ERDC Report to Sponsor

US Army Corps of Engineers®
Engineer Research and Development Center

Evaluation of Typar® Geocell Flood Fighting Barrier

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Executive Summary:

The Typar® Geocell from Fiberweb, Inc., uses lightweight geotextile sheets held together to create a series of inter-connected boxes which, when filled with sand, are designed to be used as a rapidly installed barrier to flood waters. In the laboratory tests reported herein, a wall 40 in. high by 54 in. wide with a length of 74.3 ft was assembled in approximately 10 hrs (29.6 man-hrs) by 3 men including the operator of a Bobcat™ front-end loader. Removal required just 2.9 man-hrs. No special equipment or materials were required for either installation or removal, and installation could be easily accomplished by persons unfamiliar with the product with a minimum of training or supervision.

The completed barrier was wrapped in plastic sheeting to minimize seepage past the barrier. Measured seepage rates were approximately 0.025 gpm/ft at a basin water depth of 1.0 ft, 0.08 gpm/ft at a depth of 2.0 ft, and 0.25 gpm/ft at a depth of 3.2 ft.

The structure was not affected by wave action, overtopping, or debris impact in any of the tests reported herein.

The units were not intended for re-use and were destroyed during the removal process. Cost of a 1,000 ft wall, 40-in. high, including 3 frames for use during the assembly, is about $22/ft (Oct 2010).

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Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
inches	0.0254	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
Gallons (U.S. liquid) per minute per foot	2.0699 E-04	Cubic meters per second per meter

1 Introduction

Background on Testing Program

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…." Through the General Investigation Research and Development Program, 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 test facility was laid out along the perimeter wall of a reservoir with dimensions of 115 ft by 185 ft by 4 ft deep (Figure 1). The test facility was reconfigured specifically for innovative flood-fighting experiments by allowing levees to be constructed against two wall abutments with a 30-ft opening between the walls (Figure 2). A geometric testing zone footprint was laid out on the concrete floor and all levees were required to be constructed within this given footprint. One side of the footprint abuts the concrete wall at a 90-deg angle, and the other side abuts the concrete wall at a 63-deg angle (Figure 3). The purpose for having two different angles is to simulate real-world geometric variability and demonstrate constructability and geometric flexibility of each vendor's product. Additionally, the unsymmetrical geometry allows wave loading variability during hydrodynamic testing, and it causes an apparent current along the 63-deg wall.

Inside the protected area (leeward side of the levee), an 8-ft diameter by 8-ft-deep circular pit was installed to catch any seepage or overflow water from the structure. Two 4-in.-diam pumps were installed in the pit to pump the accumulated water back into the wave basin. Two 12-in.-diam pumps (12 in. intake and 10 in. output) were also installed to pump excess water out of the pit when the capacity of the 4-in. pumps was exceeded.

The test area was instrumented with a series of lasers to measure any movement of the flood-fighting barrier, a laser to measure changes in water surface elevation within the pit, and a laser to measure water surface elevation within the basin.

Figure 1. Research basin with wave machines on the left side and the test area on the far right. The test area is shown in closer view in Figure 2.

Figure 2. Test area surrounded by a Typar® Geocell barrier, viewed from the test basin. The measurement sump and pumps are in the back of the test area.

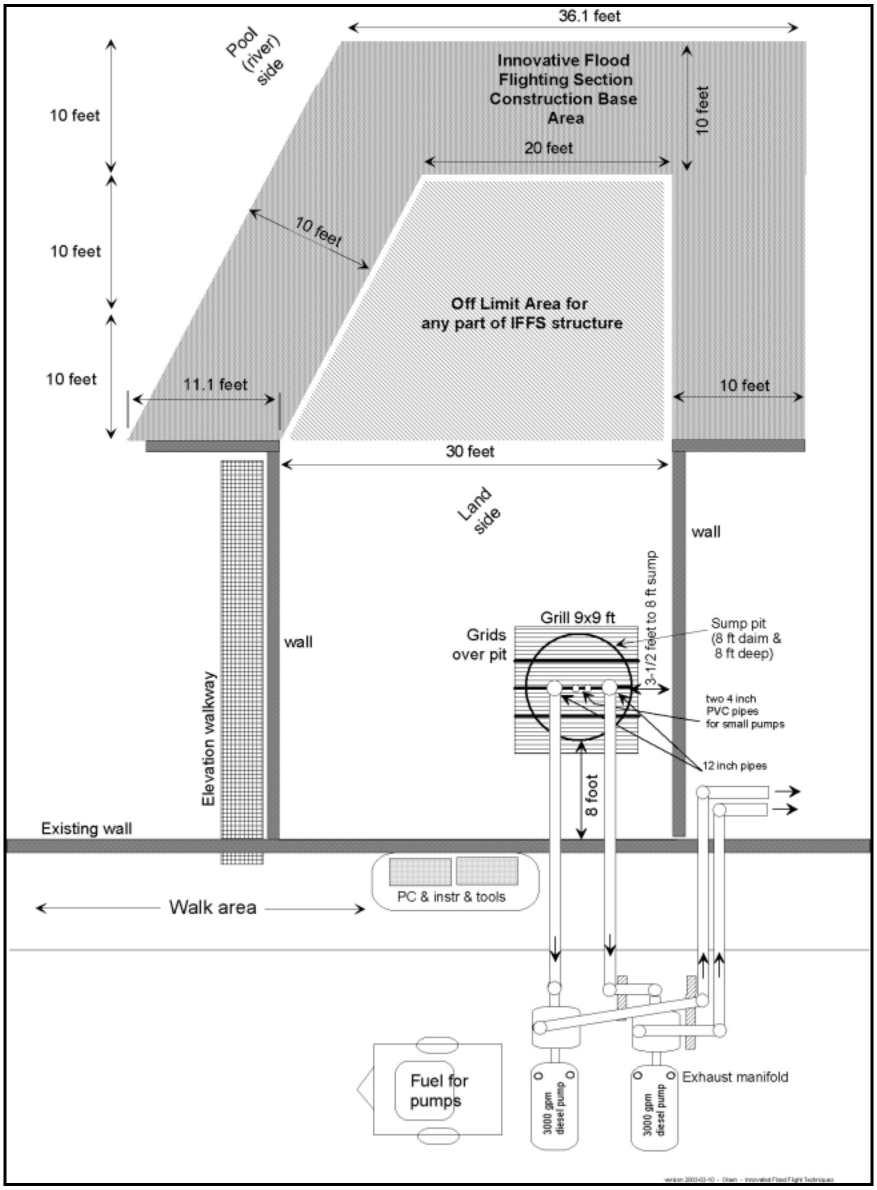

Figure 3. Layout of test area within research basin.

In the research-basin tests, products were tested in a controlled laboratory setting, but under conditions that emulated an impending flood overtopping a levee along a riverbank with moderate flow. Vendors were required to arrive at the test facility with all equipment, supplies, and personnel required to erect their product prior to testing. ERDC did not assist with the construction, but observed and documented the selected protocol-defined metrics associated with the construction including time required to install the test walls 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 copy of the standard testing protocol is available at http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=PUBLICATIONS;243

Typar® Geocell Product Description

The Typar® Geocell units are made of sheets of geotextile sewn together to form a gridwork of diamond-shaped cells arranged like a honeycomb (Figure 4). The units tested herein were the DC-2 units that had two outer walls and three inner walls constructed such that the structure is two cells wide at any point. DC-3 and DC-4 units, which are three and four cells wide, respectively, are also available. Also available is a DC-1 unit with triangular-shaped cells.

The outer two walls of the units are 24 in. tall and the inner walls are all 20 in. tall. According to the Fiberweb, Inc., representative, the geocells are also marketed to the military under the name of DefenCell™, and the heights of the walls were selected such that a soldier could easily step between cells when constructing a barrier of DefenCells™ in the field. The size of the individual cells in the honeycomb structure were designed large enough to allow a soldier wearing combat boots to easily step into a cell.

The outer walls extend four in. higher than the inner walls. If a second layer of Geocells is placed on top of the inner walls, the outer walls provide an overlap between the layers. Multiple layers can be stacked vertically.

A collapsible aluminum frame is used to hold the units open until they are partially filled with sand. If multiple units are stacked, each layer is filled with sand to the 20-in. height of the inner walls, each additional layer is placed and filled with 20 in. of sand, and the top layer is filled with sand to the entire 24-in. height of the outer walls.

Figure 4. Typar® Geocell units being filled with sand.

Delivery

All of the Typar® Geocells were delivered to the ERDC test facility in the back of a single sport utility vehicle. A hand cart was used to transport the units into the test basin, although one person could easily carry several 16-ft-long rolls of units.

2 Testing Procedure and Results

Assembly

Assembly Method

The flood fighting barrier was assembled by employees from Fiberweb, Inc., and from Civil & Environmental Consultants, Inc. Three persons, including one operating a BobCat™ front-end loader, worked on the construction at a time, while a second group of workers alternated with the first group every hour or so.

The Geocell units come in 16-ft lengths, rolled up (Figure 5). Each length was unrolled and installed separately on an aluminum framework.

Figure 5. A stack of Geocells. Each bundle is two units of 16-ft-long lengths.

The frame of 1-in. aluminum tubing comes in a custom carrying case that includes all parts needed to assemble the frame (Figure 6). The lengths of tubing fit together with push-button pins in the ends of one piece connecting into holes in the adjacent piece. All parts of the frame are numbered for quick reference (Figure 7).

Figure 6. The aluminum assembly frame comes in a custom carrying case.

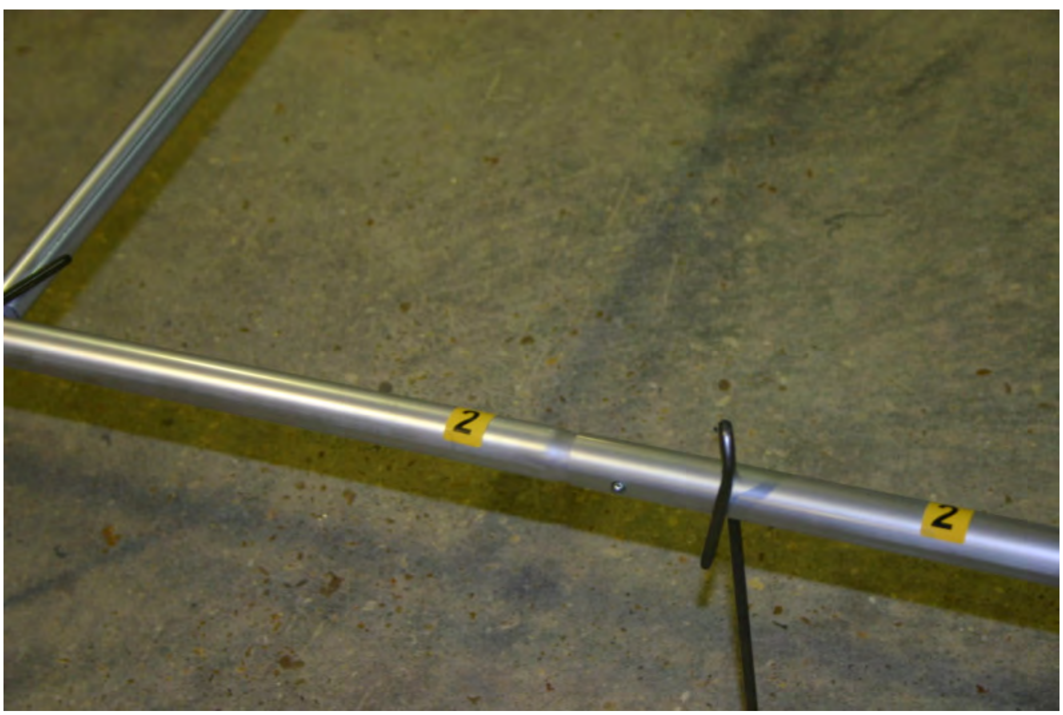

Figure 7. Framework parts are numbered at each connection for easy reference. The push-pin connecting two lengths of tubing is visible near the middle of the picture.

The framework consisted of 4 corner pieces, 2 straight lengths for each side, and one straight piece on each end. Because all Geocell units are the same length, the same frame can also be used for DC-1, DC-3 or DC-4 units just by changing the length of the end pieces. A set of straight pins was then inserted vertically through holes in the frame and clipped into place. The vertical pins were then inserted into the cells on all sides of the Geocell unit, holding the unit open and rigid and ready for filling (Figure 8).

Figure 8. Aluminum framework holding open a length of Geocells.

Multiple frames were used to allow several lengths of Geocells to be positioned and filled at one time. Where the ends of two lengths of Geocells met, the frames were overlapped to allow the convoluted ends of the cells to fit together (Figure 9).

To stay within the space designated in the testing protocol required the use of some partial lengths of Geocells. In those places the frame was shortened by overlapping sections of frame (Figure 10) and the extra cells simply cut off with a box cutter.

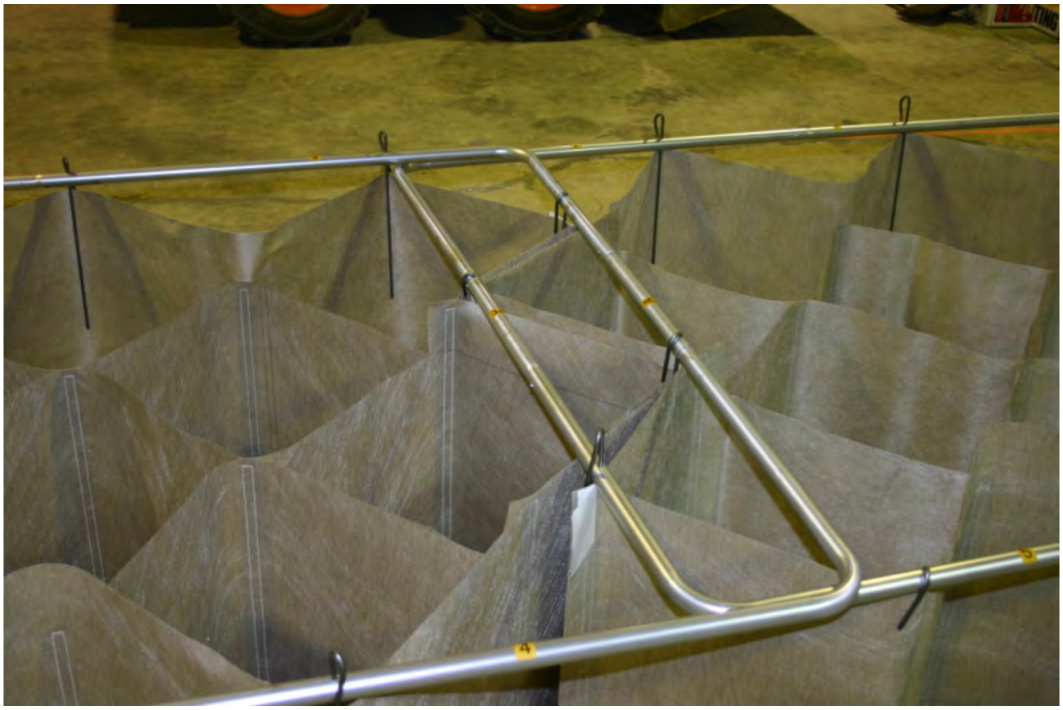

Figure 9. A junction between two lengths of Geocells. The frames are overlapped to fit the cells together.

