

Modeling Report
Spring, 2005

Floating Debris Boom Design Recommendations

- Based on physical model study & literature review at UNM -

Prepared for
Albuquerque Metropolitan Arroyo Flood Control Authority



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INTRODUCTION

Storm water runoff is one of main causes of impaired water quality. In urban areas, polluted storm water runs off relatively fast and is gathered by urban collection systems (both open and closed), and then discharged to rivers and streams. Through the NPDES (National Pollutant Discharge Elimination System) program, the U.S. EPA (Environmental Protection Agency) has required that storm water pollutants must be controlled before reaching a river and/or stream.

Floating boom barriers are one example of cost effective tools for open channel debris control. Floating boom barriers have been used for river debris management, oil contaminant prevention on the coast, and for surface pollutant exclusion at the intake channels of dams. Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) is considering the use of floating boom barriers to control storm water debris on existing arroyos that are directly connected to rivers and/or natural streams. AMAFCA requested the Open Channel Laboratory at University of New Mexico to perform a physical scale model study to investigate the best effective design and applicability of floating booms in engineered arroyos.

MODELING SCOPE

The initial test was composed of varying floating boom experiments in a 1-ft rectangular flume. The flume corresponds with flow per unit width in a wider channel section. Because of the sizing of the booms, the scale of the model is approximately 1:18. A second experiment was conducted in a trapezoidal section at a 1:8 scale. This experiment took place in the same channel built for a previous model of the North Pino Arroyo. In addition, commercial floating boom barriers were reviewed for their potential effectiveness in debris exclusion in open channels. Objectives of the model study included investigating:

- materials, shapes, and sizes of the booms;
- various connections between the booms and the piers;
- the installation angle of the piers with respect to the vertical;
- the installation angle of the boom with respect to the direction of flow;
- the floating booms performance in scaled channel models over various flow rates;
- the difference in performance between the normal trapezoidal channel and the trapezoidal channel with the debris intake entry (as found on the North Pino upstream of the North Diversion Channel); and
- comparisons of the floating boom and pier model with the commercial floating boom barriers regarding the high velocity conditions of the storm water in Albuquerque's open channels.

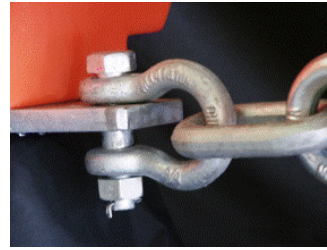
SUMMARY AND RECOMMENDATIONS

Based on the results of these modeling tests, the floating boom is recommended to be approximately 1.0 ft in diameter of Styrofoam bar covered with fiberglass in case of 6 ft deep of 132 ft² of trapezoidal sectional area arroyo. The booms should be hinged to each

other by stainless steel connectors. Figure 1 shows a commercial floating boom of such material with such connections.



