An Evaluation of

Swimming Pool Alarms

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EXECUTIVE SUMMARY

On average each year 350 children under the age of five years drown in swimming pools, with most deaths occurring in residential settings. Also each year, on average, another 2,600 children under five years of age are treated in hospital emergency rooms for near-drowning incidents in swimming pools. About 79 percent of these incidents occur at a home location. These numbers have remained relatively unchanged over the past several years.

During 1999 and early 2000, the U.S. Consumer Product Safety Commission (CPSC) staff conducted a review of commercially available swimming pool alarm systems designed to detect water disturbance or displacement. There are no voluntary standards that define applicable performance requirements for disturbance or displacement type products.

The CPSC staff evaluated four water disturbance alarms and a wristband. Two of the disturbance systems used surface wave detection circuitry, while the other two detected sub-surface disturbances. The fifth device was a wristband (to be worn by a child) intended to alarm when exposed to water. All of the products incorporated remote alarm receivers, some at an additional cost.

Test results showed that the subsurface pool alarms generally performed better. They were more consistent in alarming and less likely to false alarm than the surface alarms. When a test object, intended to simulate the weight of a small child, was pushed into the pool, the subsurface sensors detected it most reliably. The subsurface alarms can also be used in conjunction with solar covers, whereas the surface alarms cannot.

One surface alarm performed almost as well as the subsurface alarms. The wristband alarmed when submerged in pool water or exposed to another water source, such as tap water.

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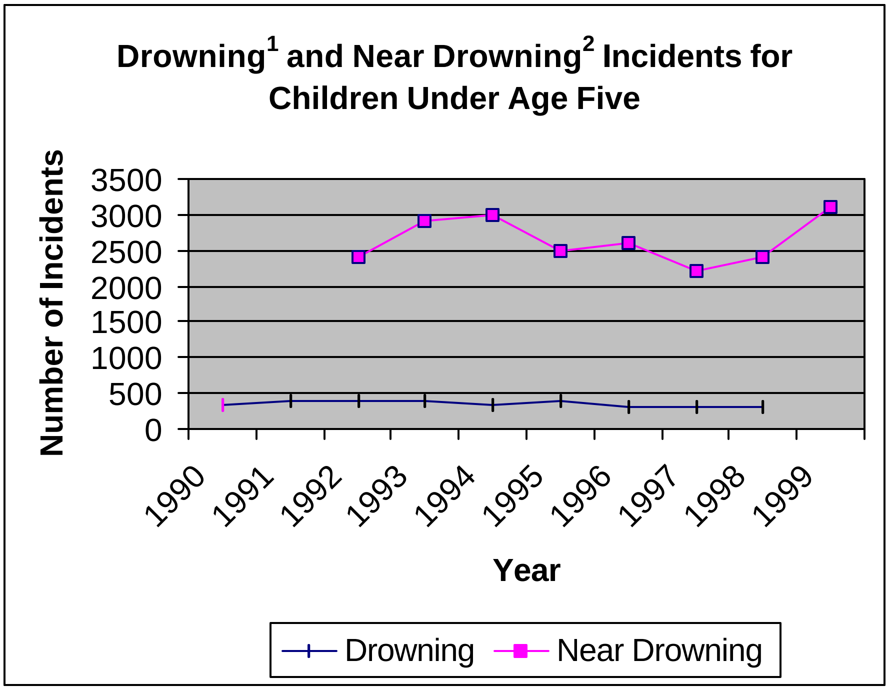
INTRODUCTION

Each year, on average, 350 children under five years of age drown in swimming pools, with most deaths occurring in residential settings. Also each year, on average, 2,600 children under five years of age are treated in hospital emergency rooms for near-drowning incidents in swimming pools. About 42 percent of the incidents require hospitalization of the child. About 79 percent of the near-drowning incidents occur in a residential setting. These numbers have remained relatively unchanged for the past several years (see graph below).



[1]Rounded to the nearest ten – CPSC Death Certificate and Injury or Potential Injury Incident Files, 1990-1998
[2]CPSC National Electronic Injury Surveillance System (NEISS), 1992-1999

During 1999 and early 2000, the U.S. Consumer Product Safety Commission (CPSC) staff conducted a review of commercially available swimming pool alarm systems designed to address pool-related injuries and drowning. A similar assessment was conducted in 1987[3]. Product designs have not changed significantly from that time.

The staff's review focused on water intrusion alarm systems designed to sense disturbance or displacement of the pool water. In addition, the staff assessed a wristband that alarms remotely when exposed to water.

MARKET INFORMATION

Water intrusion devices including a remote alarm are priced from $149 to $200 for surface wave sensor alarms and between $190 and $250 for subsurface disturbance sensor alarms. The wristband alarm system, an intrusion detector recently introduced, costs $179 for one wristband and the remote alarm. It is estimated that about 24,000 pool alarms are sold annually and that sales have doubled since 1994.

[3] Memo from Ronald L. Medford to the Commission, Contract Report on Testing of Swimming Pool Alarms, April 21, 1987.

According to recent estimates by the National Spa and Pool Institute (NSPI), there are about 7 million residential pools in the continental United States. Approximately 3.8 million pools are inground (constructed of gunite, vinyl, or fiberglass), and 3.2 million are above ground. Pool sales are from 120,000 to170,000 annually for inground pools and 300,000 to almost 500,000 for above ground pools, with the majority of inground pools being of gunite construction.

ALARM SYSTEM TECHNOLOGIES

There are no voluntary standards addressing performance or design requirements for pool water disturbance or displacement type alarm systems. Staff evaluated four different alarm systems and a wristband with remote alarm to determine their effectiveness in detecting water intrusions. Two of the displacement/disturbance devices detected surface waves while the other two detected subsurface disturbances. A fifth device was a wristband (to be worn by a child) which detected exposure to water. All of the products incorporated remote alarm receivers.

All of the alarm systems required 9-Volt batteries for operation. The remote alarm receivers required a 120 Volt outlet (step-down transformers were supplied with the power cords). One product offered the option of operating on a 9-Volt battery as well as on a 120-Volt source, which would provide continued operation during a power outage.

