus appendices. Chapter 1 is an introduction and general description of the project, and describes the selection process by which two "promising alternative flood-fighting products" were selected for testing along with the RDFW. Chapter 2 describes the laboratory portion of the project including description of test facilities, testing protocol, and results. Chapter 3 includes the field testing portion of the project including site selection and characterization, testing, and results. Chapter 4 provides the laboratory and field testing summary and conclusions. Appendix A to the report includes the congressional mandate directing the USACE to perform the work described herein. Appendix B includes the Project Management Plan and lists members of the Project Delivery Team (PDT). Appendix C provides the laboratory testing protocol.

Scope of Work

Project description

A research basin and testing protocols from previous research activities were used to test the flood-fighting products. The draft standardized protocol for prototype-scale laboratory testing of temporary barrier-type flood-fighting products was used, which includes both performance parameters (hydrostatic testing, hydrodynamic testing with waves and overtopping, and structural impact testing with a floating log) and laboratory-setting operational parameters.

For both the laboratory and field testing, quantifiable operational data such as man-hours for construction and disassembly, special equipment requirements, and quantity of fill material were recorded. Representatives from the testing PDT evaluated the test structures for qualitative operational factors such as suitability for construction by unskilled labor, suitability for construction on sloping or uneven ground, susceptibility to end effects or undercutting, long-term durability and repairability, and reasonableness of special equipment or materials when considering use at a remote location. Susceptibility of product materials to puncture or tear and ability to make repairs in the field were evaluated qualitatively. The ability to increase structure height to hold back one additional foot of water after its initial construction was evaluated at the field test site only. Disposal, reusability, and storage requirements of the structure and material were evaluated, and any previous real-world experience with the technology was documented.

During previous research, a standard sandbag flood barrier was tested in the research basin using a modified standard test protocol to develop baseline data to which data from other types of structures can be compared. The modification to the standard test protocol includes changes to the structure alignment to allow testing of oblique angles with the wave generator.

After the baseline sandbag data were collected in the research basin, the current project tested the RDFW and two other products in the same facility using the modified standard test protocol. Results of all laboratory testing have been posted on a publicly accessible Web site along with information on man-hours and special equipment required to construct and disassemble the flood-fighting structure, and reusability of the materials. That Web site address is http://chl.erdc.usace.army.mil/ffs. The selection criteria and process for the two additional flood-fighting products is described later in this chapter in the "Product Selection Criteria and Process" section.

Concurrent with the research basin experiments, barriers using the same four technologies were constructed on a field site at Vicksburg, MS, where conditions representative of real-world flood-fighting were expected. The four technologies were tested at the field site concurrently. Results of the field testing have also been posted on the Web site. The field tests allowed a complete assessment of operational concerns such as construction of the structure on uneven or sloping ground, end effects or tiebacks, and undercutting.

Non-ERDC members of the PDT observed the tests, advised ERDC members on the appropriateness of elements of the test, and provided input to the reporting. They also were asked to provide summary documentation on any real-world experience they may have with the technologies being tested, and will review the final report.

Laboratory testing

In the research-basin tests, the products were tested in a controlled laboratory setting. Product vendors were required to arrive at the test facility with all specialized equipment and supplies. The Government furnished all typical construction equipment. The vendors were required to have a representative on site to direct the construction and removal of their structures. The structures were constructed and removed by a labor force furnished by the Government. ERDC and other members of the PDT observed and documented the selected protocol-defined metrics associated with the construction and removal. Selected ERDC and PDT members observed the time required to install the test wall and any special equipment requirements. After construction, the vendor was not allowed to adjust the structure during any of the tests specified in the protocol. The protocol does allow the vendor access to the structure a maximum of three times between tests for a limited length of time if such access is required. Any such access to the structure was recorded. A delivery service contract was signed between each vendor and ERDC prior to the study and guidelines for vendor involvement and responsibilities were specified in that document. As all testing costs will be borne by the Government, this contract assured government ownership and responsibility for distribution of the testing results.

The PDT recognized that supplementary tests might be required for a specific structure to supply information deemed crucial to evaluation of the structure. The test plan allowed that these supplementary tests would be conducted in a manner that would not interfere with the standardized testing protocol. An example of a test that could be conducted in addition to the standardized testing protocol is evaluation of seepage rates on a structure with a punctured or torn seepage membrane.

The products were tested at a field site that experiences backwater impacts from the Mississippi River. The Mississippi River stage was monitored and the time window for product installation was selected based on the predicted date of a river level high enough to inundate the flood barriers being tested.