Figure 10. The unit on the left has been shortened to fit the designated area for the test. The extra cells will be cut off with a box cutter.

Before filling, plastic sheeting was placed under the outer edge of the Geocells (Figure 10). The sheeting will be wrapped over the Geocells after filling.

The floor of the test basin is not perfectly level, but the fabric sides of the Geocells easily adjusted to the contours.

A Bobcat™ front-end loader brought sand from a stockpile to fill the cells. The sand was shoveled from the bucket of the front-end loader into the individual cells to partially fill the cells and give stability to the unit. After the cells were partially filled, sand was dumped from the bucket into the cells to complete the filling (Figure 11).

Figure 11. Sand being dumped into the Geocells.

Where the unit butted against the wingwall, a sheet of flashing was placed between the wall and the Geocell to provide a seal. In addition, expanding foam insulation was sprayed between the wall and the unit to further seal the unit to the wall (Figure 12).

Figure 12. Flashing and expanding foam sealant were used to seal the Geocells to the wingwall.

To fit the Geocells around the 63 deg. bend in the designated layout, a length of Geocells was set straight, the first few cells were filled (Figure 13), then the frame and remaining cells were turned to the desired angle (Figure 14). Where the final length of Geocells angled into the second wingwall, the extra cells were removed with a box cutter and the end sealed to the wall with flashing and expanding foam sealant (Figure 15).

Figure 13. To fit the Geocells around a 63 deg. angle, the first cells are filled for a straight connection then the frame and remaining cells are turned to the desired angle.

Figure 14. The frame and remaining cells have been turned to fit the designated layout.

Figure 15. The extra cells where the final length angles into the wingwall will be removed with a box cutter.

The frames from the first layer were used to place the Geocells in a second layer (Figure 16). A line four in. up from the base of the Geocells matches the height of the overlap of the outer wall on the bottom layer, providing an easy reference that the second layer is placed correctly (Figure 17).

Figure 16. Starting the second layer of Geocells.

Figure 17. A line near the base of each Geocell matches up with the overlap of the outer wall of the first layer.

The top of the cells was raked smooth to provide a fairly uniform height around the barrier (Figure 18). The cells were not filled to the top of the outer cell walls but filled to with an inch or two of the top.

Figure 18. Leveling the top of the barrier.

After filling with sand, the plastic sheeting was wrapped around the barrier (Figure 19). Where two pieces of sheeting overlapped, flashing was used to tape the seam (Figure 20). Sandbags were used to anchor the sheeting on the inside of the barrier (Figure 21).

Figure 19. The plastic sheeting is being wrapped around the completed Geocell barrier.

Figure 20. Flashing was used to tape the seams where two pieces of sheeting overlapped.

Figure 21. Sandbags were used to anchor the plastic sheeting on the inside of the barrier.

The completed barrier is shown in Figure 22 and Figure 23.

Figure 22. The finished barrier looking towards the 90 deg. bend in the layout.

Figure 23. The finished barrier looking towards the 63 deg. bend in the layout.

Summary of Assembly

Assembly was completed by three persons working at a time, including the operator of the Bobcat™ front-end loader who assisted in the construction when not driving the loader. Total time of construction was 9 hrs 53 min, or 29.65 man-hrs. Tools used were the front-end loader, shovels, tampers, rake, knife, and wire cutters. Materials used were the sand fill, plastic sheeting, expanding foam sealant, tape, and 9-in.-wide self-adhering window flashing.

Length of the finished structure measured along the centerline of the barrier was 74.3 ft.

Hydrostatic Tests

One Foot Depth

After constructing the barrier on Monday, 13 September 2010, the basin was flooded on Tuesday, 14 September. Pumps were turned on at 1009, and water level reached 1 ft at 1158. No water was observed passing the barrier until 1400 when the first seeps of water from under the plastic sheeting were noted.

Seepage rates were determined by measuring the change in elevation in the sump located in the test area. The change in elevation, multiplied by the cross-sectional area of the sump, and divided by the time step gave the seepage rate. The rate was divided by the length of the Geocells barrier (74.3 ft) and converted to gallons per minute to yield results in gallons per minute per linear foot of structure (gpm/ft).

Figure 24 (starting at 1036 hrs) shows the change in measured seepage rates as the water in the test basin was brought up to the 1-ft depth. For approximately 40 min after the full depth was reached there was no measurable seepage. Seepage rate then gradually increased to an average of about 0.027 gpm/ft. Figure 25, which started at 1616 hrs, shows that the seepage rate was maintained throughout the day. The following morning (15 September, starting at 0727 hrs), Figure 26 shows a seepage rate averaging about 0.025 gpm/ft.

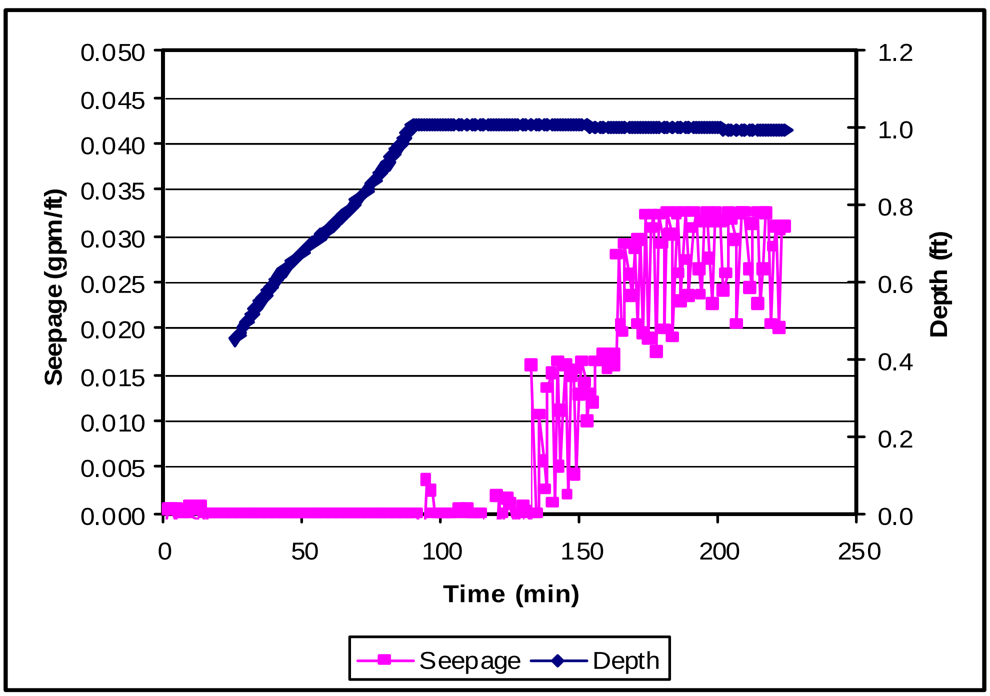

Figure 24. Seepage rate as water is brought up to 1 ft basin depth. Measurements started at 1036 hrs.

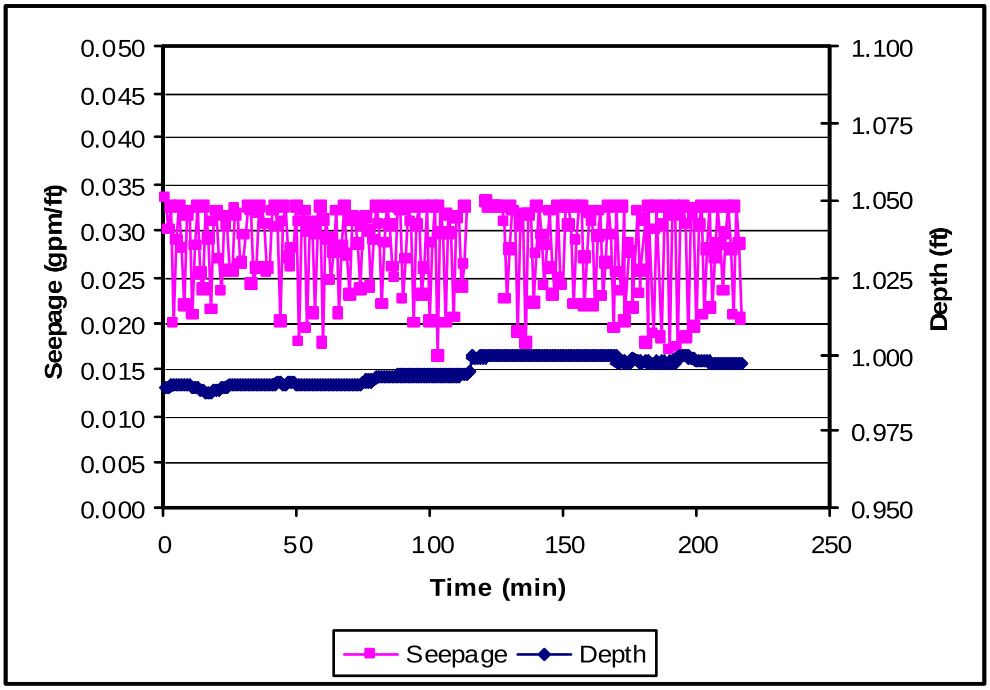

Figure 25. Seepage rate starting at 1616 hrs after 1 ft depth has been maintained for 4 hrs.

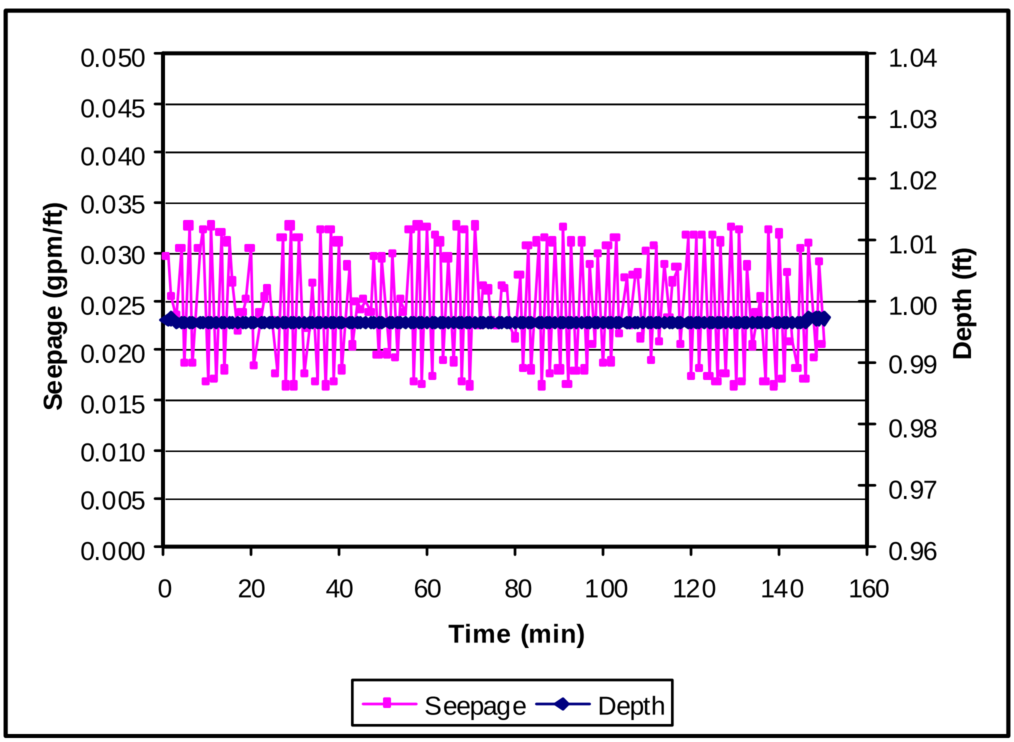

Figure 26. Seepage rate starting at 0727 hrs the following morning,

Four lasers measured any movement of the structure during flooding of the basin and any settling of the fill. When viewed from inside the test area, the Geocell barrier consists of a section on the right-hand side that extends perpendicular to the wingwall, a center section that spans part-way across the test area, and a left section that angles in to the left-hand wingwall. One laser was directed near the center of each the left section and the right section, and two lasers (one at approximately two-thirds the height of the structure and one at one-third the height) were directed at the center section. The four lasers are labeled Left, Center High and Center Low, and Right. White tape was placed on the barrier as targets for the lasers to provide good reflection.

Initial measurements (prior to filling the basin) showed the targets on the left section and right section at 36.878 ft and 39.096 ft, respectively, from the lasers, and the center high and low targets at 48.848 ft and 48.720 ft, respectively, from the lasers.

Movement of the structure during filling and settling was negligible. Figure 27 shows measurements taken during filling and one hour after filling, and Figure 28 shows measurements taken of the structure the following morning. To provide a larger scale for accuracy, the two lasers aimed at the center section of the structure are based on the primary y-axis (left-hand side) and the lasers aimed at both the left and right section of the structure are based on the secondary y-axis. Lines showing a sudden decrease in measurement (most noticeably in Figure 28) show where a person walked in front of the laser in the test area and do not represent movement of the structure.

After 22 hrs at a basin depth of 1 ft, measured distances to the targets were: left target, 36.865 ft; right target, 38.988 ft; center high target, 48.854 ft; center low target, 48.723 ft. Movement of the structure was on the order of 0.01 ft towards the lasers in each case, and is probably due to settling of the fill in the cells.