Surface Wave Sensors

Two surface wave sensors were evaluated. This type of sensor floats on the water surface. The sensor incorporates an electrical circuit that includes two contacts. One contact rests in the water; the second contact (above-surface contact) is adjusted so that it is resting above the water. When the above-surface contact is touched by water (from a surface wave), the electrical circuit is completed and an alarm sounds. The sensitivity of the device can be adjusted by positioning the above-surface contact closer or further away from the water surface. Sensitivity increases as the contact is positioned closer to the water surface (see Figures 1 and 2).

Subsurface Disturbance Sensors

Two subsurface disturbance sensors were evaluated. These sensors mount on the side of a pool, with portions of the devices being located 1/2 to 12 inches below the water surface. Each device relies on a wave-induced pressure change to activate alarm circuitry. One type of sensor (see Figure 3) uses a pressure-sensitive switch located at the top of a sensing throat. Water movement creates pressure changes within the sensing throat, which activates a switch to initiate an alarm. The other device relies on movement of a magnetic float below a magnetic sensor to create a signal that activates the alarm (see Figure 4).

Both sensors use electrical adjustments to control circuit response to stimuli. One of the subsurface sensors also uses a mechanical adjustment for the depth of the sensor to increase or decrease sensitivity. Sensitivity increases when the sensor is located closer to the water surface; the device is less responsive when it is placed farther below the surface.

Figure 1. Surface Wave Sensor (Sensor A)

Figure 2 Surface Wave Sensor (Sensor B)

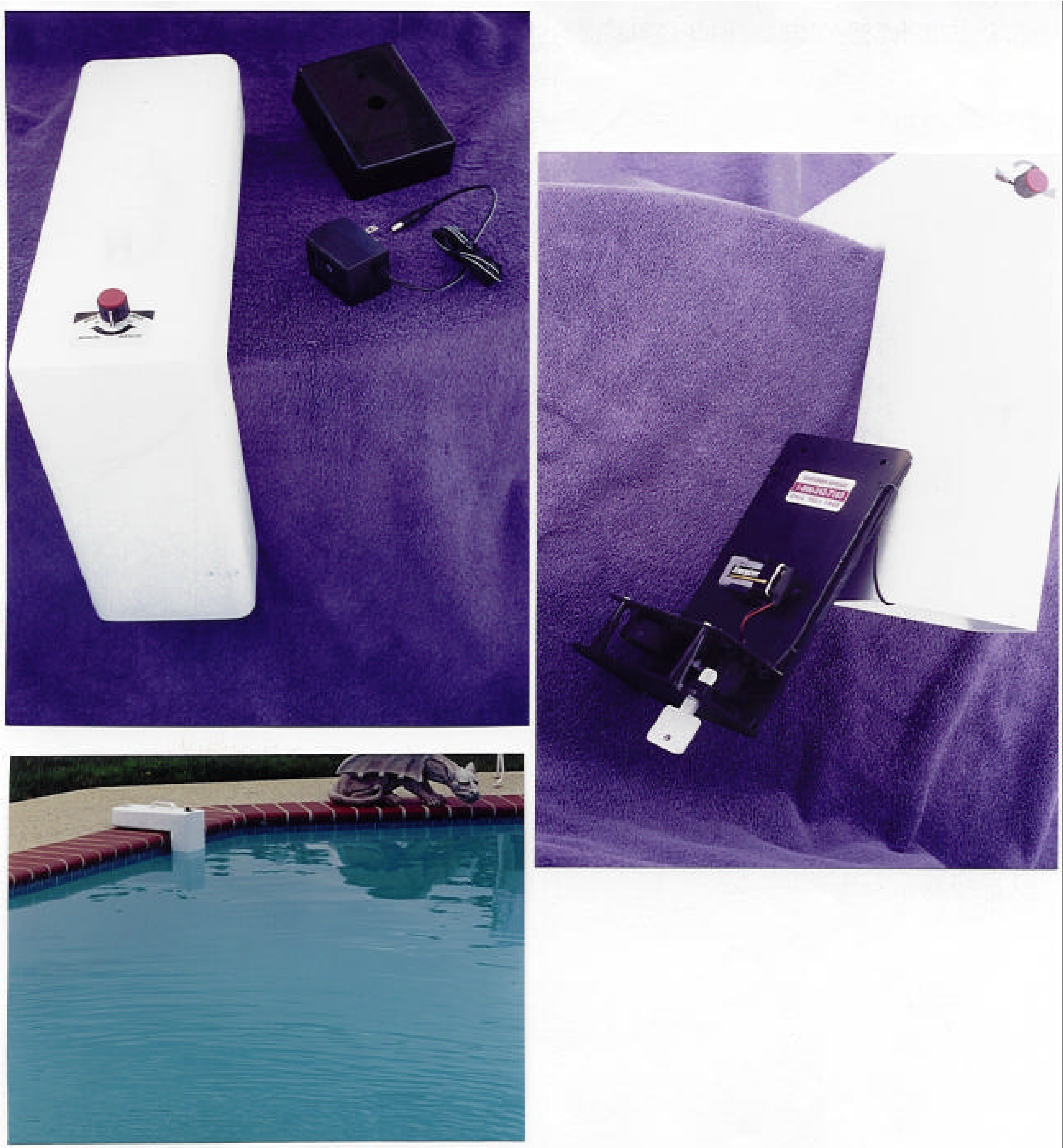


Figure 3. Subsurface Disturbance Sensor (Sensor C)