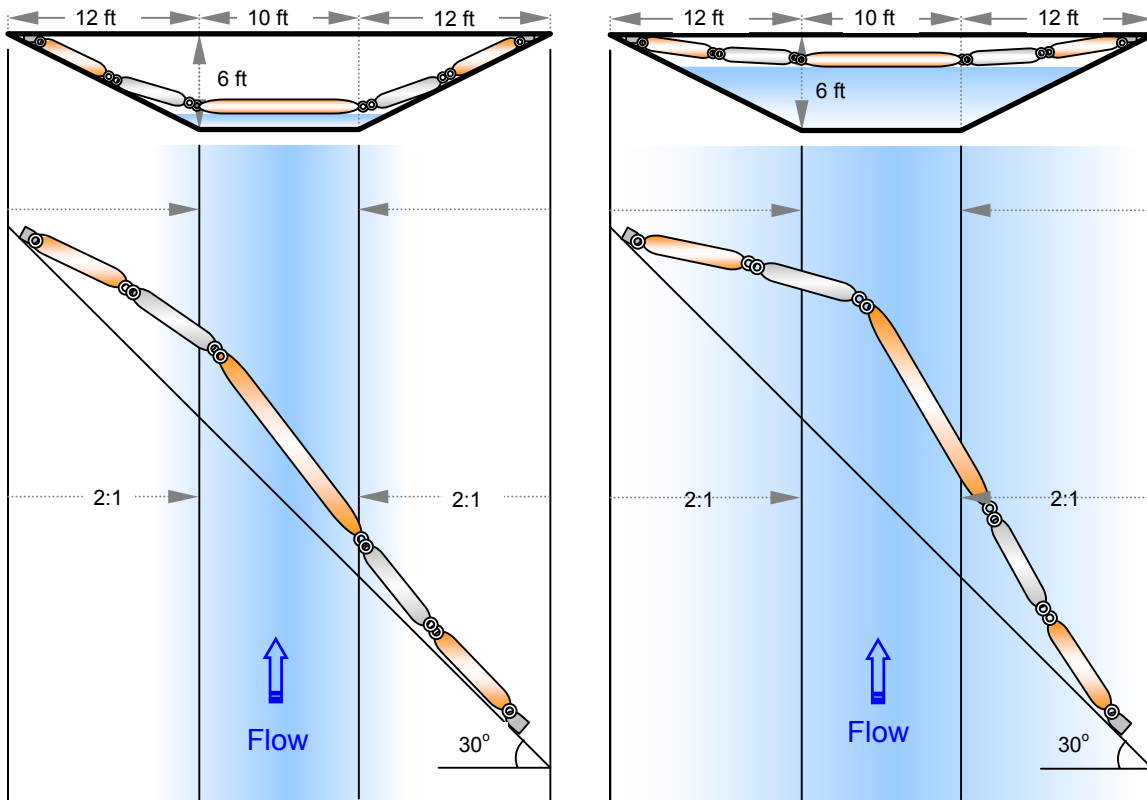
a) Floating boom materials



b) Boom hinged connections

Figure 1. Commercial Floating Boom (www.tuffboom.com)

For the floating boom setup, a 30° or less boom barrier approach angle and the pier (What piers?) sloped toward downstream are recommended. Combinations of the log boom and buoyancy boom are suitable for storm water debris control in trapezoidal open channels, while the buoyancy boom is good for sediment detentions or reservoirs. Length of the log boom should match the bed width of the channel (when placed at an angle), and couples of the buoyancy booms are good for the sidewalls because of the better flexibility to follow low and high water depth as shown Figure 2.



a) Low water depth performance

b) High water depth performance

Figure 2. Floating Boom Application in Trapezoidal Arroyo

RECTANGULAR EXPERIMENTAL FLUME TASK

Design Scenarios

Six booms were constructed from various materials and tested in the rectangular flume. The floating booms were tested at approximately an 1:18 scale based on the size of the boom diameters. The data were gathered based on tests from four flow rate conditions. Data were also gathered, where feasible, with a change in slope of the flume to increase the velocity of flow. Three screws were screwed into the bottom of the flume to simulate the boom holding piers. Plastic straws were installed around the piers to reduce the friction of the threading of the screws. The approximate angle of the booms from the flume side was 27 degrees. The location of the screw holes in the flume restricted tests at varying angles. Design scenarios are as shown in Table 1.

Table 1. Floating Boom Rectangular Flume Task Scenarios

| Materials | Connections | No. Flow Cond. | Brief Results |
|-----------|--------------|----------------|---|
| Wooden | Hinge | 3 | Booms do not easily move because of the hinge |
| | Drilled hole | 3 | Booms are not free and cantilevered with change in flow |
| PVC | Hinge | 2 | Booms are submerged because too heavy |
| | Drilled hole | 2 | Booms are more submerged |
| Styrofoam | Hinge | 4 | Works good, but hinge allows too much movement |
| | Drilled hole | 4 | Works very well, best performing design |

Modeling Summary

The hinge seemed to cause many problems when adjusting to various water depths. It caused the booms to often get caught and/or trapped, despite the material type. The hole drilled in the boom limited the boom to excessive cantilevering. It however can be a problem if material is not smooth enough for easy movement along the screw or pipe holding it in place. Therefore, It would be recommend against a hinge attached to the booms. The lighter the material shows better performance. The Styrofoam worked very well in the flume experiments. To protect it, it may be covered by perhaps fiberglass as seen in the design of surfboards.