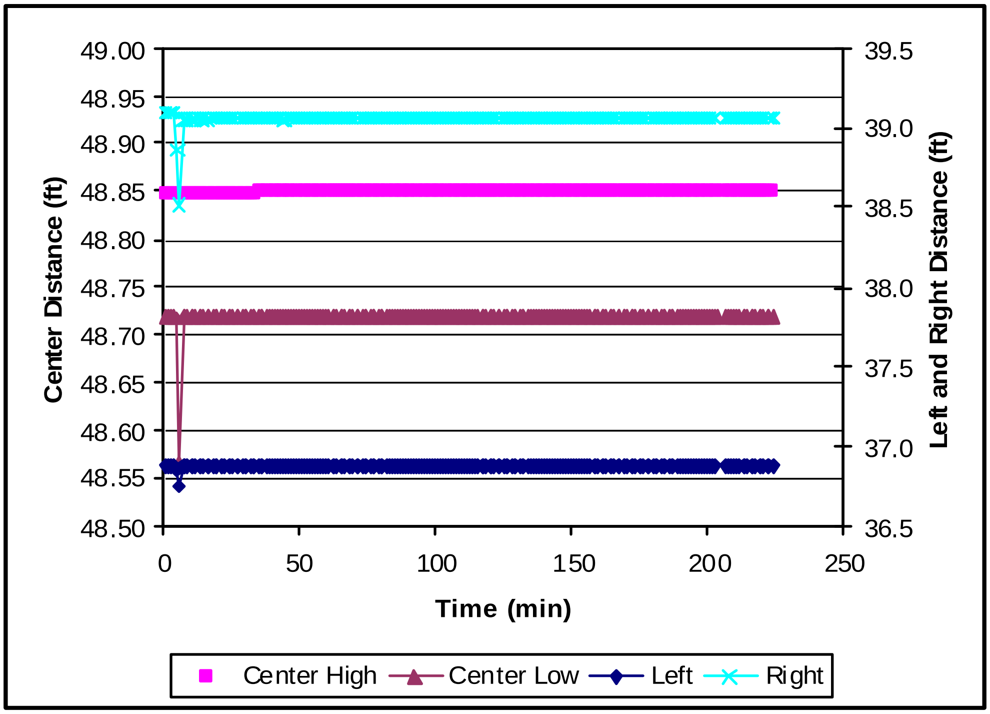

Figure 27. Distance to structure during filling to 1 ft basin depth, measurements started at 1036 hrs.

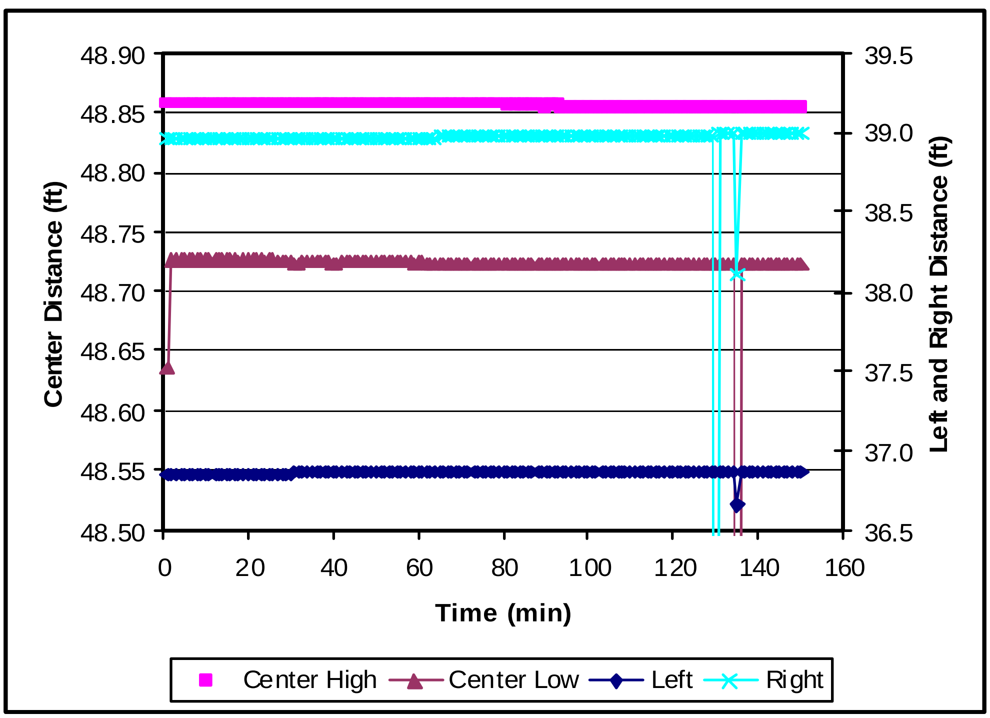

Figure 28. Distance to structure starting at 0727 hrs the following morning.

Two Foot Depth

On 15 September, the pumps were turned on at 1003 hrs and a basin depth of 2 ft was reached at 1158 hrs.

Seepage rates gradually increased with the increasing depth in the basin, averaging slightly above 0.12 gpm/ft about 40 min after the depth of 2 ft was reached. Seepage rates then decrease slightly as the sand consolidated, dropping to about 0.115 gpm/ft (Figure 29). Seepage rates continued to drop throughout the afternoon (Figure 30) reaching a low of about 0.09 gpm/ft the following morning (Figure 31). However, it is seen in Figure 31 that the basin water level dropped overnight when the automatic water level control lost power. As water level was brought back up to 2 ft from 1.95 ft, seepage rates rose to about 0.10 gpm/ft.

A leak was discovered in one wall of the test area. As the water level in the basin rose to the 2 ft depth, the leak became more pronounced. Near the end of the 22 hr test period at a 2 ft depth, the leakage through the wall was measured at 0.061 gpm, which would add 0.0008 gpm/ft to the barrier seepage rate.

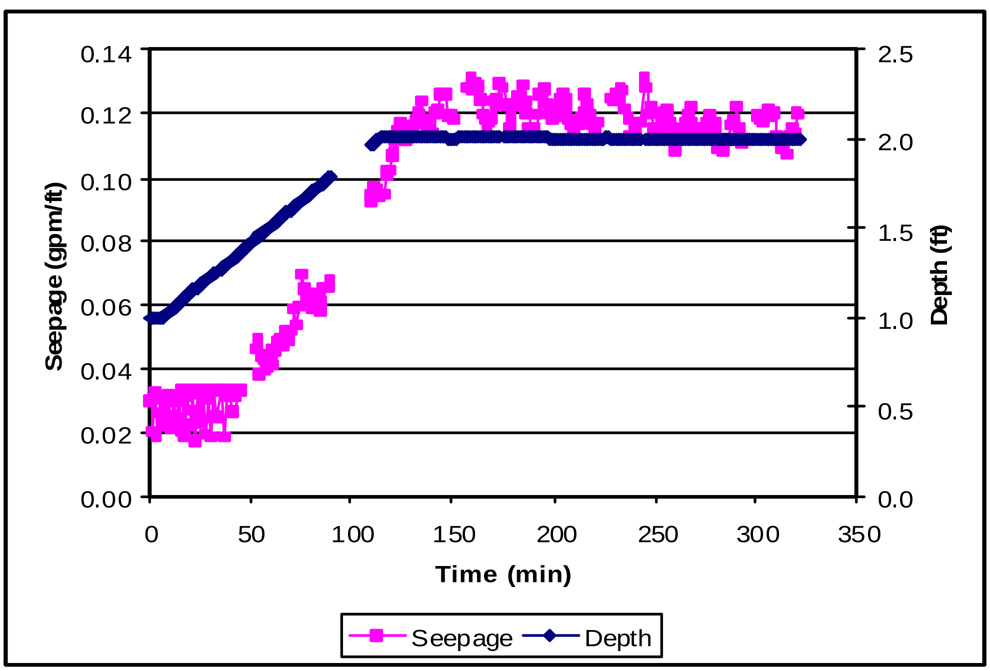

Figure 29. Seepage rate as basin water level raised to 2 ft. Measurements started at 1000 hrs.

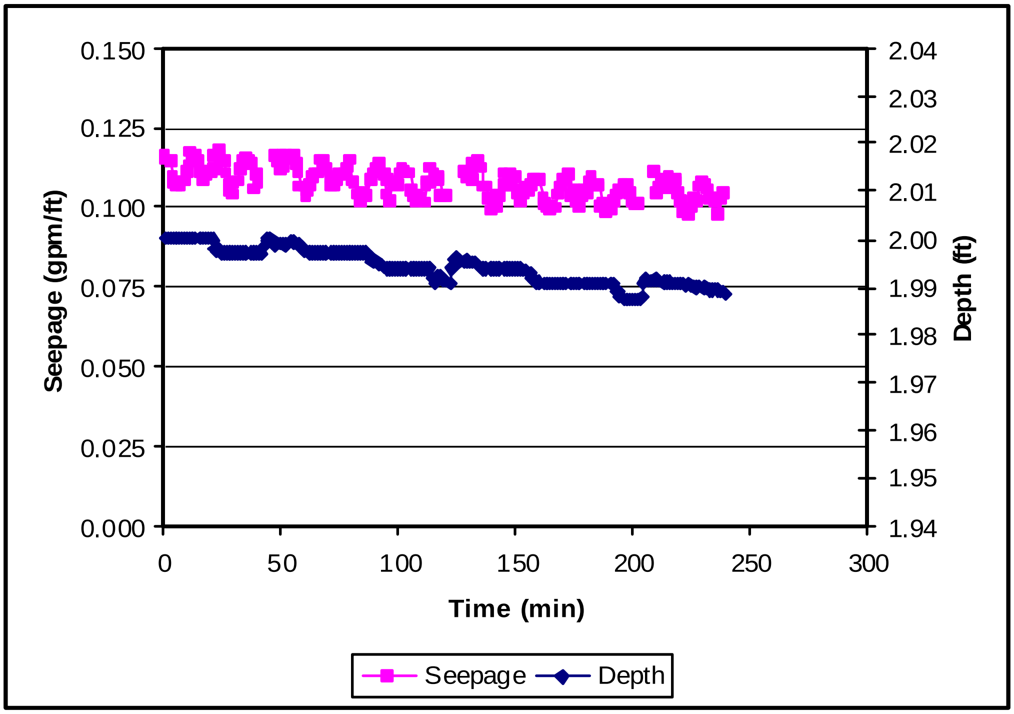

Figure 30. Seepage rates with basin water level at 2 ft. Measurements started at 1531 hrs.

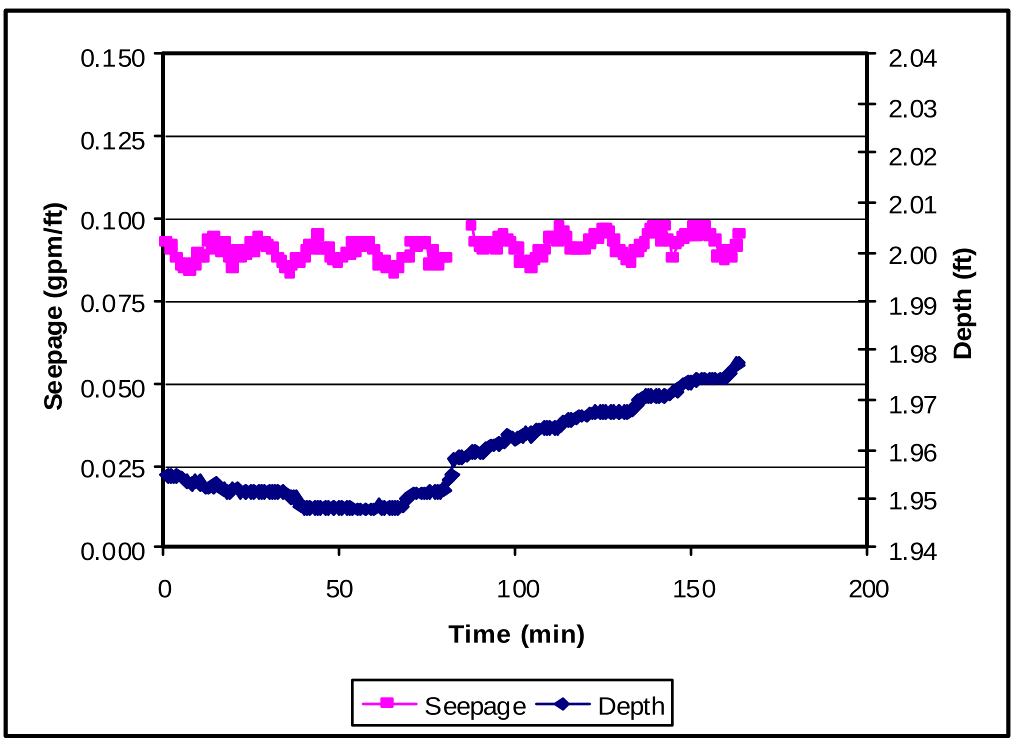

Figure 31. Seepage rate the following morning, measurements starting at 0710 hrs.

There was no discernable movement of the structure while the water was brought up to the 2 ft depth (Figure 32). At the end of the 22 hrs with water level at 2 ft, distances to the target were: left section, 36.846 ft; right section, 38.335 ft; center high and low lasers, 48.858 ft and 48.723 ft, respectively.

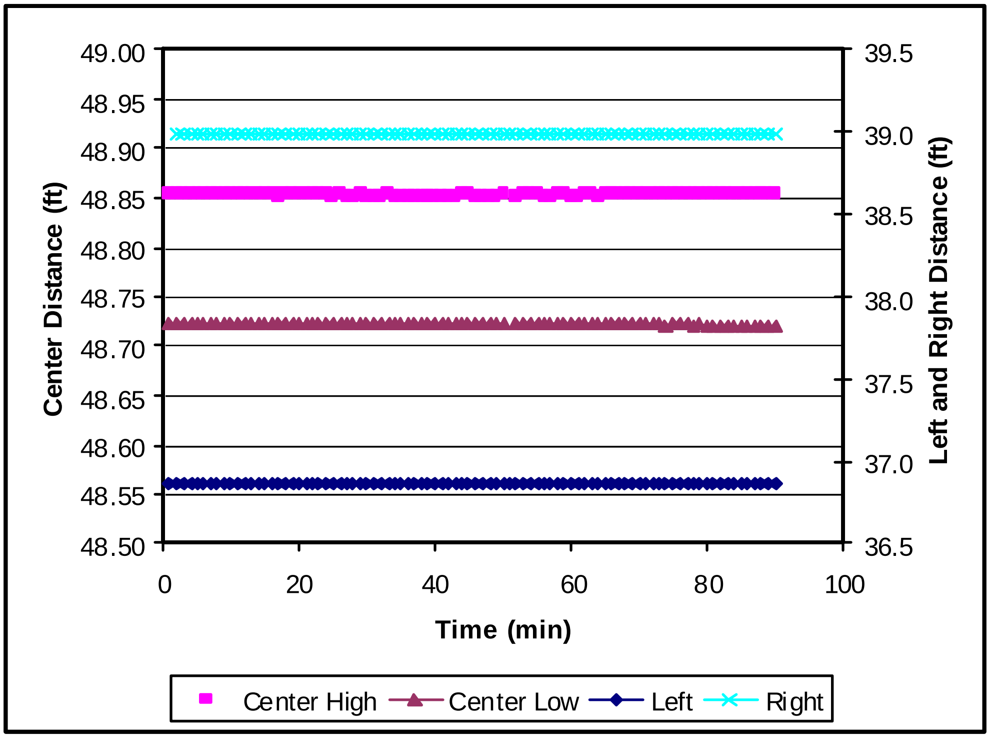

Figure 32. Measurements to structure walls as water level was raised to 2 ft. Measurements started at 1000 hrs.