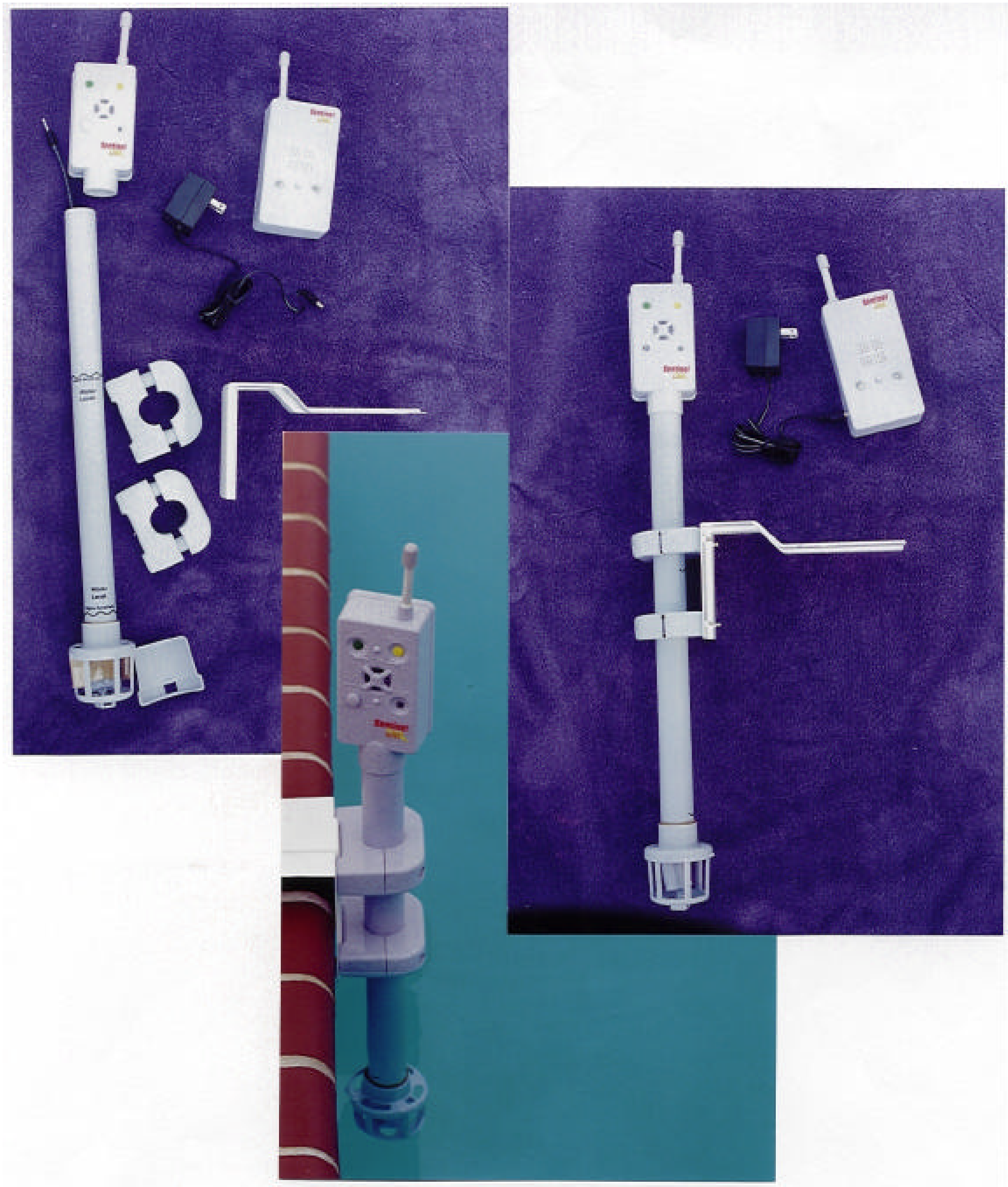


Figure 4. Subsurface Disturbance Sensor (Sensor D)

Wristband

A wristband with a remote alarm was also evaluated (see Figure 5). The wristband must be placed on a child's arm by a parent or caregiver; a locking key prevents the child from removing the band. When the sensor on the band becomes wet, the remote alarm is activated, warning the parent that the wristband has been exposed to water. There are no sensitivity adjustments for the wristband. The wristband is battery operated, and the unit is sealed. Once the battery is discharged, the wristband sensor must be replaced. The user must be cognizant of the receiver "turtle" color and be sure the replacement wristband matches that color to insure proper alarm operation.

TEST FACILITIES

Alarm tests were conducted at six different pool sites. The pools were both indoors and outdoors and differed in size, shape, and depth. The reason for different test sites was to determine whether the shape and depth of the pool had any influence on the effectiveness of the alarms. The pools varied in width from 14 feet to 30 feet and length from 35 feet to 50 feet. All but one pool were of the "spoon" design, starting at a depth of 3-4 feet and going to a depth of 6 to 10 feet. The one exception was an indoor/outdoor pool of the "hopper" design where both ends were 3½ feet deep and the depth at the center of the pool was 6 feet.

TEST METHODOLOGY

The manufacturers' instruction manuals were reviewed prior to testing. Alarm systems were assembled and placed around the test pools (diagrams provided in appendices) according to the instructions.

The surface wave sensors (labeled A[*] and B in the figures of appendices A-F) were tied to tethers (between two and six feet long) and centrally located along the perimeter of the pools. An effort was made to maintain a distance of at least six inches between the sensor and the pool wall, according to the manufacturers' instructions. The subsurface disturbance sensors (labeled C[*] and D[*]) were placed at the deep end of the pools. The sensitivity of each unit was adjusted during preliminary testing to obtain the best performance results. The remote alarm function for each sensor was also tested.

The systems were tested under two conditions:

- Detection
    - To determine whether the surface and subsurface wave sensors would alarm when a test object entered the pool, and
    - To determine whether the wristband would alarm when exposed to pool water.

[*] A=PoolSOS/Allweather Inc., C=Poolguard/PBM Industries, D=Sentinel LINK/Lambo Products Inc.