It would be advantageous to conduct tests with a variance of angles for the booms. The flume limited this experiment to an angle of approximately 27 degrees. In additions, a hinged boom barrier model would be tested instead of the cantilevered boom system.

TRAPEZOIDAL SCALED ARROYO MODELS TASK

Design Scenarios

With experience and results of the rectangular flume task, the floating boom model was tested in the 1:8 scaled trapezoidal arroyo models. In this task, four design main objectives were considered: scaled floating booms design to test in the scaled arroyo model, floating boom barrier approach angle against inflow direction, boom holding pier angle, and boom applicability of different types of arroyo. Sixteen boom models were tested in five experimental setups and flow conditions over various flow rates changing from 11 cfs to 261 cfs in prototype as shown Table 2.

Table 2. Floating Boom Scaled Arroyo Task Scenarios

| Run # | Approach | Pier Bend | Boom Design | Arroyo Model | Results |
|-------|----------|-----------|---------------|--------------|---|
| 1 | 45° | Vertical | PVC | Intake Entry | Booms are submerged. All debris is passed. |
| 2 | 45° | 15° | PVC, Barriers | Intake Entry | Booms move easier. Side boom barrier works. |
| 3 | 30° | Vertical | PVC, Barriers | Intake Entry | Approach angle 30° is better than. |
| 4 | 30° | 15° | PVC, Barriers | Intake Entry | Best boom setup. 43% of debris is excluded. |
| 5 | 30° | 15° | PVC, Barriers | Normal | Similar results as #4. No intake entry influence. |

Modeling Summary

A range of 0.8 ft to 1.3 ft diameter boom was the best model in this test. Less and more diameter boom was easily stuck on the channel bed and did not move well following the water surface respectively. An angle of 30° of boom barrier approach angle works better than a 45° model because the 30° angle makes a longer and effective screening area. The 15° bent pier from vertical to the flow direction helps easier boom movement. The storm water debris intake entry did not effect significantly to the boom performance.

A high buoyancy boom would be recommended for easy floating. However, turbulent flow makes boom unstable moving, and it reduces debris-keeping capacity. Moreover, it is founded the set of the cantilevered boom with pier is not effective because of the disturbance of the boom movement from both boom cantilevering and piers. The hinge connected boom barrier without pier, which was installed at sidewall, showed better performances in aspect of debris keeping and model simplicity. Additional study and filed experience reviews are needed focusing on the boom barrier without pier design application in high turbulent flow.

COMMERCIAL FLOATING BOOM BARRIER REVIEW

Floating boom system has been used to install for debris or oil contaminant management, and dam/hydraulic structure safety, and waterway security. Usually commercial floating boom manufacturer divides into three different boom system; buoyancy boom, log boom, and skirt boom. Among of them, the buoyancy boom and the log boom are chosen for storm water debris exclusion, while the skirt boom is for oil contaminant catching in relatively small pollutant area.

According to the boom manufacturers, the buoyancy boom is good for debris prevention of low velocity areas such as retention and dam because independent buoyancy boom is connected each other and can cover large place as shown Figure 3. The boom material is Styrofoam covered by fiberglass, and each boom hinged with stainless steel connectors.



a) Buoyancy boom installation



b) Debris prevention on dam

Figure 3. Buoyancy Boom Applications (www.tuffboom.com)

The log boom was designed for storm water outfall diversion barriers to divert debris into recesses pollution traps as shown Figure 4. Long floating booms are hinge connected each other and are attached to a channel sidewall with steel wires. It seems not moving easier than the independent connected buoyancy booms. However, it is expected better storm water debris exclusion capability due to the debris diverting to traps especially in high velocity conditions.