95% of Structure Height

Multiple measurements taken of the height of the completed structure showed elevations ranging from 39 in. to 42 in., with 40 in. appearing to be a "typical" height of structure. The basin was therefore filled to 95% of 40 in., or 38 in. depth. Pumps were turned on at 1017 hrs on 16 September. A depth of 38 in. (3.17 ft) was reached at 1245 hrs.

Seepage rate during filling reached a maximum of about 0.33 gpm/ft about 40 min after the depth of 3.17 ft was reached (Figure 33). Seepage rate then dropped during the afternoon to about 0.28 gpm/ft (Figure 34), leveling out at about 0.26 gpm/ft by the following morning (Figure 35).

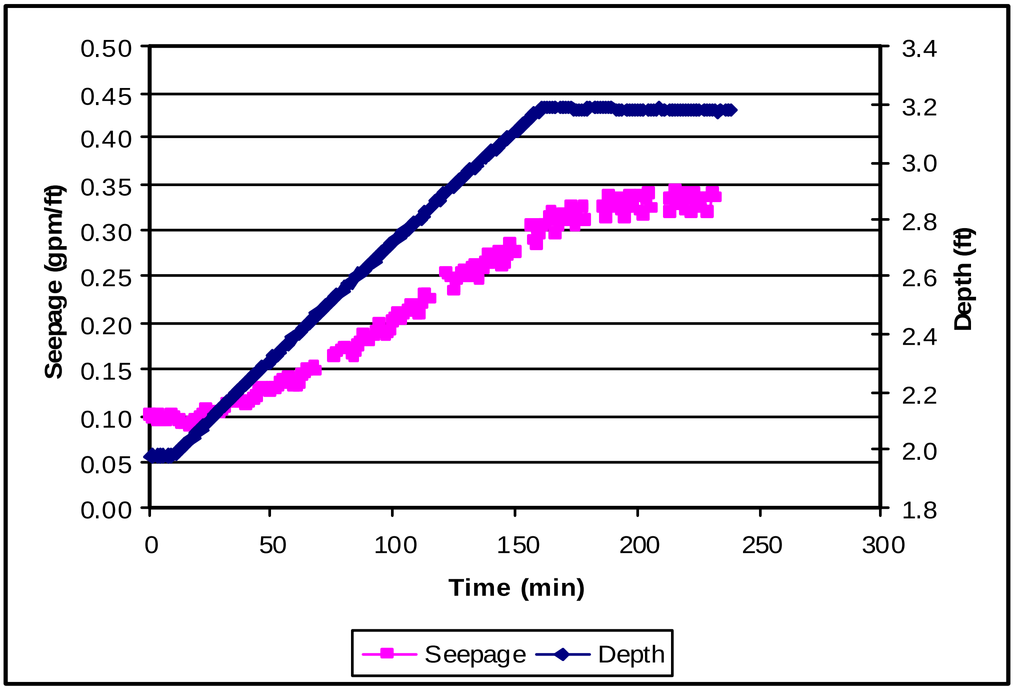

Figure 33. Seepage rate during filling to 95% of structure height. Measurements started at 1010 hrs.

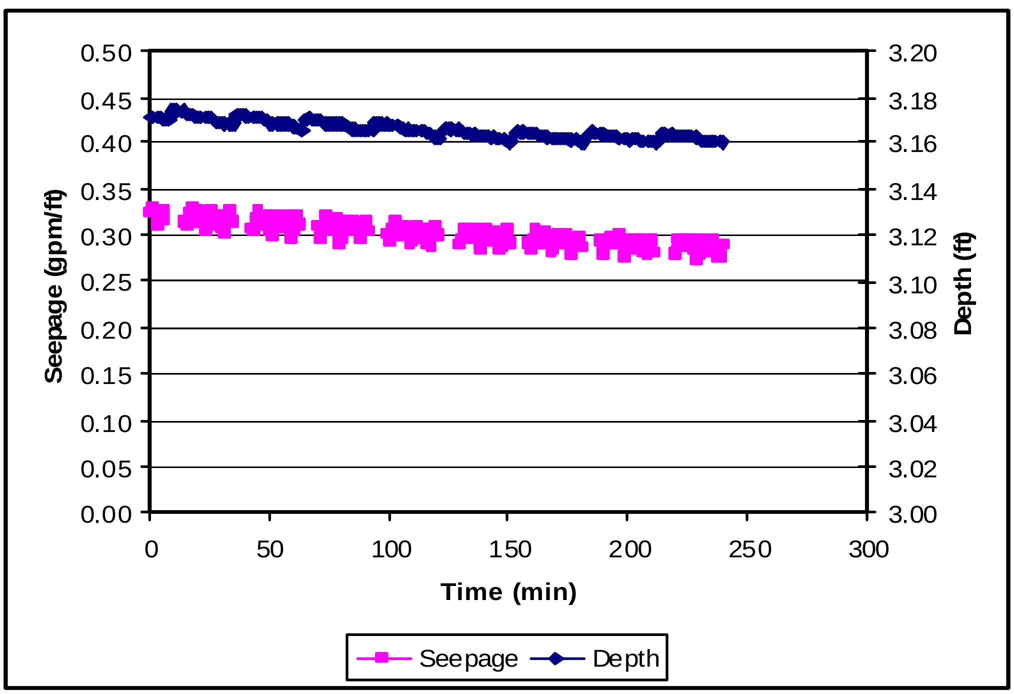

Figure 34. Seepage rates starting about 2.5 hrs after depth of 3.17 ft reached. Measurements started at 1517 hrs.

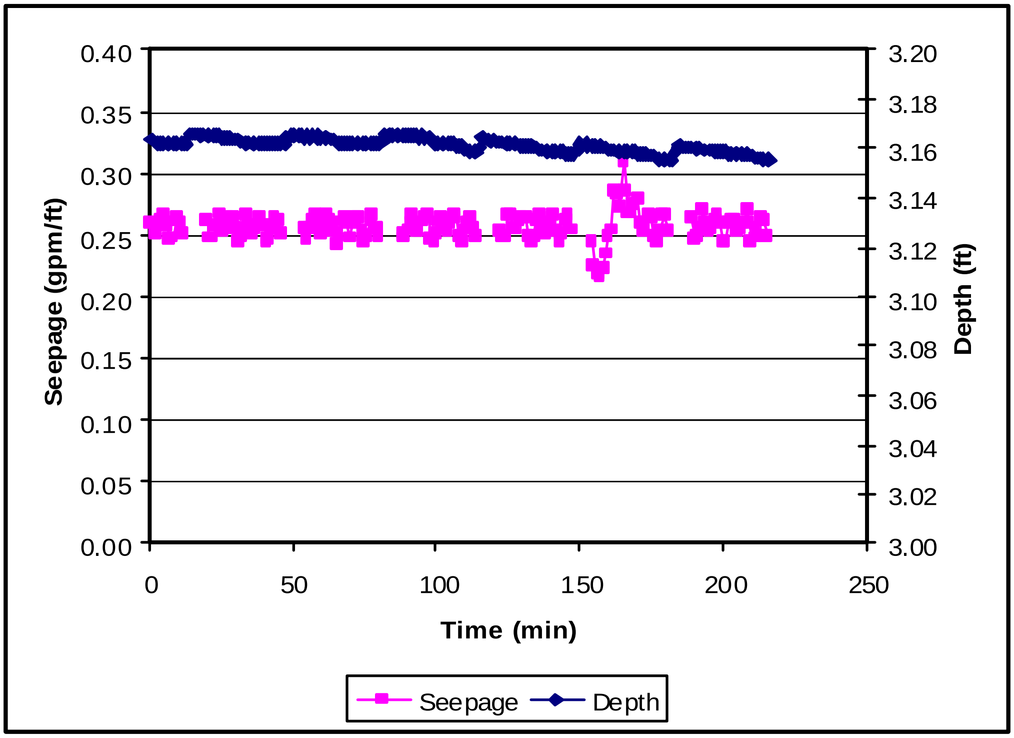

Figure 35. Seepage rate the following morning. Measurements started at 0711 hrs.

By the end of the 22 hrs at a depth of 3.17 ft, the leak in the wall of the test area had nearly doubled to about 0.12 gpm, or 0.0016 gpm/ft.

Figure 36 shows slight movement of the wall sections of the structure during filling to 95% of structure height. Four hours after starting to fill the basin, and about 1.5 hrs after maximum depth was reached, both the center high and center low targets had moved 0.010 ft closer to the lasers (approximately 1/8 in.). There was no recorded movement of the right wall section, and the left wall section had moved 0.014 ft away from the laser.

After 22 hrs at a depth of 3.17 ft, distances to the laser targets were: left, 36.859 ft; right, 38.975 ft; center high and low, 48.848 ft and 48.713 ft, respectively.

Table 1 lists distances to the targets at the end of each water depth test. Little movement of any Geocell section was recorded, and any movement observed may have been due to shifting of the plastic sheeting around the barrier.

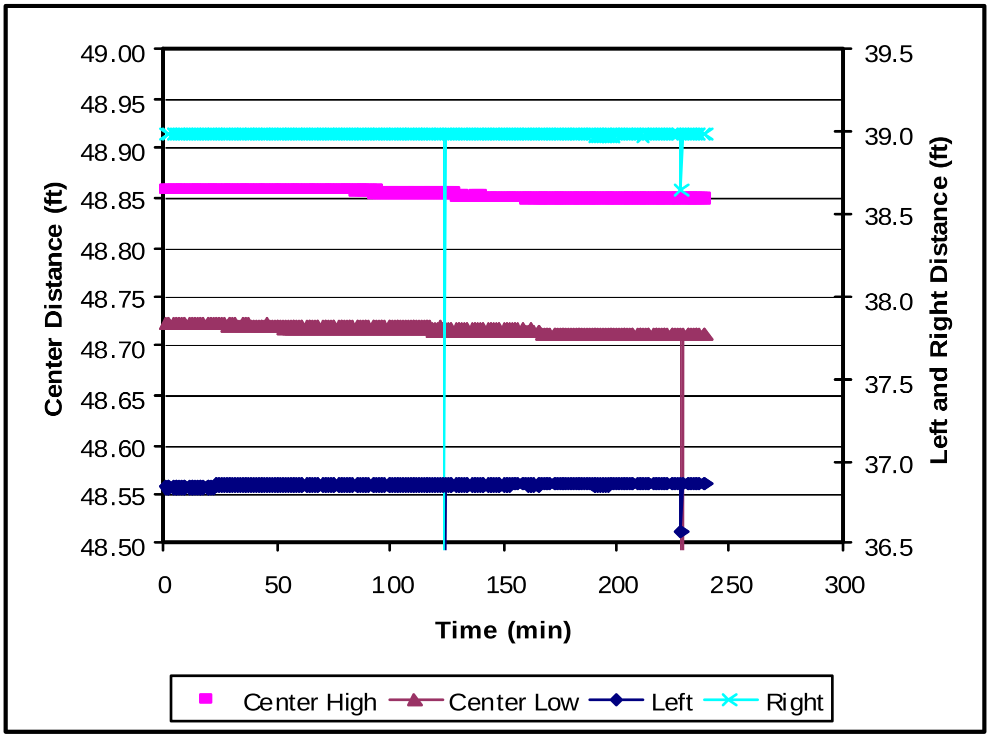

Figure 36. Structure movement during filling to depth of 3.17 ft. Measurements started at 1010 hrs.

Table 1. Distances to targets at start of testing and at end of each 22-hr depth test.

	Left	Center High	Center Low	Right
Start	36.878	48.848	48.720	39.096
1 ft	36.865	48.854	48.723	38.988
2 ft	36.846	48.858	48.723	38.985
3.17 ft	36.859	48.848	48.713	38.975
Difference (start to 3.17 ft depth)	0.019	0.000	0.007	0.121

Hydrodynamic Tests

Low water, small waves

The basin drains were opened at 1105 hrs, and the water had drained to a depth of 2.22 ft (66.7% of 40 in. structure height) by 1310 hrs.

Small waves (2-in. wave height, 2-sec wave period) were started at 1322 and generated for 2.5 hrs of the 7 hrs required for the test. The basin was then drained and shut down for the weekend.

Before filling the basin after the weekend, flashing was placed along the outside of the crack in the test area wall that had been leaking. The leak was almost completely stopped.

The pumps were turned on at 0825 hrs on 20 September. A depth of 67% of structure height (2.22 ft) was reached at 1205 hrs (actually the basin was over filled by about 1 in., then water level was brought back down before starting waves test). Seepage rates measured during the filling of the basin are shown in Figure 37. There was no discernable movement of the structure wall sections during filling of the basin (Figure 38).

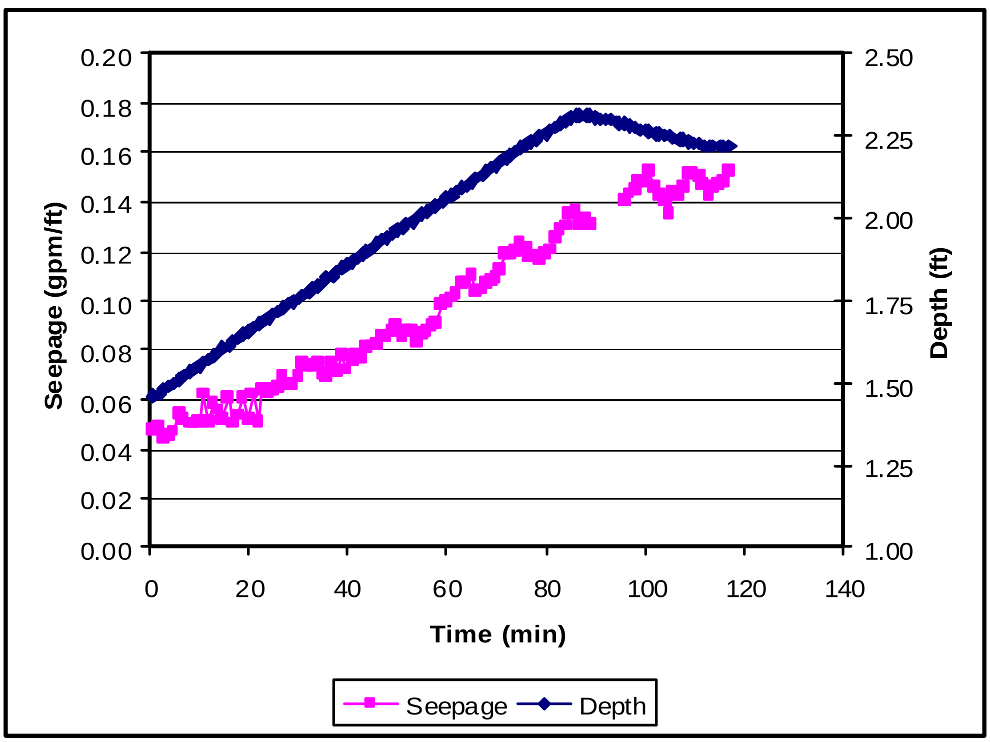

Figure 37. Seepage rates while filling basin to depth of 2.22 ft for hydrodynamic tests. Measurements started at 1040 hrs.