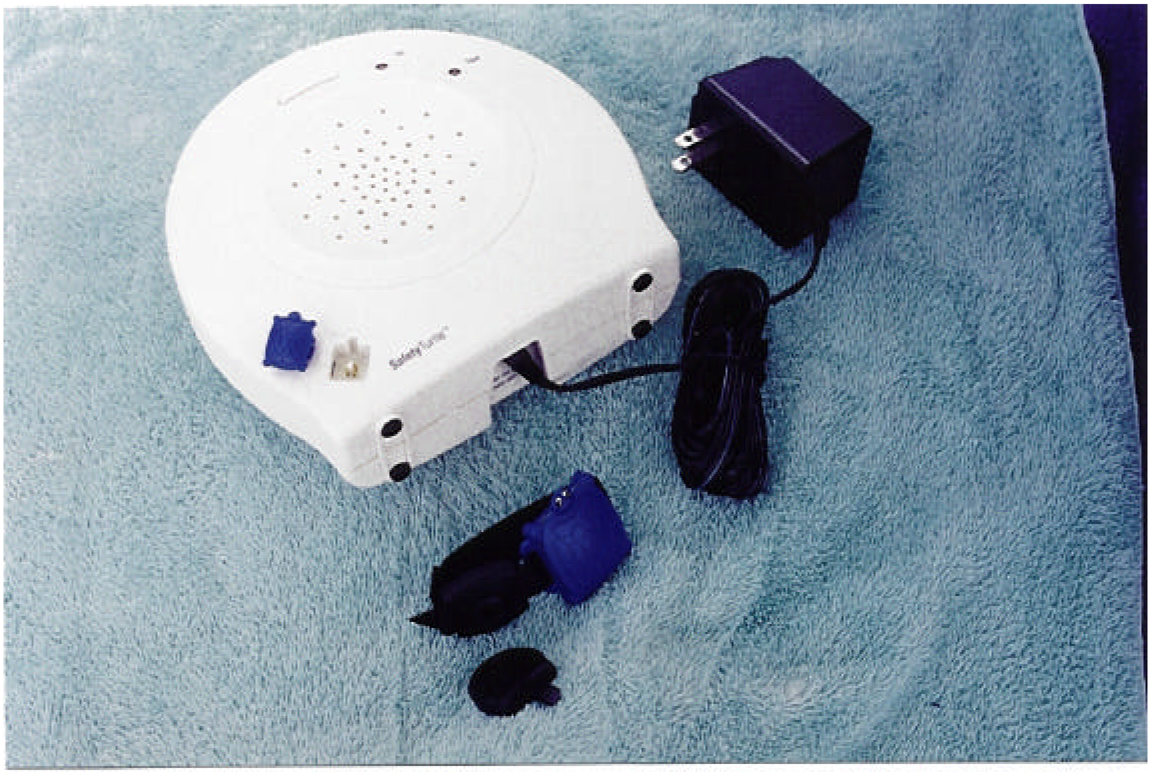


Figure 5. The Wristband and Receiver

- False Alarm

    - To determine the susceptibility of the surface and subsurface wave sensors to alarm when water displacement was not created by the test object, and

    - To determine whether the wristband would alarm under non-threatening conditions, such as washing hands.

Detection (Surface and Subsurface Disturbance Sensors)

During the first round of testing, two sets of detection tests were conducted using three, one-gallon containers filled with water and tied together. One manufacturer recommended this procedure for testing the alarm sensitivity. There were ten trials conducted for each set of tests. Each trial was concluded after two minutes. The containers were positively buoyant; they would initially sink toward the bottom of the pool then rise to the surface. To conduct detection tests, the test object was placed at the pool edge and pushed into the water. To simulate worst-case conditions, the test object was pushed into the shallow end of the pool at a point farthest from the subsurface disturbance sensors. The surface wave sensors were located near the midpoint of the pool, according to manufacturers' instructions. A second set of tests was performed with the test object introduced near the midpoint of the pool. The measured distance between the water entry point (marked with an "X" and "Y", respectively) and each of the sensors (labeled "A" through "D") is shown in figures provided in the appendices.

Subsequent rounds of testing consisted of two and three, one-gallon containers filled with water and tied together. These were used to simulate the minimum weights of a 12-15 month old child (approximately 18.3 pounds) up to a 42-54 month old child (approximately 25 pounds) in an effort to determine an operational sensitivity for the sensors. The lowest weight for the youngest child was chosen after a review of the CPSC database found that 1 and 2 year old children are at greatest risk of pool drowning in a home swimming pool.

Two sets of detection tests were conducted with ten trials comprising each set. As with previous trials, each was concluded after two minutes. In the first set, either the two-gallon or the three-gallon test object was introduced into the pool at the shallow end, generally opposite the subsurface disturbance sensor location. The distance between the surface wave sensors and the water entry point was roughly one-half to three-quarters the length of the pool. The measured distances between the water entry point and each of the sensors is shown in the figures provided in the appendices. For the second set of detection tests, the other test object was introduced from the same general location.

False Alarm

To determine the propensity of the surface and subsurface sensors to false (nuisance) alarm, environmental conditions likely to cause water disturbance – wind and rain – were simulated (see Figure 6). In addition to any wind present naturally, wind was simulated using a large household fan. The fan was supported above the water surface, and the fan speed was adjusted to its highest setting. A garden hose and sprinkler were used to simulate rainfall. Additionally, objects such as a beach ball, a basketball, and a soccer ball were introduced to determine whether an alarm distinguished between desired activation and incidental disturbances. The sensors were also left "unattended" for a period of time (once on a clear day and once during a rainstorm) to determine whether they would false alarm.

Figure 6. Wind and Rain Simulation

TEST RESULTS – DETECTION

First Round Testing – Pool 1 (Appendix A)

This test facility was a rectangular shaped pool measuring 22'x 42' with various alcoves molded into the gunite. The pool depth ranged from 3 1/2 – 4 feet on the shallow end up to 8 feet at the opposite end. A schematic of the pool, along with the locations of the various alarms can be found in Appendix A. As this was the first pool tested, and there are currently no performance requirements, the manufacturer-recommended three-gallon object was used for testing.

From Location "X" (Shallow End)

The first surface wave sensor, labeled A (Sensor A), alarmed in 6 out of 10 trials, with response times ranging from 16.1 seconds to 23.9 seconds. The second surface wave sensor, Sensor B, failed to alarm after two minutes in all trials. (Sensor B was set to its most sensitive detection position.)

Both subsurface wave sensors alarmed 100 percent of the time. Response times for Sensor C ranged from 10.4 seconds to 76.3 seconds. Response times for Sensor D ranged from 13.3 seconds to 116.6 seconds. Detection results and individual trial response times are shown in Tables A1 and A2 of Appendix A.

From Location "Y" (Mid-point)

Sensor A alarmed in 6 out of 10 trials, with response times ranging from 4.0 seconds to 25.1 seconds. Sensor B alarmed in 1 of 10 trials, with a response time of 5.7 seconds.
Sensor C alarmed in all 10 trials, with response times ranging from 7.7 seconds to 10.4 seconds. Sensor D alarmed in 7 out of 10 trials. Response times ranged from 7.8 seconds to 13.4 seconds. Detection results and individual trial response times are shown in Tables A3 and A4 of Appendix A.