a) Storm Water Drain Channel Installation



b) Debris prevention and diverting to trap

Figure 4. Log Boom Applications (www.mentanzapl.com)

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APPENDIX A: FLUME TASK RESULTS

Wooden with hinge

Diameter: 0.38 inches

Length: 7.94^A, 7.88^B, and 6.94^C inches



$Q = 200$ cfs/ft; $V = 6.3$ ft/s; $S = 0.3\%$

- Water traveled mostly over the boom A and decrease to B and C. Therefore, boom A was furthest under the surface of the water than C.
- Hinge does not allow for easy movement.
- Debris cannot be trapped by the booms because the surface area of the booms above the water surface is not sufficient.
- Hinge allowed booms to cantilever.

$Q = 500$ cfs/ft; $V = 16.3$ ft/s; $S = 0.3\%$

- Same results with one pump except the depth of the booms from the surface of the water was much greater for each booms.

$Q = 230$ cfs/ft; $V = 7.7$ ft/s; $S = 0.6\%$

- Hinge allIncreased slope created greater velocity and trapped the booms against the screws, which did not allow for much movement of the booms.

Wooden without hinge – hole drilled through boom

Diameter: 0.38 inches
Length: 7.94^A, 7.88^B, and 6.94^C inches
Hole Diameter: 0.25 inches



$Q = 200$ cfs/ft; $V = 6.3$ f/s; $S = 0.3\%$

- Water traveled mostly over the boom A and decrease to B and C. Therefore, boom A was furthest under the surface of the water than C.
- Increased friction of hole and plastic surrounded screw. Decreased movement of boom along screw.
- Debris cannot be trapped by the booms because the surface area of the booms above the water surface is not sufficient.
- Booms easily cantilevered with change in flow.

$Q = 500$ cfs/ft; $V = 16.3$ f/s; $S = 0.3\%$

- Same results with one pump except the depth of the booms from the surface of the water was much greater for each booms.

$Q = 230$ cfs/ft; $V = 7.7$ f/s; $S = 0.6\%$

- Increased slope created greater velocity and trapped the booms against the screws, which did not allow for much movement of the booms.

PVC pipe with hinge

Diameter: 0.81 inches
Length: 7.69^A, 7.68^B, 7.19^C inches



$Q = 200$ cfs/ft; $V = 6.3$ f/s; $S = 0.3\%$

- Too heavy, water traveled mostly over the boom A and decrease to B and C. Therefore, boom A was furthest under the surface of the water than C.
- Debris cannot be trapped by the booms because booms are underwater

$Q = 500$ cfs/ft; $V = 7.7$ f/s; $S = 0.3\%$

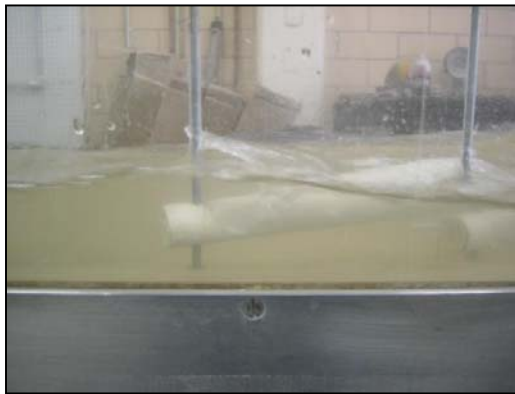
- Hydraulic jump created due to submerged boom.