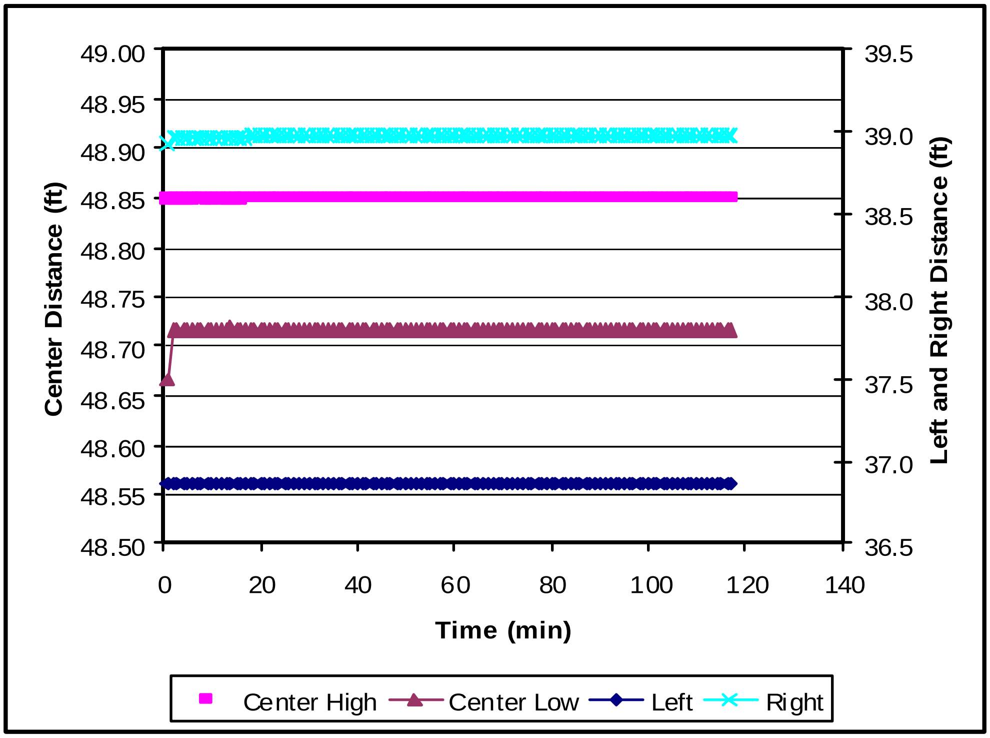

Figure 38. Movement of barrier walls during basin filling to 2.22 ft. Measurements started at 1040 hrs.

Small waves (2-in. wave height, 2-sec wave period) were started at 1234 hrs. Waves were generated for 4.5 hrs to complete the 7 hr test. Seepage rates during the test were about 0.15 gpm/ft (Figure 39). For comparison, seepage rates in the first few hours of the hydrostatic tests were about 0.11 at a depth of 2.0 ft and 0.30 at a depth of 3.2 ft.

There was no discernable movement of the structure walls during the small waves test (Figure 40).

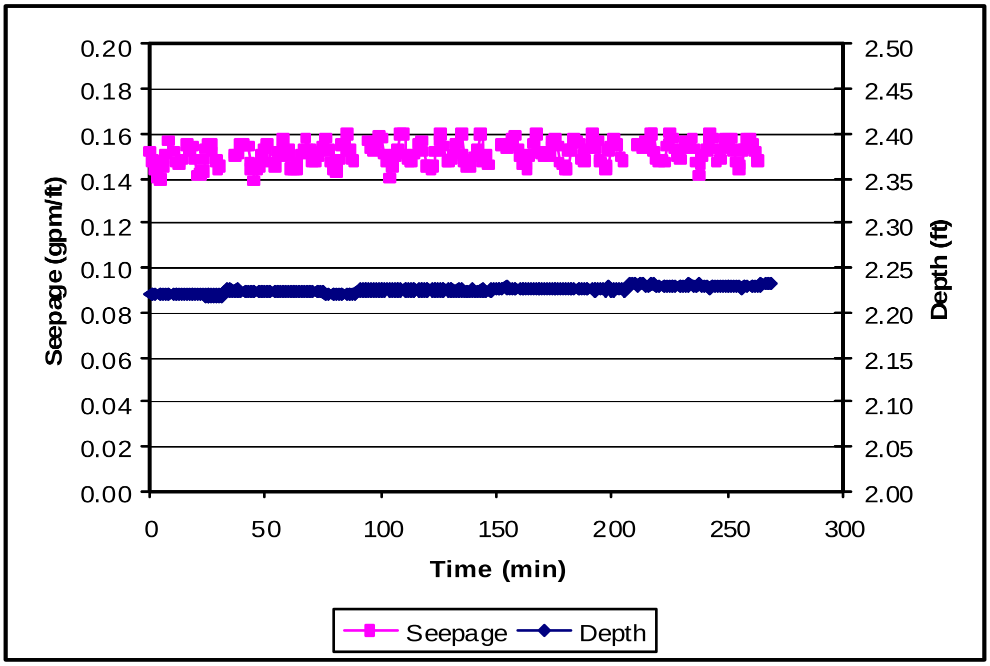

Figure 39. Seepage rates during tests at low water, small waves. Measurements started at 1238 hrs.

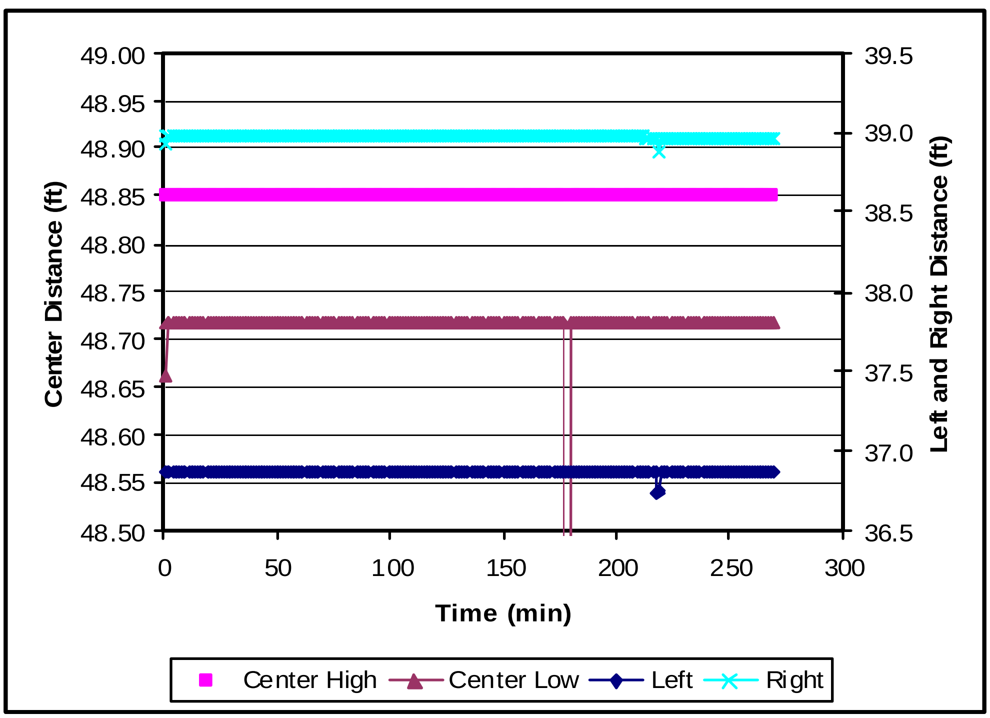

Figure 40. Measurements of wall movement during tests at low water, small waves. Measurements stated at 1238 hrs.

Low water, medium waves

On 21 September, with water level still set at 2.22 ft (66.7% of structure height), the small waves were generated for 31 min to allow time for the photographer to take some pictures. The small waves stopped at 1057 and the basin was allowed to still.

Medium waves (6- to 8-in. wave height, 2-sec wave period) were generated in three bursts of 10 min each with time after each burst to allow the basin to still. The first burst was generated at 1106 hrs, the second burst at 1140 hrs, and the third burst at 1219 hrs. The third burst was allowed to run an additional 11 min to allow time for the photographer to take pictures.

The medium waves caused minor overtopping of the structure but no discernable movement. Regrettably, the laser program was turned on at 1054 hrs, but collected data for only 3 sec before shutting down for unknown reasons without the knowledge of the researcher. Seepage rates and structure movement data were therefore not collected during the low water medium and large waves.

Low water, large waves

With the basin water depth maintained at 2.22 ft, a single 10-min burst of large waves (10- to 12-in. wave heights, 2-sec wave period) was generated starting at 1313 hrs. Although there was more overtopping than with the medium waves, the amount of overtopping was still low. There was no discernable movement of the structure. Again, the laser program was not collecting data during this test run.

High water, small waves

The water level in the basin was raised to a depth of 80% of structure height, or 32 in. (2.67 ft). Small waves (2-in. wave height, 2-sec wave period) were generated for 1 hr starting at 1440 hrs. Seepage rates during the test were about 0.18 gpm/ft (Figure 41).

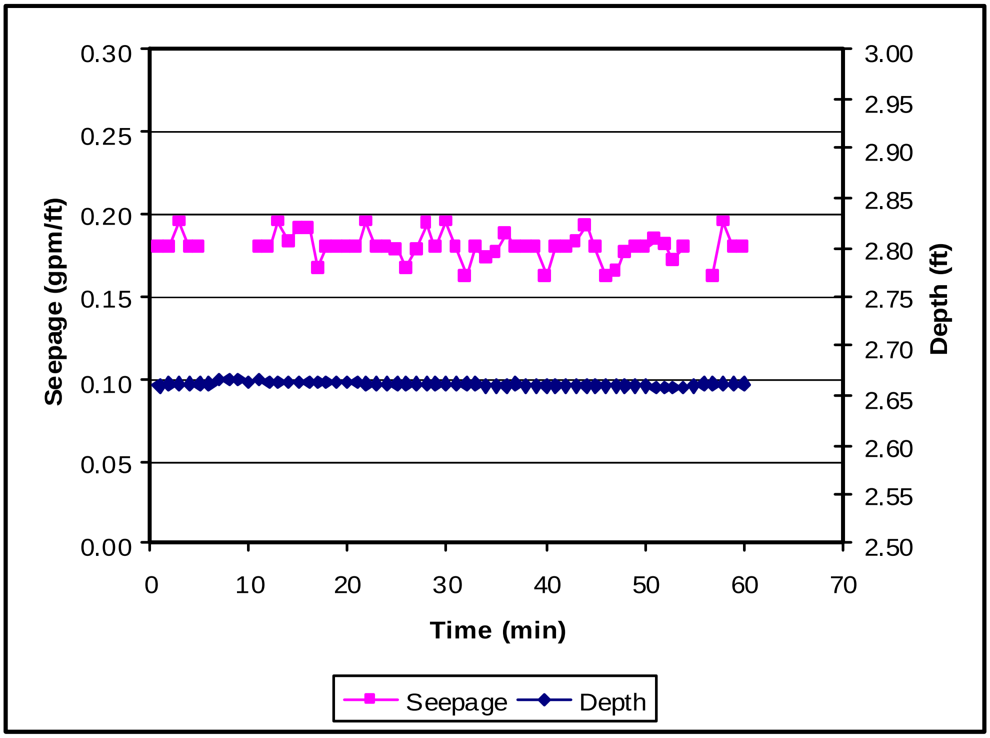

Figure 41. Seepage rates during tests with high water and small waves. Measurements started at 1444 hrs.

Laser measurements of the structure show a sudden change in the center high distance at about 50 min. into the test, indicating the target moved away from the laser by about 0.06 ft (Figure 42). It is not likely that the structure would move away from the lasers when the water pressure is pushing the structure towards the lasers. The laser target is taped to the plastic sheeting wrapped around the structure. It is probable that the plastic sheeting shifted and caused the target to move the 0.06 ft. However, this is just conjecture.

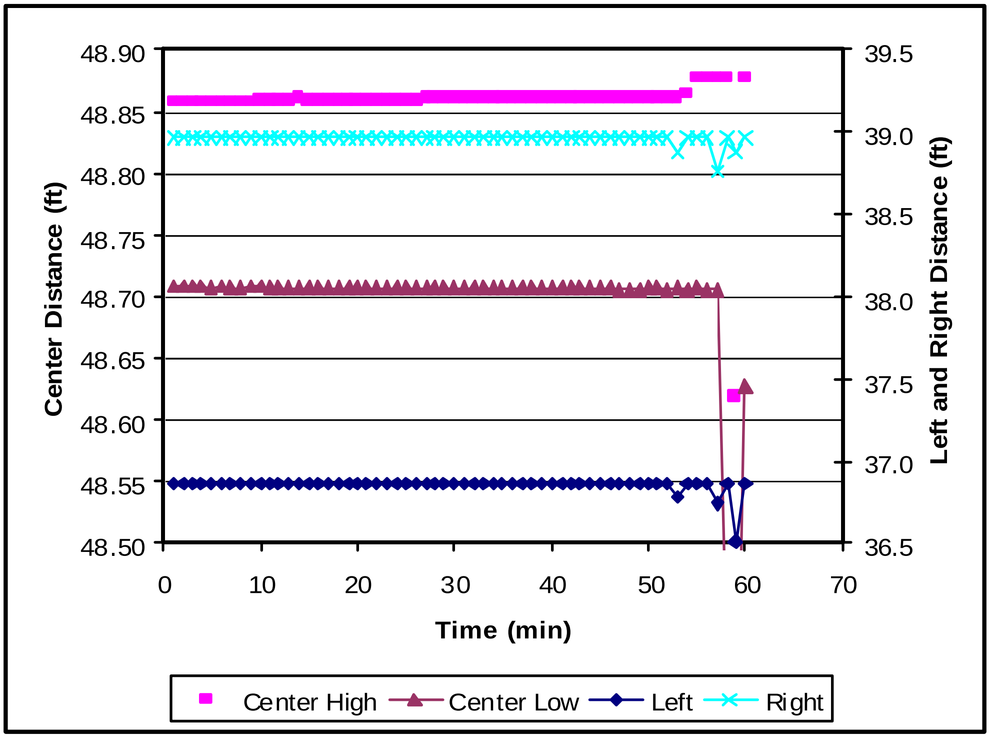

Figure 42. Movement of structure sections during tests at high water with small waves. Measurements started at 1444.