Wristband

The wristband alarmed immediately upon submersion into the pool water. Once the wristband was completely dried, it was tested again. It alarmed immediately upon submersion.

Subsequent Testing – Pools 2-6 (Appendices B-F)

Pool 2 (Appendix B)

This test facility was a rectangular pool measuring 18'x 36' with a steel and concrete shell covered with a vinyl liner. The pool was unique in that the depth ranged from 3 1/2 feet on either end up to 6 feet in the middle, a "hopper" design rather than the typical "spoon" design, shallow on one end and gradually deeper towards the opposite end. A schematic of the pool, along with the locations of the various alarms can be found in Appendix B.

From Location "X" (Right-side of Entrance Steps)

Surface wave sensor A alarmed in 5 out of 5 trials using the three-gallon test object and 5 out of 5 trials using the two-gallon test object. The response times ranged from 19.1 to 22.4 seconds for the three-gallon object and from 21.3 to 24.7 seconds for the two-gallon object. The second surface wave sensor, Sensor B, responded in 5 out of 5 trials for the three-gallon test object and 4 out of 5 trials for the two-gallon test object. The response times were from 7.59 to 9.71 seconds and 9.86 to 12.18 seconds respectively.

Both subsurface disturbance sensors alarmed 100 percent of the time. Response times for Sensor C ranged from 15.1 to 15.7 seconds with the three gallon test object and 15.0 to 19.6 seconds when the two-gallon test object was used. Response times for Sensor D ranged from 15.7 to 20.5 seconds and 20.8 to 23.5 seconds respectively.

<u>From Location "Y"</u> (Left-side of Entrance Steps)

Using the three-gallon object, Sensor A alarmed in 5 out of 5 trials, with response times ranging from 17.8 to 40.7 seconds. Sensor B alarmed in 3 of 5 trials, with a response time of 12.6 to 13.3 seconds. With the two-gallon object, Sensor A alarmed in 5 out of 5 trials, as did Sensor B. The response times ranged from 11.3 to 20.7 seconds for Sensor A and 11.3 to 14.4 seconds for Sensor B.

Subsurface sensors C and D alarmed in all 5 trials using each object. The response times ranged from 7.4 to 12.1 seconds and 16.9 to 17.6 seconds with the three-gallon object. For the two-gallon object, the times ranged from 13.0 to 20.0 seconds and 16.6 to 27.6 seconds respectively. A summary of the detection results and individual trial response times is shown in Appendix B.

<u>Pool 3</u> (Appendix C)

This test facility was a rectangular pool measuring approximately 14'x 40' and appeared to be a typical gunite shell construction. The pool ranged from 4 feet at the entrance steps to 6 feet at the opposite end. There was a small, built-in hot tub at the shallow end adjacent to the steps. A schematic of the pool, along with the locations of the various alarms and the test results can be found in Appendix C. Due to the size and shape of the pool, and the results of the first test trials, presumed to be the worst-case scenario, there was only one drop point used for the test objects.

<u>From Location "X"</u> (Shallow End)

Surface wave sensors A and B alarmed in all 10 trials using both the three-gallon and the two-gallon test objects. For Sensor A, the response times ranged from 7.1 to 29.8 seconds for the three-gallon object and from 7.4 to 27.0 seconds for the two-gallon object. Sensor B response times were from 9.7 to 15.1 seconds and 8.8 to 12.8 seconds, respectively.

Both subsurface sensors alarmed in all 10 trials as well. Response times for Sensor C ranged from 5.8 to 15.7 seconds with the three-gallon test object and 8.8 to 22.1 seconds when the two-gallon test object was used. Response times for Sensor D ranged from 15.9 to 19.0 seconds and 16.6 to 20.6 seconds, respectively.

<u>Pool 4</u> (Appendix D)

This test facility was a rectangular pool measuring 30'x 50' and appeared to be a typical gunite shell construction. The pool ranged in depth from 4 feet at the entrance steps to 10 feet at the opposite end. A schematic of the pool, along with the locations of the various alarms and the test results can be found in Appendix D. Due to the pool size, two surface Sensor B alarms were used. As a result of the first test trials, presumed to be a worst-case scenario, and the use of two Sensor B units (a second Sensor A was not available), there was only one drop point used for the test objects.

<u>From Location "X"</u> (Shallow End)

Surface wave Sensor A alarmed in all 10 trials using the three-gallon test object and in 9 out of 10 trials using the two-gallon test object. For Sensor A, the response times ranged from 25.0 to 33.4 seconds for the three-gallon object and from 14.2 to 54.6 seconds for the two-gallon object. For the two Sensor B units, there was a single response during the 10 trials using the three-gallon object. The response time was from the unit located farthest from the test object entrance point and occurred over one minute after the test object was introduced into the pool. There were two responses from each unit when using the two-gallon test object. The response times were 7.2 and 54.1 seconds from the farthest unit and 33.2 and 53.2 seconds from the nearer unit.

Both subsurface sensors alarmed in all 10 trials involving the three-gallon object. Response times varied from 10.1 to 24.5 seconds for Sensor C and from 24.8 to over two minutes for Sensor D. For the two-gallon object, Sensor C alarmed in 8 out of 10 trials with response times ranging from 17.3 to 43.0 seconds while Sensor D responded in 7 out of 10 trials with response times between 31.0 and 49.3 seconds.

<u>Pool 5</u> (Appendix E)

This test facility was a rectangular pool measuring 17.5'x 26' with additional 6 foot semi-circles on either end of the rectangle. The pool appeared to be a typical gunite shell and ranged in depth from 3 feet at the stairs to 8 feet at the opposite end. A schematic of the pool, along with the locations of the various alarms and the test results can be found in Appendix E. Due to the pool size and alarm locations, there was only one drop point used for the test objects.

<u>From Location "X"</u> (Shallow End)

Surface wave Sensor A alarmed in all 10 trials using the three-gallon test object and in 9 out of 10 trials using the two-gallon test object. The response times ranged from 14.1 to 21.4 seconds for the three-gallon object and from 15.1 to 20.2 seconds for the two-gallon object. The Sensor B unit responded once during the 10 trials using the three-gallon test object. The response time was 23.0 seconds. There were four responses when using the two-gallon test object. The response times ranged from were 17.1 to 23.6 seconds.