PVC pipe without hinge – hole drilled through boom

Diameter: 0.81 inches

Length: 7.69^A, 7.69^B, and 7.19^C inches

Hole Diameter: 0.25 or 0.38 inches



$Q = 200$ cfs/ft; $V = 6.3$ f/s; $S = 0.3\%$

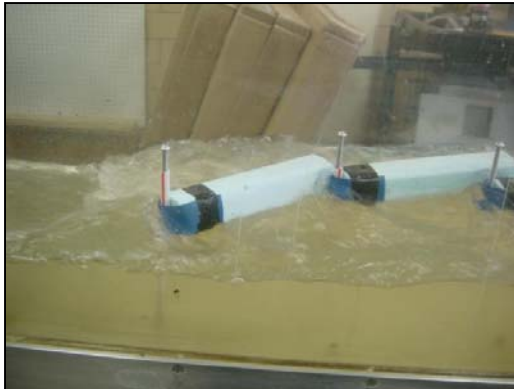
- Too heavy, water traveled mostly over the boom A and decrease to B and C. Therefore, boom A was furthest under the surface of the water than C.
- Booms are submerged

$Q = 500$ cfs; $V = 7.7$ f/s; $S = 0.3\%$

- Hydraulic jump created due to submerged boom.

Styrofoam with hinge

Diameter: 0.38 inches
Length: 8.25^A, 7.19^B, and 7.13^C inches



$Q = 200$ cfs/ft; $V = 6.3$ f/s; $S = 0.3\%$

- Float very well.
- Debris is easily trapped by the booms because the majority of the booms are above water surface.
- Hinge on booms allow for too much movement and often prevent easy movement.

$Q = 500$ cfs/ft; $V = 16.3$ f/s; $S = 0.3\%$

- Still float well, but some problems adjusting to water depth because of hinge.

$Q = 200$ cfs/ft; $V = 7.7$ f/s; $S = 0.6\%$

- Still float well, but some problems adjusting to water depth because of hinge.

$Q = 500$ cfs/ft; $V = 16.2$ f/s; $S = 0.6\%$

- Still float well, but some problems adjusting to water depth because of hinge.

Styrofoam without hinge – hole drilled through boom

Diameter: 0.38 inches
Length: 8.25^A, 7.19^B, and 7.13^C inches
Hole Diameter: 0.31 inches



Q = 200 cfs/ft; V = 6.3 f/s; S = 0.3%

- Float very well.
- Debris is easily trapped by the booms because the majority of the booms are above water surface.
- Hole allows for easier movement of booms, yet restrains to prevent major cantilever.

Q = 500 cfs/ft; V = 16.3 f/s; S = 0.3%

- No problems, adjusts well.

Q = 230 cfs/ft; V = 7.7 f/s; S = 0.6%

- No problems, adjusts well.

Q = 500 cfs/ft; V = 16.2 f/s; S = 0.6%

- No problems, adjusts well.

APPENDIX B: ARROYO MODEL TASK RESULTS

Modeling results summary

Model Performance Diagram

| <u>Model</u> | <u>Run 1</u> | <u>Run 2</u> | <u>Run 3</u> | <u>Run 4!</u> | <u>Run 5</u> | <u>Rating</u> | <u>Rank</u> |
|-------------------|--------------|--------------|--------------|---------------|--------------|---------------|-------------|
| 1 | No | n/a | n/a | n/a | n/a | 0 | 15 |
| 2 | No | No | 100% | 100% | n/a | 50 | 9 |
| 3 | No | Maybe | 100% | 100% | n/a | 50 | 8 |
| 4 | No | Maybe | 98% | 91% | *91% | 83 | 1 |
| 5 | No | Maybe | 16% | 68% | n/a | 45 | 10 |
| 6 | No | Maybe | 14% | 77% | n/a | 47 | 11 |
| 7 | n/a | Maybe | 90% | 99% | *56% | 74 | 2 |
| 8 | n/a | Maybe | 78% | 73% | n/a | 67 | 3 |
| 10 | n/a | Maybe | 43% | 83% | 60% | 59 | 7 |
| 8 (sides) | n/a | Maybe | 83% | n/a | n/a | 67 | 5 |
| 10 (sides) | n/a | Maybe | 78% | n/a | 60% | 63 | 6 |
| 7 (back) | n/a | No | n/a | n/a | n/a | 0 | 14 |
| 10 (back) | n/a | No | n/a | n/a | n/a | 0 | 13 |
| 5 mod. | n/a | n/a | n/a | 96% | *38% | 67 | 4 |
| 6 mod. | n/a | n/a | n/a | 59% | *26% | 43 | 12 |

No Did not work
 Yes Worked
 Maybe about half boom (s) worked
 n/a Not Tested
 % % peanuts diverted during test

Rating: avg. % and No/Maybe/Yes
 No=0
 Maybe=50
 Yes=100

! hydraulic jump and eddy caused prob.
 * model run with model 8 (sides)

Rank: ties were broken by evaluating the rest of the data and test observations.