High water, medium waves

Three runs of 10-min length each were made at a depth of 80% of structure height (2.67 ft) and medium waves (6-8-in. wave height and 2-sec wave period). Waves were observed increasing in height during the run due to reflected wave energy, which is the reason runs with larger waves are limited to bursts of 10-min each. Overtopping was observed towards the left-hand end of the center section and where the structure abutted to the wing walls. Combined overtopping and seepage rate was about 3.5 gpm/ft (Figure 43). Where seepage data is missing in Figure 43 it is because the sump was being pumped down.

The water depths shown in Figure 43 should not be confused with wave action. Depth measurements were taken inside a dampening tube which will not reflect the actual motion of waves with a 2-sec period. Instead the depths shown in Figure 43 are 10-sec averages of the readings inside the dampening tube. The fluctuations in elevation are a result of the wave action, but are not to be confused with a direct recording of the waves.

A slight movement (0.01 ft) is observed at the center high laser during the first 100 sec of the run (Figure 44). It is likely that this apparent movement is due to wave action tightening the plastic sheeting across the top of the barrier and causing the plastic sheeting inside the barrier to move slightly away from the barrier and towards the laser. Total movement is about one-eighth in.

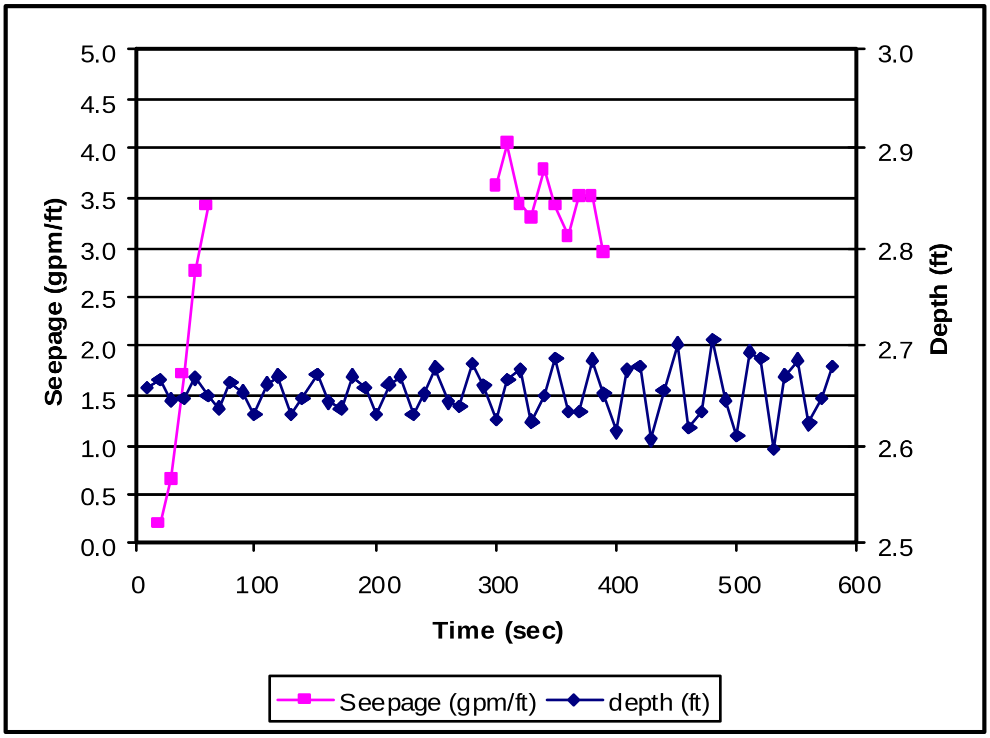

Figure 43. Seepage, overtopping, and water surface elevation during second run with high water and medium waves.

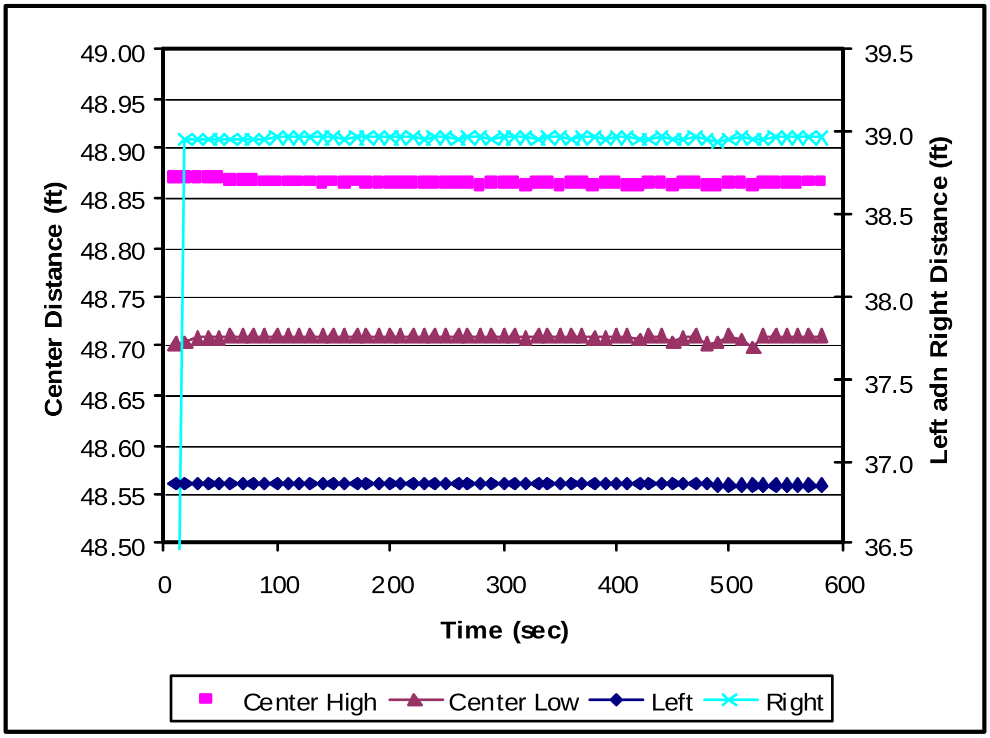

Figure 44. Structure movement during second run with high water and medium waves.

High water, high waves

Before starting the run with high waves (10-to 12-in. wave heights and 2-sec wave period), the seepage rate was about 0.16 gpm/ft. With the overtopping from the waves, the combined seepage and overtopping was about 5 gpm/ft (Figure 45). The increase in fluctuations in water surface elevation due to the waves in evident in Figure 45, but again the fluctuations shown are 10-sec averages of depths taken inside a dampening tube and are not direct representation of wave action.

The apparent movement of the structure seen in Figure 46 is most likely due to laser reflections off the overtopping water. The laser data is collected at about 30 Hz, but the plot shows the data reduced to 10-sec averages in order to keep the file sizes manageable. As a wave overtops the structure, the overtopping water flows down in front of the target taped to the plastic sheeting surrounding the structure (Figure 47). The lasers reflect off the water surface instead of the target, causing false indications of structure movement. No actual movement of the structure was observed.

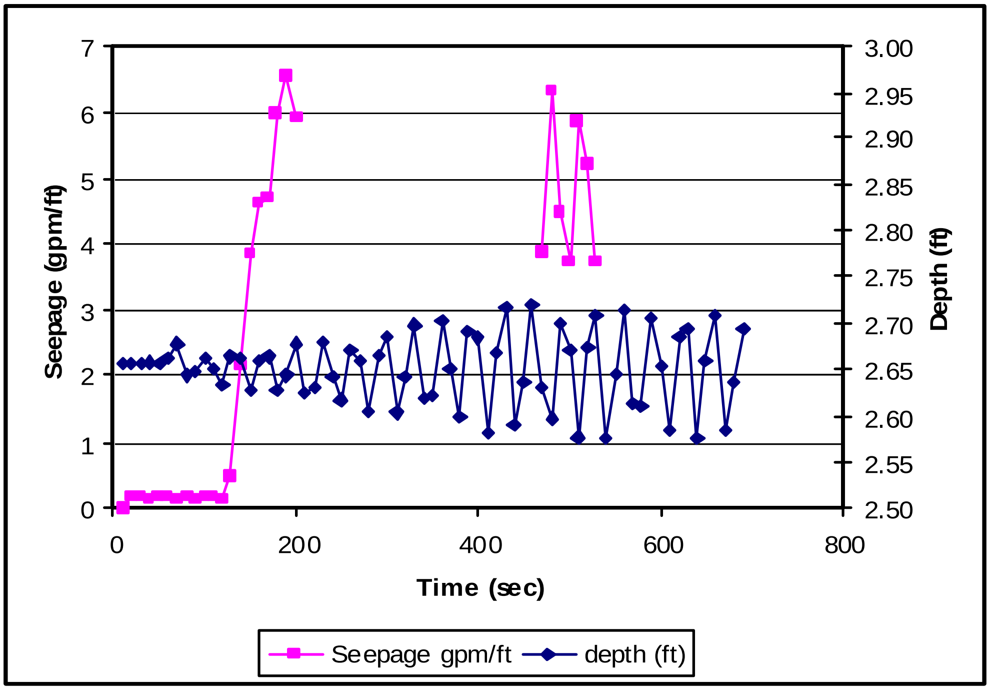

Figure 45. Seepage plus overtopping, and water surface elevation during tests with high water and large waves.

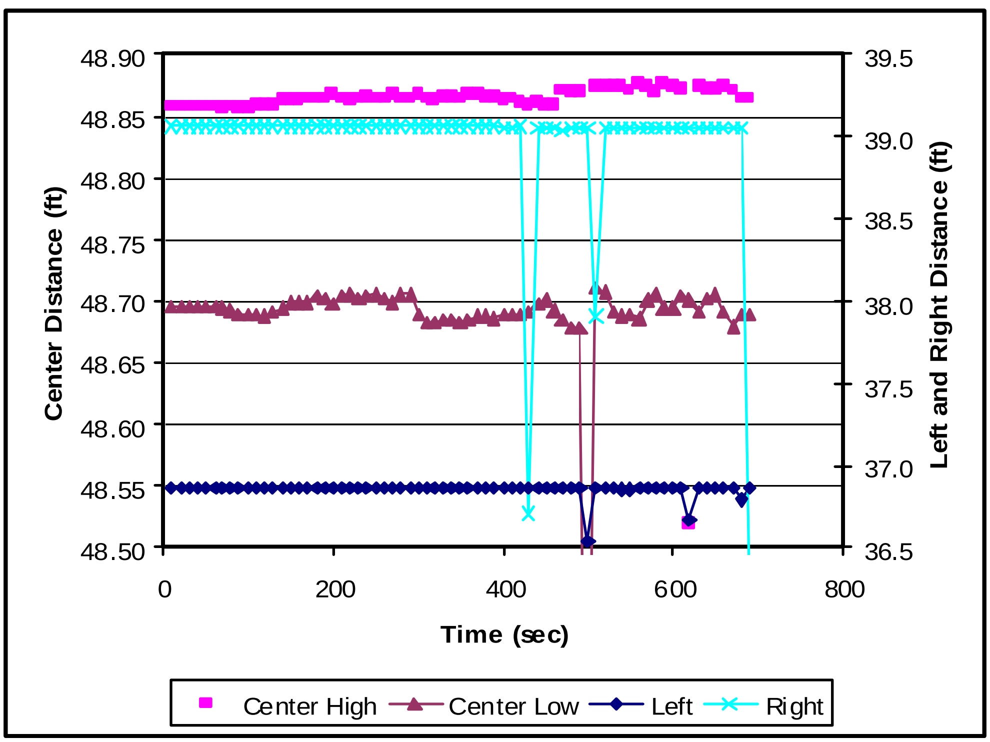

Figure 46. Structure movement during test with high water and large waves.

Figure 47. Wave overtopping during test with high water, large waves.

Overtopping Test

On 22 September, pumps were turned on at 0815 to raise the water level for the overtopping test. Seepage plus overtopping as the water level was brought up are shown in Figure 48 and structure movement is shown in Figure 49.

Water reached the front edge of the structure at a depth of 39.8 in., but had not yet started flowing over the structure. Actual overtopping began at 0919. By 1019, the water was at a depth of 42.4 in. which resulted in a flow over the left section of the structure between 1.5 and 1.75 in. deep, flow across the center section was between 1.75 and 3 in. deep, and part of the right section was dry.

The water level was dropped to a depth of 42.2 in. for the duration of the test. Depths of flow over the structure ranged from 1 in. to 3.5 in., except for about one-half of the right section which was dry. Overtopping during this time period is shown in Figure 50.

No movement or damage to the structure was observed during the test.