Both subsurface wave sensors alarmed in all 10 trials involving both the three-gallon and the two-gallon test objects. Response times with the three-gallon test object varied from 6.3 to 10.6 seconds for Sensor C and from 9.4 to 18.1 seconds for Sensor D. For the two-gallon object, Sensor C response times were from 6.9 to 13.6 seconds while Sensor D response times were between 7.1 and 31.6 seconds.

<u>Pool 6</u> (Appendix F)

This test facility was a kidney shaped pool measuring approximately 35.5' in length with the widest area being about 16.5' in width and 3 feet depth. The deeper end of the pool was about 13.5' in width and 8 feet in depth. This pool also appeared to be a typical gunite shell. A schematic of the pool, along with the locations of the various alarms and the test results can be found in Appendix F. Due to the pool size, shape, and location of the alarms, there was only one drop point used for the test objects.

<u>From Location "X"</u> (Shallow End)

Surface wave Sensor A alarmed in all 10 trials using the three-gallon test object and in 8 out of 10 trials using the two-gallon test object. The response times ranged from 10.9 to 21.2 seconds for the three-gallon object and from 12.8 to 25.1 seconds for the two-gallon object. Surface wave Sensor B responded in 7 of the 10 three-gallon object trials and 5 out of 10 two-gallon trials. The response times were from 8.1 to 16.3 seconds and 9.7 to 11.1 seconds, respectively.

Both subsurface wave sensors alarmed in all trials involving both the three-gallon and the two-gallon test objects. However, there was one test involving the three-gallon object where Sensor C responded just as the test object was introduced into the pool. It was determined to be a false alarm and that trial was not counted for that sensor. The response times with the three-gallon test object were from 9.7 to 19.7 seconds for Sensor C and from 11.2 to 25.8 seconds for Sensor D. For the two-gallon object, Sensor C response times were from 8.8 to 22.2 seconds while Sensor D response times were between 16.6 and 20.6 seconds.

TEST RESULTS – FALSE ALARM

During the first round of testing, surface wave Sensor A alarmed in conditions of simulated wind, simulated rain, and during a rainstorm. Surface wave Sensor B did not alarm during either of the environmental simulations nor during actual weather events. Neither surface wave sensor alarmed when objects were tossed into the pool unless the objected landed within approximately five feet of the sensor. Subsurface wave Sensor C did not false alarm in any of the environmental simulations or during actual weather related disturbances. Subsurface wave Sensor D did not alarm in simulated wind or rain conditions; it did alarm during the rainstorm. Neither subsurface wave sensor alarmed when objects were tossed into the pool. A summary of False Alarm Test Results is shown in the various appendices where false alarm tendencies were investigated.

The wristband alarmed immediately when subjected to a stream of running tap water.

CONCLUSION

Test results showed that the subsurface pool alarms generally performed better. They were more consistent in alarming and less likely to false alarm than the surface alarms. When a test object, intended to simulate the weight of a small child, was pushed into the pool, the subsurface sensors detected it most reliably. The subsurface alarms can also be used in conjunction with solar covers, whereas the surface alarms cannot.

One surface alarm performed almost as well as the subsurface alarms. The wristband alarmed when submerged in pool water or exposed to another water source, such as tap water.

A pool alarm can be a good additional safeguard in that it provides an additional layer of protection against child drownings in swimming pools. Since pool alarms rely on someone remembering to activate them each and every time the pool is in use, they should not be relied upon as a substitute for supervision or for a barrier completely surrounding the pool. A remote alarm feature that will sound inside the house is important to have with a pool alarm. Some alarms include this; with other alarms it has to be purchased separately.

The wristband can also provide an additional layer of protection. However, it relies on someone putting it on the child and, since children often reach the pool unexpectedly from the house, it would be important for a child to wear the wristband all the time. This may present some difficulties since it alarms when exposed to any water, e.g., when washing hands.