Vendors were allowed to preposition material at a government-furnished site in the Vicksburg, MS, area. Each selected vendor was contacted and given a notice to proceed to install his barrier. Each vendor was required to install the barrier at the field site within 5 calendar days from the time the notice to proceed was received. The following requirements and information were provided to each vendor:

> Each vendor will be provided with a marked 25-ft right of way for construction. Each barrier must be constructed within a 15-ft-wide footprint for the structure within the 25-ft right of way. Actual right-of-way used by each vendor within the provided 25-ft right of way will be measured and reported. The Government will install a large buried concrete tank on the protected side of each vendor's barrier to collect seepage water. Each vendor is required to adapt their construction to overcome any problems that might arise from the tank. The Government will prepare four separate work areas at the field test site for installation of four different temporary barrier-type structures. A random drawing will be conducted to determine which product is constructed on each area.

Construction

For the laboratory testing, each structure was constructed by laborers from the ERDC-WES (Waterways Experiment Station) Department of Public Works (DPW). While skilled at numerous construction tasks, the laborers were not familiar with the vendor products being tested. Each manufacturer provided one person to train and oversee the construction crew. There were no restrictions on number of laborers or equipment operators that could be used, but only one representative of the vendor could work with the crew. Restrictions on heavy equipment (front end loaders, fork lifts, etc.) were based only on what could safely be used at the test facility. However, total man-hours and types of equipment used were recorded and included in this report. The vendor was responsible for construction and removal, transportation, and delivery of its product.

For field-testing, the vendors were required to furnish the appropriate quantity of their flood-barrier material. Unskilled laborers from the U. S. Army Engineer District, Vicksburg, were provided by the Government to construct and remove the structures. This labor force worked under the direction of a vendor representative. Subsequent to completion of all testing, the structures were removed. If the vendors anticipated that their product and materials were reusable, then they were requested to direct removal so as to maintain the reusability of the product. The Government monitored both the installation and removal. The planned field test sections were u-shaped or half-box-shaped structures with the riverward face of the structure a minimum 100 ft long. Test sections were placed along the channel bank line and tied back into high ground. The length of the tieback sections varied but did not exceed 50 ft in length. The tiebacks had to be long enough that the riverward face of the structures overtopped before the tiebacks flanked.

Additional construction information provided to each vendor included the following:

> The Government will grade to bare ground a portion of the field-test-site footprint for the barrier structures prior to installation of the selected vendors' products. The Government reserves the right to artificially wet the field-test site prior to the vendors' installation of their products to best simulate possible real-world flood-fight conditions. Each vendor's product must be sufficiently high to protect against 3 ft of water against the structure. The vendors also will be required to raise his structure during the testing to a height required to protect against 4 ft of water. Each vendor can use the method of his choice to achieve this raise.

Engineering

ERDC activities included engineering support of the testing procedures, instrumentation, observation, and analysis of the structural response to the flood forces, and reporting of the results. ERDC personnel did not assist with construction or removal of the structure.

ERDC engineers and technicians conducted the field and laboratory tests including operation and maintenance of pumps and valves, operation of the wave generator, and operation of the automated data control and processing computers and equipment.

Instrumentation for the laboratory tests included a laser measurement system for determining seepage rates through the structure, laser measurements of deflection of the structure at various key locations, and capacitance wave rods to measure incident wave conditions during hydrodynamic testing. In addition, continuous video recordings were made from two angles during the entire test period, plus additional video and still shots to document all phases of construction, disassembly, and testing.

Instrumentation for the field tests included capacitance rods for measuring water elevation within the structures and external to the structures and for incident wave conditions. Also, continuous high resolution digital camera captures were recorded from two cameras positioned on each structure. Additional video and still shots also documented the construction and disassembly of each structure as well as the actual testing of the structures. The instrumentation also included the development of a method for determining seepage rates that was based on wetter surface area of the structures.

Environmental

The PDT included an environmental engineer who was tasked to issue an environmental opinion concerning use and disposal of products used in the tests. The plan was to include consideration that the product may have become coated or the fill material may have absorbed contaminants due to exposure to floodwaters.

Product Selection Criteria and Process

The Corps was directed by Congress to develop real-world testing procedures for Rapid Deployment Flood Wall (RDFW) and other promising flood-fight technologies.

Due to the need for timely laboratory and field testing of these technologies, the decision was made to test two other products. To select these two products, the PDT issued a solicitation for technical proposals for temporary, barrier-type flood-fight products during March 2004 on the FedBizOpps Web page. Nine vendors provided proposals in response to this solicitation. The vendors' products can be classified as one of three general types. The first type is an impermeable membrane liner either with or without a supporting frame. The second type is a granular-filled container. The third type is water-filled bladders. Of the nine submitted proposals, four were impermeable membrane liners, two were sand-filled containers, and three were water-filled bladders. Table 1 provides a summary of the vendor proposals.