Table 3. Buoyancy of Models

| Model | Buoyancy |
|--------------|-----------------|
| 1 | 0.67 |
| 2 | n/a |
| 3 | n/a |
| 4 | 0.54 |
| 5 | 0.34 |
| 6 | 0.51 |

Setup 1st Run

- 45 degree approach angle
- 6 x 5" spaced piers w/ plastic coating
- Flow rate range: 11 cfs ~ 261 cfs
- Testing of boom models 1 ~ 6



#1: Sank- sealant disintegrated



#2: No movement-water over top



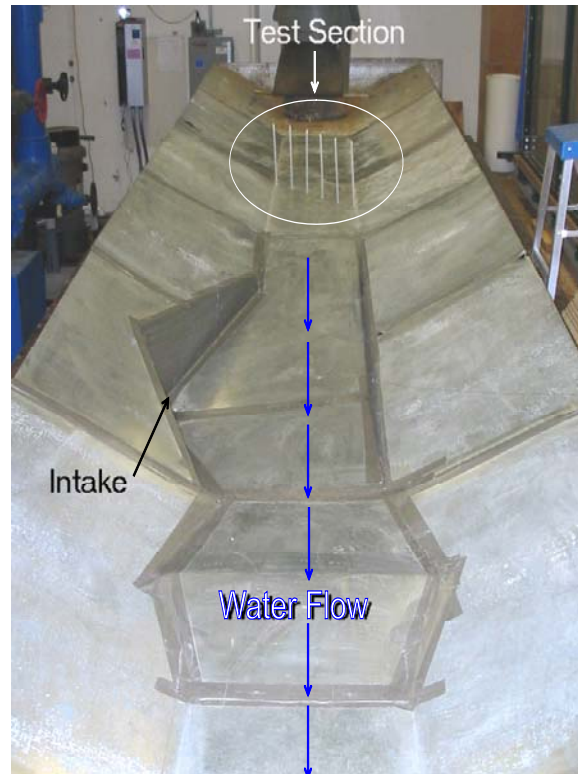
#3: No movement-water over top



#4: No movement-water over top

Setup 2ND Run

- 45 degree approach angle
- 6 x 5" spaced piers w/ plastic coating
- Flow rate range: 11 cfs ~ 261 cfs
- Testing of boom models 2 ~ 6 +7, 8, 10 & Side 8,10



#6: Cantilever/ water slightly over top
#8: Part floated/trapped under #5



#8: Rose up/ water over top/
ends rose above water



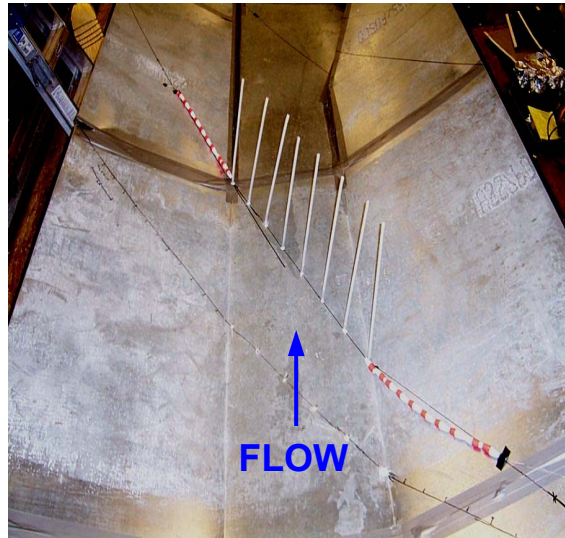
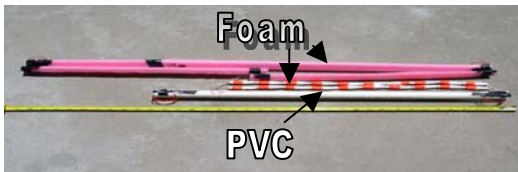
#10 (back): Bend in center/ float
rose above water