Appendix A

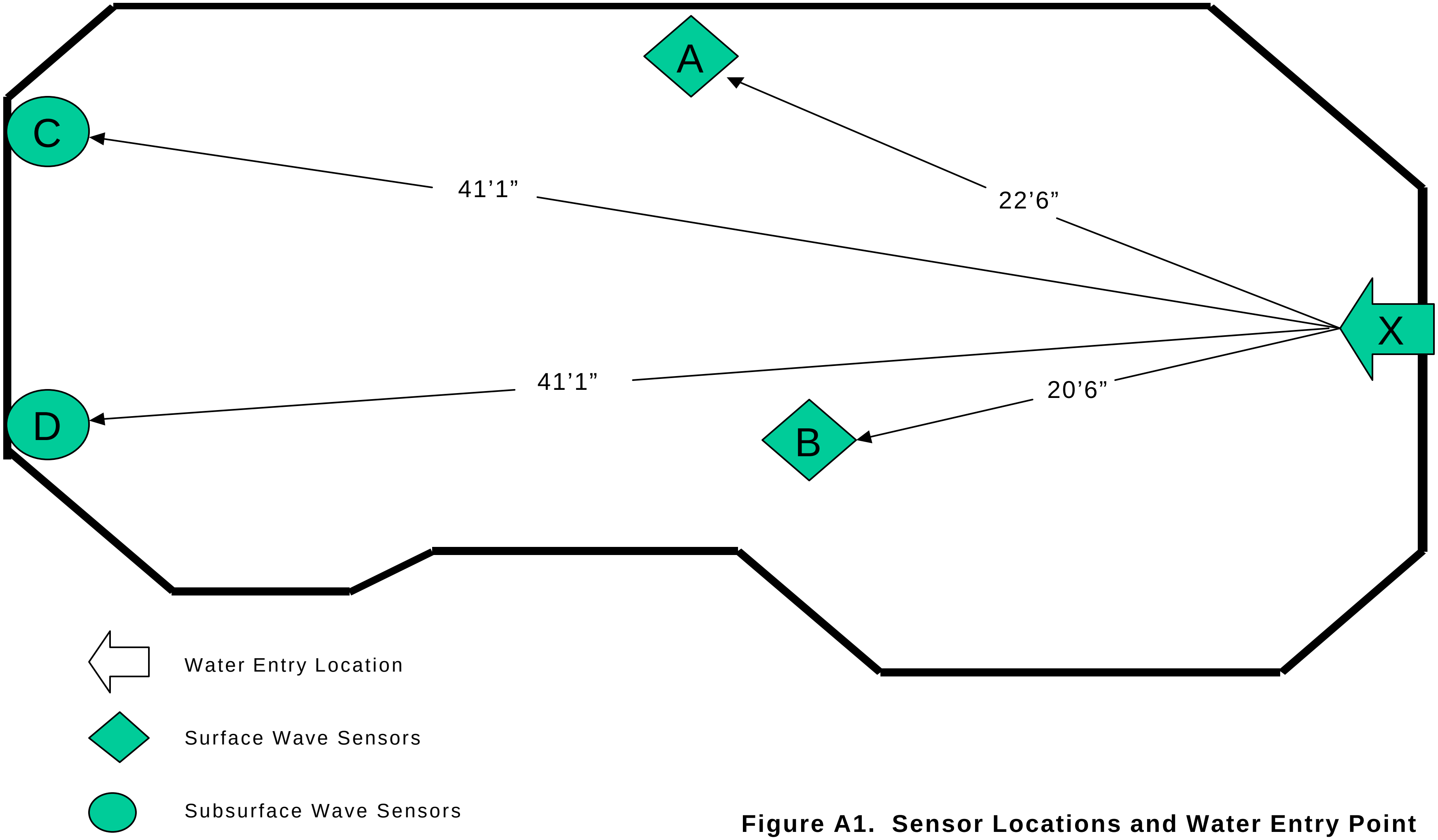


Figure A1. Sensor Locations and Water Entry Point

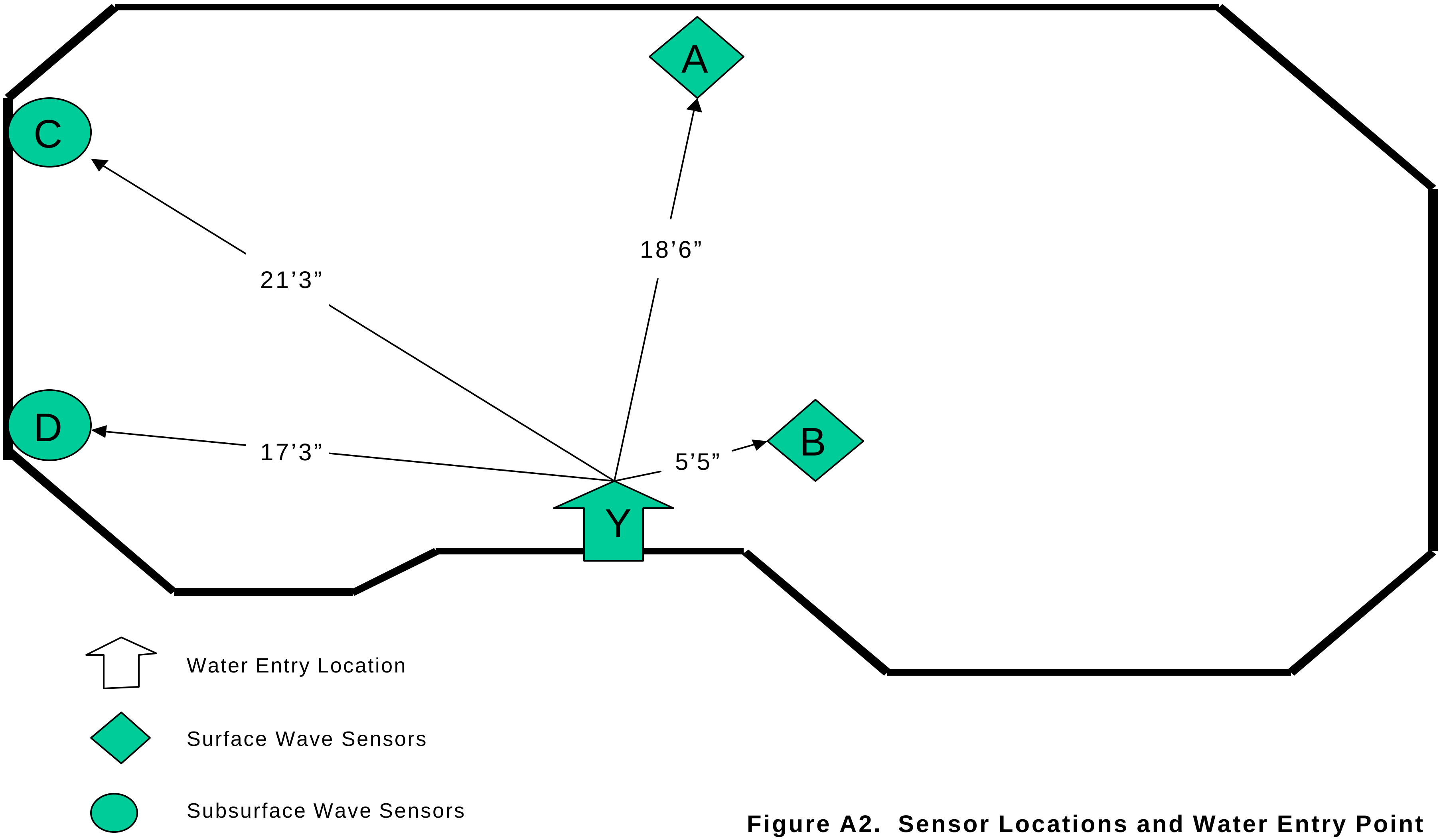


Figure A2. Sensor Locations and Water Entry Point

TABLE A1. DETECTION RESULTS FROM WATER ENTRY POINT "X"

Sensor	Distance to Water Entry Point	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	22 ft 6 in	60	High	16.1 to 23.9
B	20 ft 6 in	0	Highest	N/A
SUBSURFACE WAVE SENSORS				
C	41 ft 1 in	100	Mid-Range	10.4 to 76.3
D	41 ft 1 in	100	Lowest	13.3 to 116.6

TABLE A2. INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"