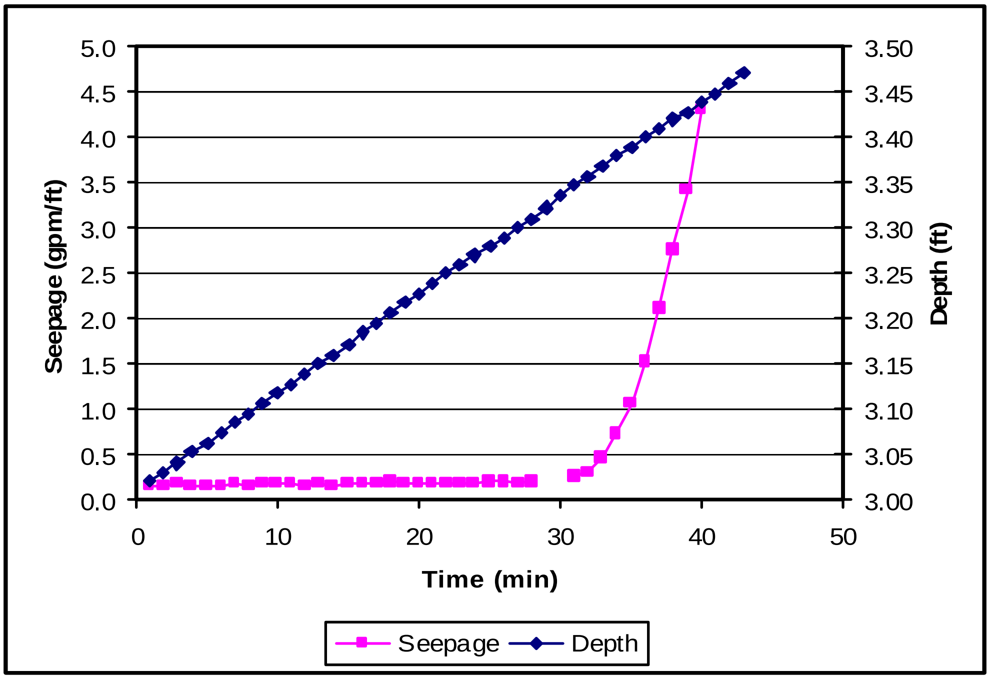

Figure 48. Water level and seepage rate as water is brought up for overtopping test. Measurement started at 0850 hrs.

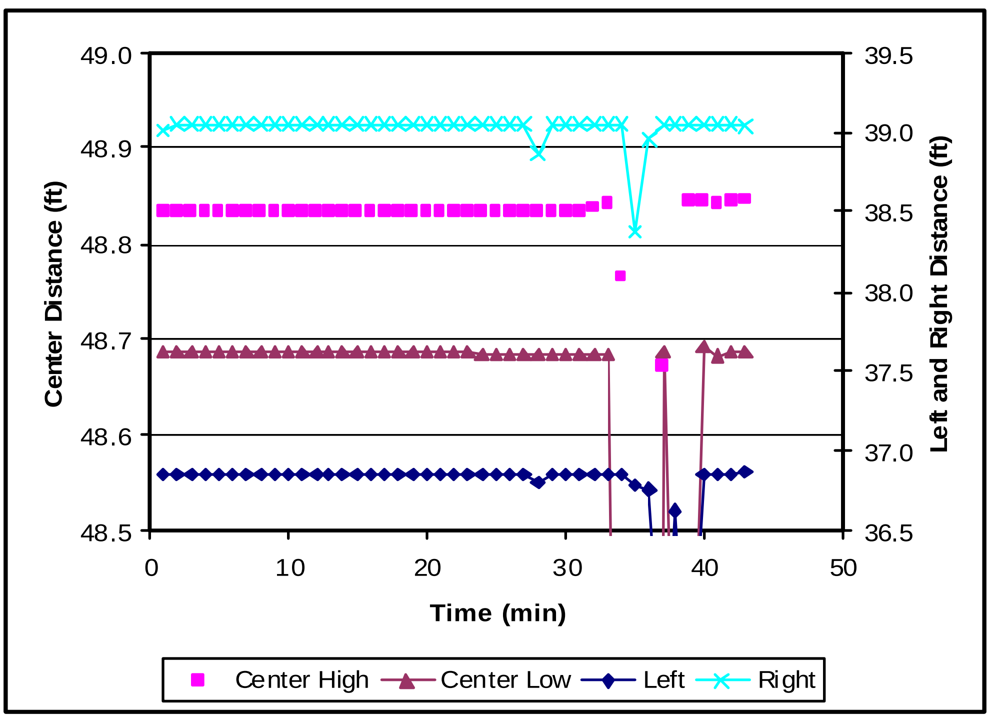

Figure 49. Structure movement as water level is increased for overtopping test. Measurements started at 0850 hrs.

Figure 50. Flow over the barrier during the overtopping test.

Debris Impact Test

To test the flood fighting structures for their ability to withstand impact from debris floating by in an actual flood, a debris impact test was conducted as part of the Standardized Testing Protocol. The debris impact test involved towing two logs into the structure with a winch located inside the test area (Figure 51). The logs were towed in at a 20-deg angle at a speed of 5 mph (7 ft/sec), and power to the winch was cut just prior to impact with the structure. Both logs were 10-ft-long and cut from a creosote-coated telephone pole. The smaller log was 12 in. diameter and weighed 610 lbs dry; the larger log was 16.5 in. diameter and weighed 790 lbs dry. Both logs had been soaking in water for 1-1/2 weeks prior to testing and undoubtedly had increased in weight. A piece of plywood was placed on top of the barrier to protect the plastic and fabric from being torn by the cable (Figure 52).

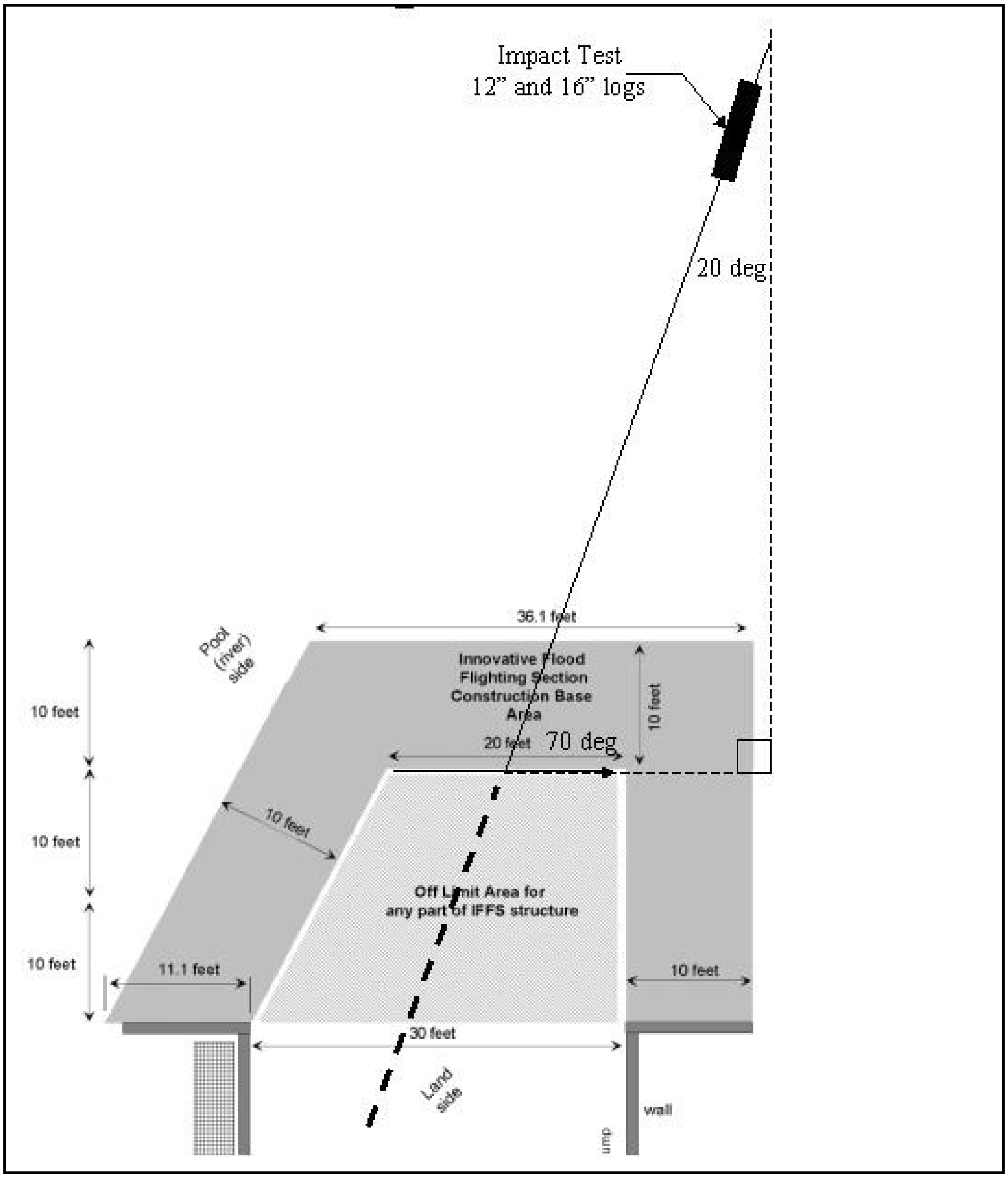

Figure 51. Setup for debris impact tests.

Figure 52. Log and protective plywood covering on the barrier.

The two logs were towed into the structure one at a time, the smaller log first (Figure 53 and Figure 54). Neither log caused any noticeable damage to the structure, not even a tear in the plastic sheeting. When the plastic sheeting was removed during disassembly at the end of test series, the Geocell fabric was searched for any signs of damage from the logs. No damage was found.

The debris impact test was conducted at a water depth of 66.7% of structure height, or 2.2 ft. Seepage rates recorded as the water depth was lowered to the test level and held throughout the test are shown in Figure 55.

Figure 53. Debris impact test with log towed into the barrier.

Figure 54. Debris impact test as log struck barrier.

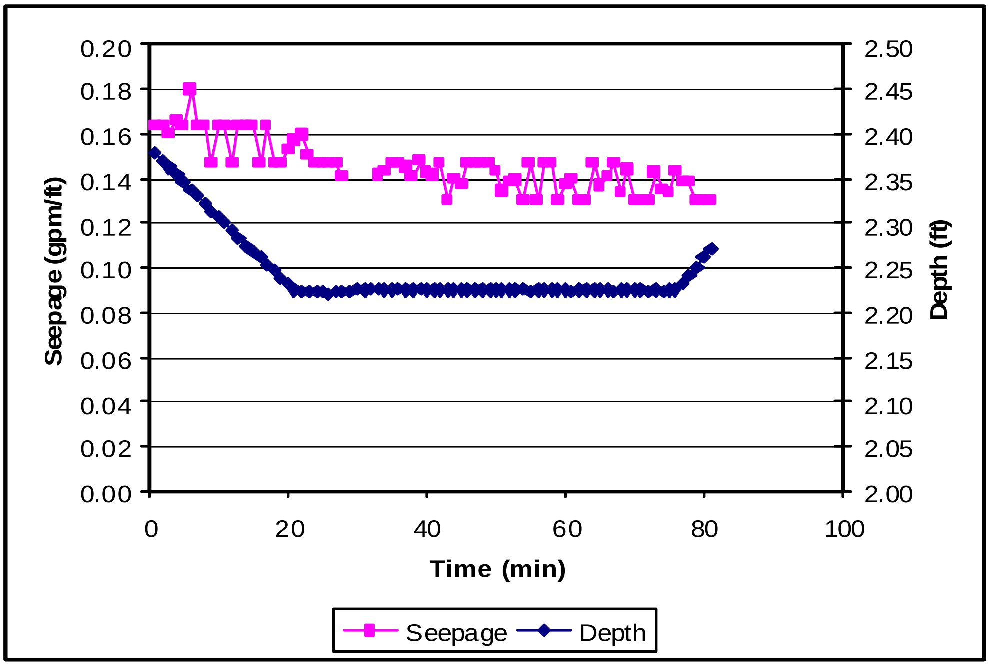

Figure 55. Seepage rates during debris impact test.

Movement of the structure is shown in Figure 56. Lines in the figure that drop below the graph were caused by people walking between the lasers and the targets.

Data recording for Figure 56 started at 1342 hrs. From the video of the log impact, the first log impact was at 1427 and the second one at 1438 hrs. Although the computers were not synchronized, impacts should therefore appear in Figure 56 at approximately minutes 45 and 56. There are no indications of an impact at minutes 45 and 56 in the figure, but there appear to be small movements in the center low data indicated at minutes 57 and 68, and it is possible the computer clocks could differ by 10 minutes. However, the data points in Figure 56 are 1-min averages of the laser data recordings. Examination of the raw data shows that none of the apparent movements of the structure are associated with movements of less than one-half meter, and it is clear from the video that there was no movement of anywhere near that magnitude. In fact, there was no movement at all visible in the video. In other words, the apparent small movements in Figure 56 were caused by someone walking in front of the target for a short period of time such that the one-min average showed a small movement in the target.

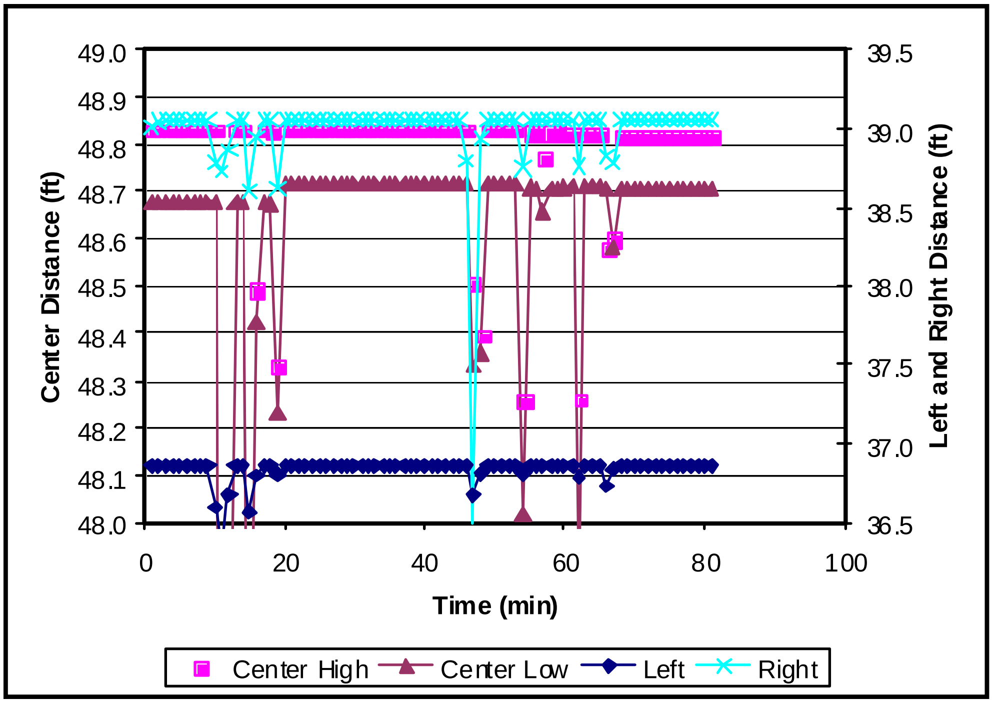

Figure 56. Structure movement during debris impact test.