#10 (front): Floats/ velocity: low-works
high-doesn't work

Setup 3RD Run

- 45 degree approach angle
- 8 x 5" spaced piers w/ plastic coating
- Flow rate range: 11 cfs ~ 261 cfs
- Testing of boom models 2 ~ 6 +7, 8 10 & Side 8,10



#6: Doesn't work-cantilever/
water over top



#7: + floats/ diverts floaters
- doesn't lower



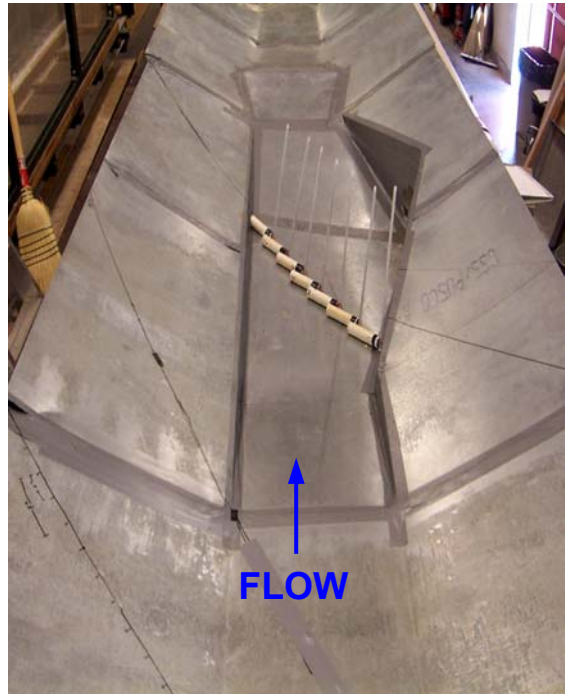
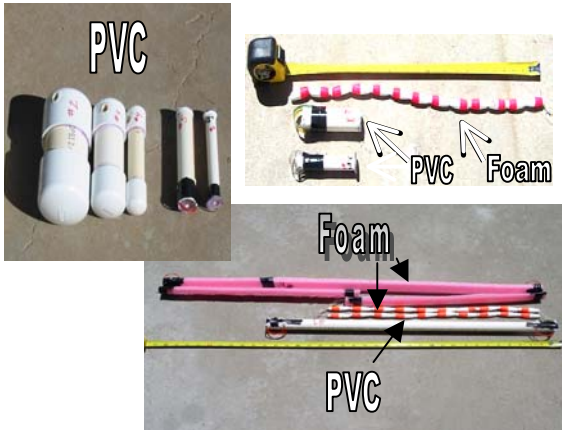
#8: + diverts most floaters/ floats
- ends don't lower



#8 (sides): + floats
- doesn't lower

Setup 4th Run

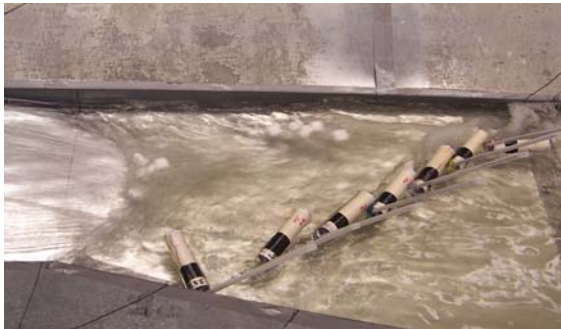
- 30 degree approach angle
- 8 x 5" spaced piers w/ plastic coating
- Flow rate range: 11 cfs ~ 261 cfs
- Testing of boom models 2 ~ 6 +7, 8
5 & 6 mod