Table 1-1
Vendor Proposals

Vendor	Product Name	Type Product
Portadam	Portadam	Impermeable-membrane liner with supporting frame
Water Guard Pallet Barrier	Water Guard Pallet Barrier	Impermeable-membrane liner with supporting frame
Hendee	Rapidam	Impermeable-membrane liner
Megasecur	Water Gate	Impermeable-membrane liner
Hesco Bastion	Concertainer	Granular-filled, fabric-lined wire baskets
West Wind Levee	The Wall	Granular-filled membrane bag
Aqua Levee	Aqua Levee	Water-filled bladder
Hydrosolutions	Protecdam	Water-filled bladder
Flood Master	Flood Buster	Water-filled bladder

The vendors' proposals were evaluated by a multidisciplinary team on technical criteria. The criteria were developed by the PDT prior to the issuance of the solicitation. The evaluation team consisted of three ERDC researchers and two Corps District employees. The ERDC researchers were Fred Pinkard (ERDC-CHL, research hydraulic engineer), Thad Pratt (ERDC-CHL, research physicist), and Jim Warriner (ERDC-GSL, research geotechnical engineer). The two District team members were Larry Buss (Omaha District, hydraulic engineer) and Matt Hunn (St. Louis District, emergency management civil engineer).

The evaluation criteria required the proposals to be technically sound, operationally functional, and economically feasible. The evaluation criteria, as provided to potential vendors, are furnished as follows.

a. Documentation shall be furnished that the barrier structure can be installed and removed in the footprint defined in the scope of work for both the field and laboratory deployment. The installation and removal of the structure must be performed using whatever equipment would normally be necessary to install and remove the structure as designed. The vendor must provide enough detail in their installation/removal plan to adequately define all logistical aspects including all labor and equipment requirements for the installation and removal processes. In responding to this item the vendors must cover at a minimum:

(1) Product's physical footprint requirements (length/width/minimum turns or radius considerations) and construction right of way requirements for field test installation and removal.

(2) Durability.

(3) Ease of construction.

(4) Constructed of environmentally acceptable materials (include materials safety data sheets if applicable).

(5) Time required to install at field site.

(6) Manpower required to install at field site.

(7) All equipment required to install at field site.

(8) Time required for removal at field site.

(9) Manpower required for removal at field site.

(10) Additional equipment required for removal at field site.

(11) Adaptability to varying terrain.

(12) Environmental considerations at removal to include contamination from floodwaters.

(13) Physical storage requirements including space and other considerations such as exposure to elements (sunlight, temperature, acid rain, etc.). Storage space requirements should be provided for a volume of the vendor's product that is required to protect a 1,000-ft-long section with 3 ft of water against it.

(14) Seepage through section joints for a 1,000-ft-long section with 3 ft of water against it.

(15) Seepage through product barrier for a 1,000-ft-long section with 3 ft of water against it.

(16) Fill requirements.

(17) Detailed cost and time estimate to construct a 1,000-ft-long section that would hold back 3 ft of water against it based on federally published labor costs for the Vicksburg, MS, area.

b. The vendor's proposal must provide engineering details about the barrier structure to show that the structure has the ability to withstand hydrostatic and uplift forces, has adequate anchoring, and provides a factor of safety against sliding and overturning with 3 ft of water against it (to include if anchoring is provided). The vendor should provide an engineering opinion as to the performance of its product against debris and wave impact and resistance to tearing or breaking during installation and removal.

c. Documentation shall be furnished as to how the barrier structure will perform on a freshly graded surface, a grass surface, and a finished concrete surface. Both the freshly graded surface and the grass surface will be present at the field test site. For the laboratory testing, the structure will be constructed on finished concrete.

d. The vendor must provide sufficient details for plans of how to repair and maintain their barrier structure during the field test process.

e. The vendor must provide documentation as to how their barrier structure will perform against 3 ft of water against it. They will also have to show in sufficient detail how they will raise the level of their structure by whatever means possible to protect against an additional foot of floodwater during the field-testing process.

As a result of the evaluations, the Portadam and Hesco Bastion products were selected as the promising flood-fight technologies to be tested along with the RDFW and sandbags. The Portadam proposal had the best overall combination of technical soundness, operational functionality, and economic feasibility. Hesco Bastion's proposal while technically sound and operationally functional was especially strong in economic feasibility. Contracts with both Portadam and Hesco Bastion were signed on 21 April 2004.