Closer examination of the raw data shows that center high target moved inward by 0.003 m (0.12 in.) and the center low laser target moved inward by 0.002 m (0.08 in.) at minute 54 in the recording, and that the structure then stayed in the new position. It is assumed that this movement was caused by impact with the large log. There was no evidence of any movement caused by the small log.

Disassembly

After the final test on 22 September, the plastic sheeting was removed from the structure and the structure examined while the basin was flooded at a depth of 2.88 ft. With the plastic removed, it was evident that much of the seepage was coming through the structure at the joint between Geocells where a bend was made in the Geocell to make the 63 deg angle in the layout specified by the protocol (Figure 57 and Figure 58). Although it could not be measured separately, it appeared that about one-half the total seepage was coming through this one seam. There was very little seepage where the structure was tied into the wing walls, and no other areas of concentrated flow.

Figure 57. Seepage flow through joint in barrier near the angled Geocell unit.

The joint that included the bend in the Geocells was formed by filling the first few cells in a straight line with the previous Geocell, then turning the framework and the remainder of the Geocell to form the bend (Figure 13 and Figure 14). When the frame was rotated, the Geocell was only lightly held in place because only the first cells had been filled. It is likely that the seal with the previous Geocell was loosened allowing the seepage to develop through the seam. It was not clear if the weak seam occurred in both layers of Geocell or only in the top layer.

On 23 September, the drain was opened at 0825 and disassembly started at 1538. Disassembly was conducted by 2 people including an operator for the Bobcat™ front-end loader. Equipment used included shovels and knives. Both front-end bucket and forks were used on the Bobcat™.

Figure 58. Close up of flow through joint in Geocell unit.

The plastic sheeting had already been removed. Using a box cutter, the outer wall of each cell in the Geocells was sliced vertically allowing the sand to fall out (Figure 59). All cells were cut by 1545 hrs. With one person on the Bobcat™ and one person to help pull on the fabric, the Bobcat™ operator inserted the front forks of the Bobcat™ between the upper and lower layers of Geocells and lifted the upper layer, allowing the remaining sand in the upper layer to drain out of the cells (Figure 60 and Figure 61). The Geocells thus removed were stacked for later removal.

Figure 59. Geocells are sliced open with a box cutter for removal.

Figure 60. A forklift lifts the fabric from the top layer of Geocells.

Figure 61. As the fabric is lifted, the sand separates from the cells.

The top layer of Geocells was removed by 1557 hrs.

While the top layer of Geocells lifted easily out of the sand, the Bobcat™ operator had more trouble with the lower layer. Many of the Geocells ripped when being lifted by the forks. Because the Geocells were not intended for re-use, tearing the cells was only an issue in that it made removal more difficult. The forks on the Bobcat™ were therefore swapped for the front bucket. Because the outer walls of the cells had been cut, much of the sand could be removed with the front-end loader (Figure 62). After removing the outer areas of sand, the center section was picked up with the bucket, picking up both sand and fabric. By careful dumping, the sand was dumped into the pile while the fabric either remained with the bucket or was easily removed from the sand pile by hand.

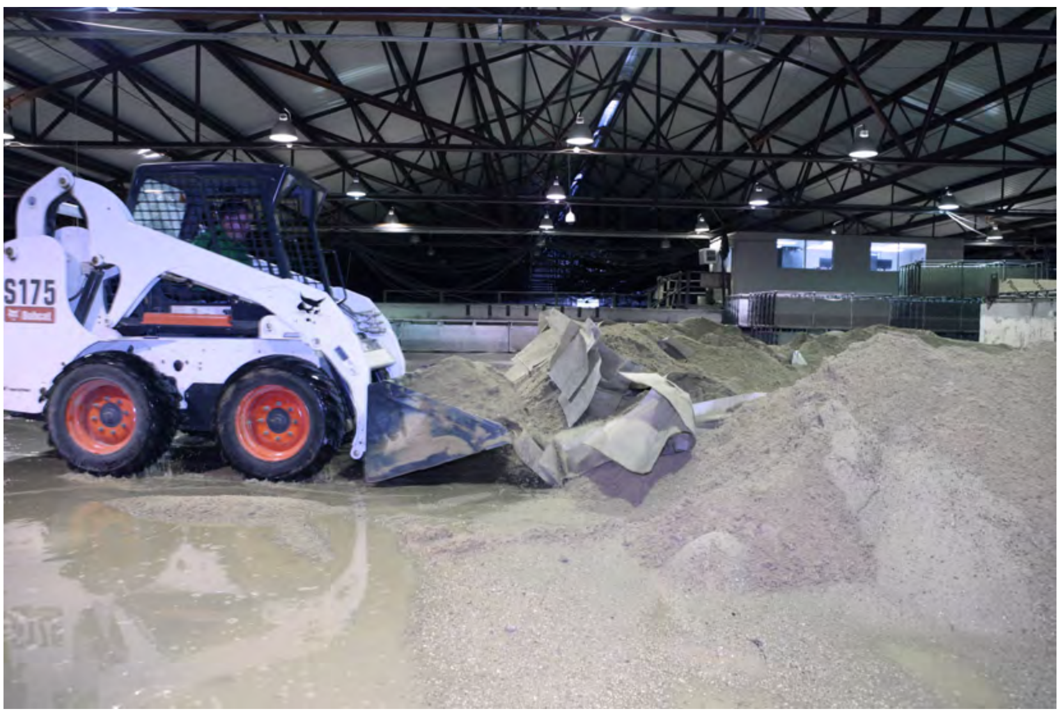

Figure 62. Sand is removed with front-end loader from each side of the barrier.

The bottom layer of Geocells was removed and the area cleaned up at 1733 hrs. Excluding safety breaks called by ERDC, the total time required to take down and clean up the site was 2.87 man-hrs.

3 Summary

The Typar® Geocell flood barrier from Fiberweb, Inc, was constructed by a 3-person crew using hand tools and a small Bobcat™ brand front-end loader. Two crews were on station and rotated in to spell the working team. Construction of the 74.3-ft-long by 54-in.-wide by 40-in. high barrier took 9 hrs 53 min, or 29.6 man-hrs, not including a lunch break.

Shovels were used to place the sand in each cell for the first part of each fill, after which sand was more readily dumped from the front-end loader with minor distribution of the sand by shovels. The time required to fill the units with sand is therefore partially dependent on the type of loading equipment, distance from the sand source to the barrier wall, and number of workers unloading the front-end loader. Total time to construct could be reduced by the use of a larger front-end loader to reduce the number of trips to the sand pile, or by placing the sand source closer to the structure.

The barrier was wrapped in plastic sheeting to reduce seepage and sealed to the wing walls with expanding foam sealant and flashing.

There was no discernable movement of the barrier during the filling of the basin and no indications the barrier was not completely stable throughout the tests.

Seepage rates are shown in Figure 63 for the hydrostatic tests in week 1 of the testing (1.0 ft, 2.0 ft, and 3.17 ft depths) and in week 2 at the start of the hydrodynamic tests at low water (2.22 ft depth) and high water (2.67 ft). Seepage rates for the two weeks are consistent. On disassembly it was found that much of the seepage, at least at high water levels, was coming through one seam between adjacent Geocell units that may have been loosened during construction. At a basin depth of 2.88 ft, it appeared that one-half the seepage was coming through this one seam.

Tests with waves, overtopping, and debris impact had no noticeable effect on the structure.

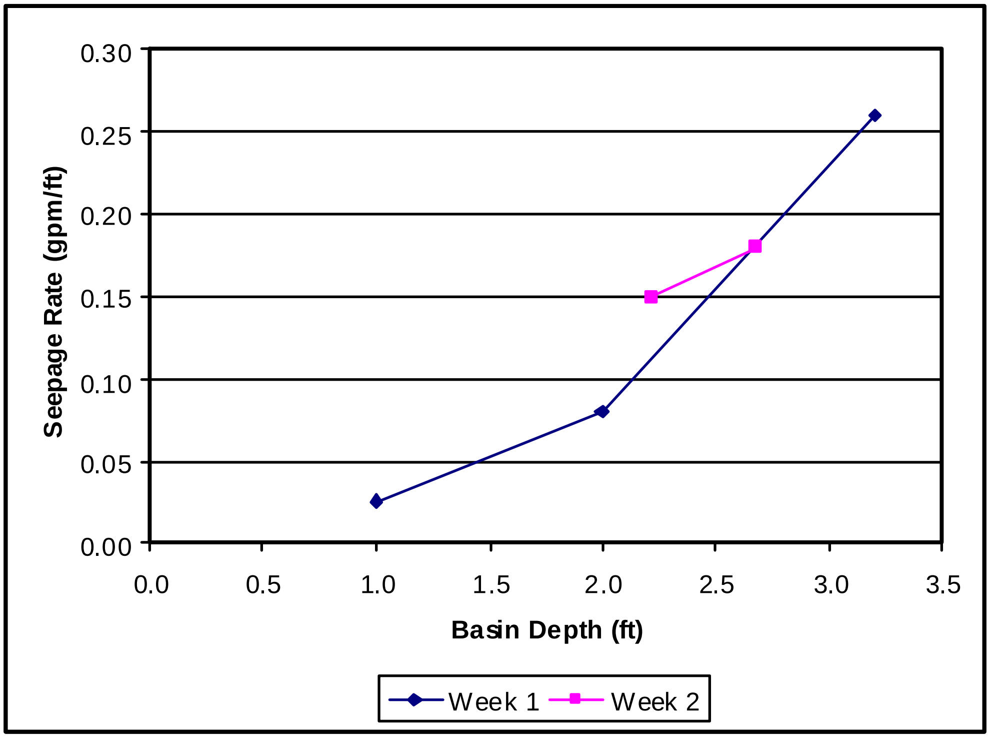

Figure 63. Summary of seepage rates. Week 1 included the hydrostatic tests. The points from Week 2 were at the start of the small waves test at low water and high water.

Disassembly was extremely quick using only shovels and the Bobcat™ front-end loader, this time equipped with forks part of the time and bucket part of the time. Total time to disassemble the structure and conduct general cleanup of the site was 2.87 man-hrs.

Table 2. Summary of Tests with Typar® Geocell.

Test	Measurements
Construction/Repairs/Disassembly	
Construction (man-hrs)	29.6
Repairs (man-hrs)	n/a
Disassembly (man-hrs)	2.9
Hydrostatic Seepage Rates (gpm/lft)	
1 ft Head	0.02
2 ft Head	0.08
0.95H Head (3.17 ft)	0.26

Other Factors

Constructability and Re-usability

The units were placed without any specialized equipment. The only mechanized equipment used was a small front-end loader/forklift. Because no large equipment or machinery is required, the units could be placed in an area with a minimum right-of-way or over surfaces not suited to heavy equipment. Although the units were placed by factory personnel, it was evident that unskilled labor could easily construct the barrier with a minimum of training or supervision.

Equipment used, in addition to the front-end loader/forklift, included shovels, box cutters, hand tampers, rakes, and wire cutters.

In addition to the sand, supplies required included plastic sheeting, expanding foam sealant, and window flashing.

The units were not intended to be re-usable and were destroyed in the removal process.

The units are designed to be stacked, and a two-unit high stack of DC-2 units was shown to be fully stable. No information is available on the maximum water depth that a wall of units can safely hold back. For water depths greater than the two layers tested, use of the wider DC-3 or DC-4 units should be considered.

Environmental

The geotextile in the Typar® Geocell units is generally inert and can be disposed of safely. However, there is a possibility of the fabric picking up contaminants from the flood waters and require special disposal.

The aluminum framework is environmentally inert and does not require disposal due to its re-usability.

The sand placed within the units will pick up any contaminants carried by the flood waters. In addition, as the sand was removed from the units during disassembly, pieces of geotextile were picked up with the sand and dumped in the refuse pile. For these reasons, special disposal of the sand may be required.

The expanding foam sealant and the window flashing used to seal the barrier to the wingwalls can be disposed of safely.

Unless contaminants are picked up during the flood, there do not appear to be any special environmental concerns with use of or disposal of a Geocell barrier.

Cost

The cost of 1,000 ft of a Typar® Geocell wall, two layers high, including 130 units of Geocell and 3 frames, is $22,140 as of October 2010.

Comparison to Sandbags Baseline Data

Table 3 compares measured parameters from the Typar® Geocell tests reported herein to baseline data collected in 2004 with a sandbag barrier following the same protocol.

Table 3. Comparison of Typar® Geocells to sandbag baseline data.

	Typar Geocell	Sandbags
Install/Remove	**Man-hrs**	
Construction	29.6	205.1
Repair 1	n/a	2.0
Repair 2	n/a	2.0
Repair 3	n/a	2.0
Disassembly	2.9	9.0
Depth (ft)	**Seepage (gpm/ft)**	
1.0	0.025	0.47
2.0	0.08	0.23
2.85		0.53
3.17	0.26	

The Typar® Geocell barrier outperformed the sandbags in every category:

- Although the sandbag barrier was only 36 in. in height and the Geocell barrier was 40 in. tall, the sandbag barrier took seven times as long to build as did the Geocell barrier, three times as long to remove, and required more heavy equipment.

- The Geocell barrier outperformed the sandbags in seepage rate at every water level tested.

- The sandbag barrier was damaged during tests with waves and failed during the overtopping test; the Geocell barrier was undamaged by waves or overtopping.

4 Conclusions

The Typar® Geocell flood fighting barrier from Fiberweb, Inc, appears to be a cost-effective means of rapidly raising a levee or providing a barrier against rising flood waters. Two layers of the Geocell DC-2 units tested easily held back waters to a depth of 3.2 ft. A barrier of the wider DC-3 of DC-4 units should be capable of holding back deeper waters, but were not tested.

Using no heavy equipment except for one Bobcat™ front-end loader, the 40-in.-high by 74.3-ft-long barrier was constructed in 29.6 man-hrs, or 0.40 man-hrs per ft. This included time spent sealing the ends of the barrier to the concrete wingwalls of the test basin, and included making both a 90-deg bend and 63-deg bend in the planform. Less time would be required to construct the barrier in a straight line as in a more typical application. Removal required only 2.9 man-hrs.

The units are not intended for re-use, except for the aluminum frames used in the construction.

The units are designed such that one man can erect a barrier by hand using only a shovel, and sufficiently lightweight that an entire length of wall can be easily transported in a backpack.

Compared to the baseline sandbag barrier data from 2004, the Geocells were much quicker to install and remove using less equipment, had less leakage at every water level tested, and were undamaged by any test in the series. The sandbags, on the other hand, were damaged during tests with large waves and failed during the overtopping test.

Evaluation of Typar® Geocell Flood Fighting Barrier, US Army Engineer Research and Development Center Coastal and Hydraulics Laboratory, Donald L. Ward, November 2010