#5: + 4 booms float
- doesn't lower



#6: + 3 booms float
- doesn't lower



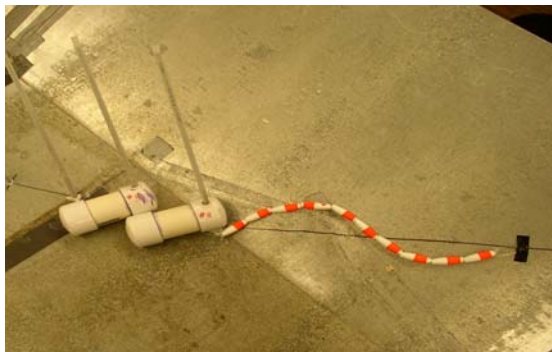
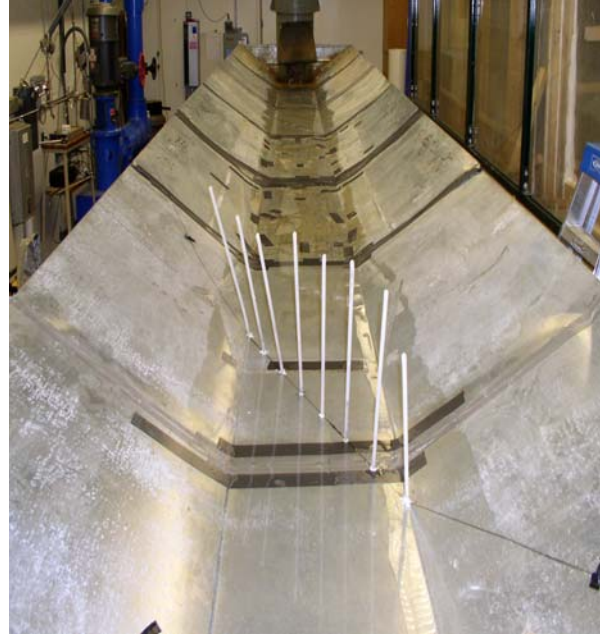
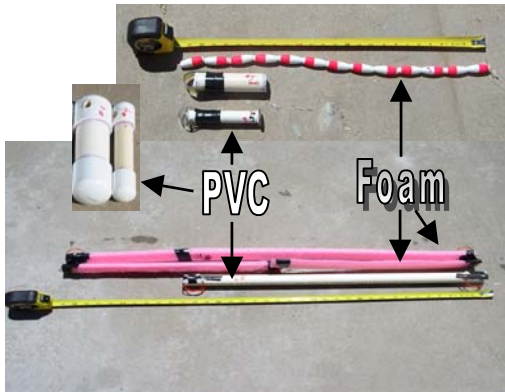
#5 (mod): Work/ don't lower well/
don't rise immediately



#6 (mod): Work/ don't lower well/
Don't rise immediately

Setup 5th Run

- 30 degree approach angle
- 8 x 5" spaced piers w/ plastic
- Flow rate range: 11 cfs ~ 261 cfs
- Testing of boom models 3 ~ 6 +7, 8, Side 8, 10



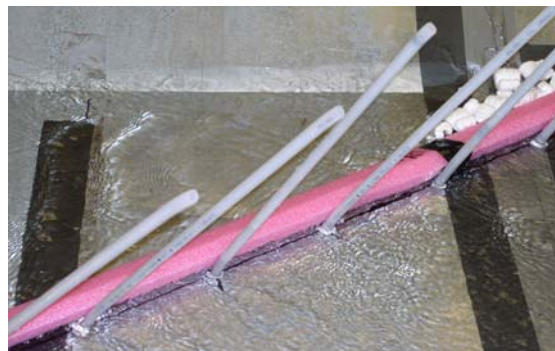
#3: Don't lower (testing cancelled)
#8: n/a



#4: Works
#8: Floaters over occasionally/ worked



#7: Works at low flow
#8: Works



#10: Works