Trial	1		2		3		4		5		6		7		8		9		10	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	P	19.3	F	-	F	-	F	-	P	17.9	P	16.1	P	23.9	F	-	P	18.9	P	16.3
B	F	-	F	-	F	-	F	-	F	-	F	-	F	-	F	-	F	-	F	-
SUBSURFACE WAVE SENSORS																				
C	P	10.4	P	11.8	P	11.7	P	22.1	P	24.2	P	20.9	P	76.3	P	10.4	P	10.5	P	19.8
D	P	26.5	P	26.5	P	51.5	P	39.3	P	31.3	P	25.3	P	13.3	P	26.6	P	113.2	P	116.6

TABLE A3. DETECTION RESULTS FROM WATER ENTRY POINT "Y"

Sensor	Distance to Water Entry Point	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	18 ft 6 in	60	High	4.0 to 25.1
B	5 ft 5 in	10	Highest	5.7
SUBSURFACE WAVE SENSORS				
C	21 ft 3 in	100	Mid-Range	7.1 to 10.4
D	17 ft 3 in	70	Lowest	7.8 to 13.4

TABLE A4. INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "Y"

Trial	1		2		3		4		5		6		7		8		9		10	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	P	25.1	P	18.1	P	4.0	P	11.1	F	-	F	-	P	13.1	P	22.3	F	-	F	-
B	F	-	P	5.7	F	-	F	-	F	-	F	-	F	-	F	-	F	-	F	-
SUBSURFACE WAVE SENSORS																				
C	P	8.6	P	10.4	P	7.3	P	7.1	P	9.3	P	9.6	P	7.9	P	9.4	P	9.5	P	9.5
D	P	8.7	P	10.4	P	10.9	P	11.1	P	9.4	F	-	P	7.8	F	-	F	-	P	13.4

TABLE A5. FALSE ALARM TEST RESULTS

Sensor	Simulation		Objects	Actual Weather		Sensitivity	Comments
	Wind	Rain		Wind	Rain		
SURFACE WAVE SENSORS							
A	Alarmed	Alarmed	Silent	Silent	Alarmed	High	Affected by surface conditions
B	Silent	Silent	Silent	Silent	Silent	Highest	Unaffected by conditions
SUBSURFACE WAVE SENSORS							
C	Silent	Silent	Silent	Silent	Silent	Mid-Range	Unaffected by conditions
D	Silent	Silent	Silent	Silent	Alarmed	Lowest	Affected in rainstorm only

Appendix B

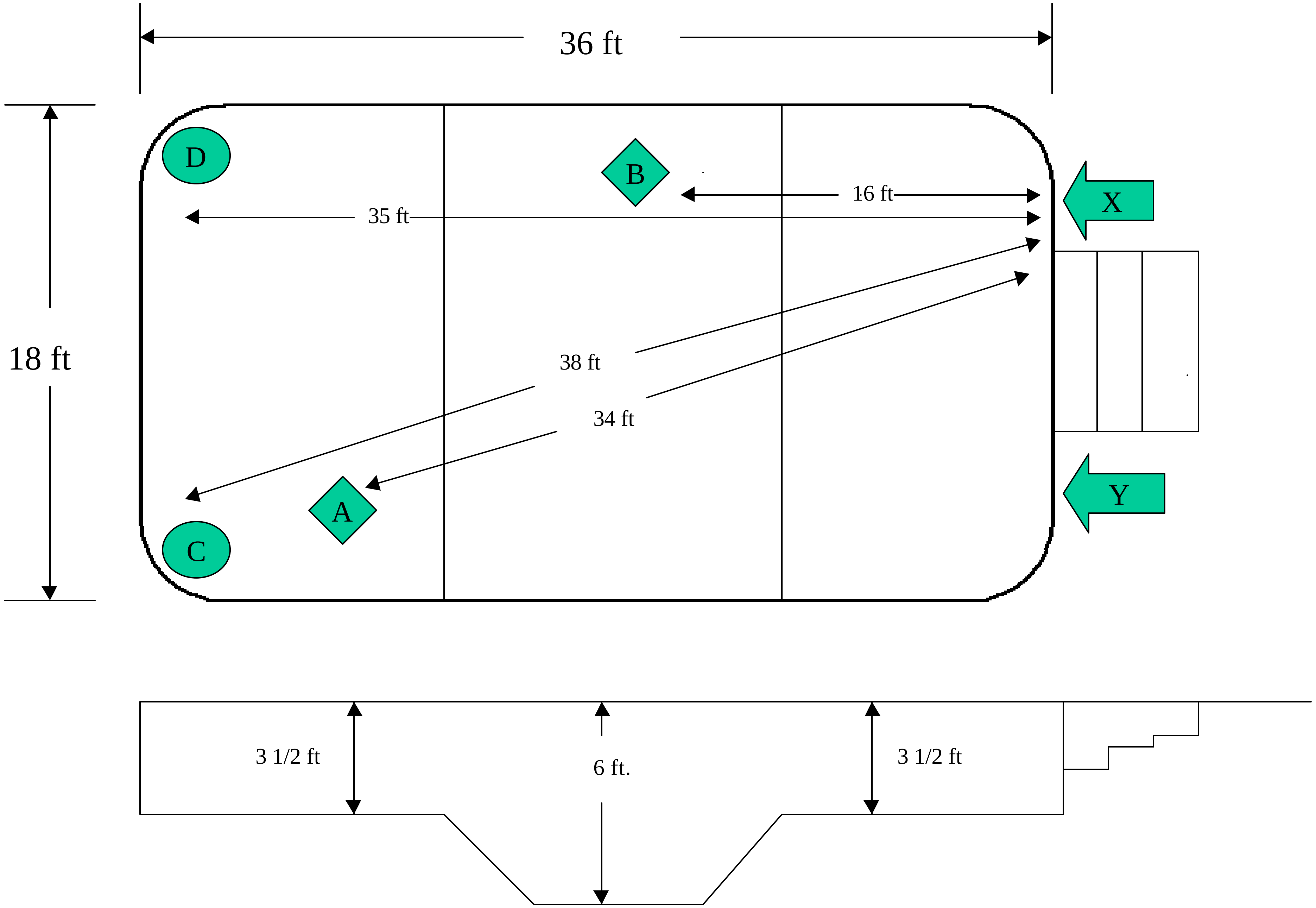


Figure B1. Sensor Locations and Water Entry Points

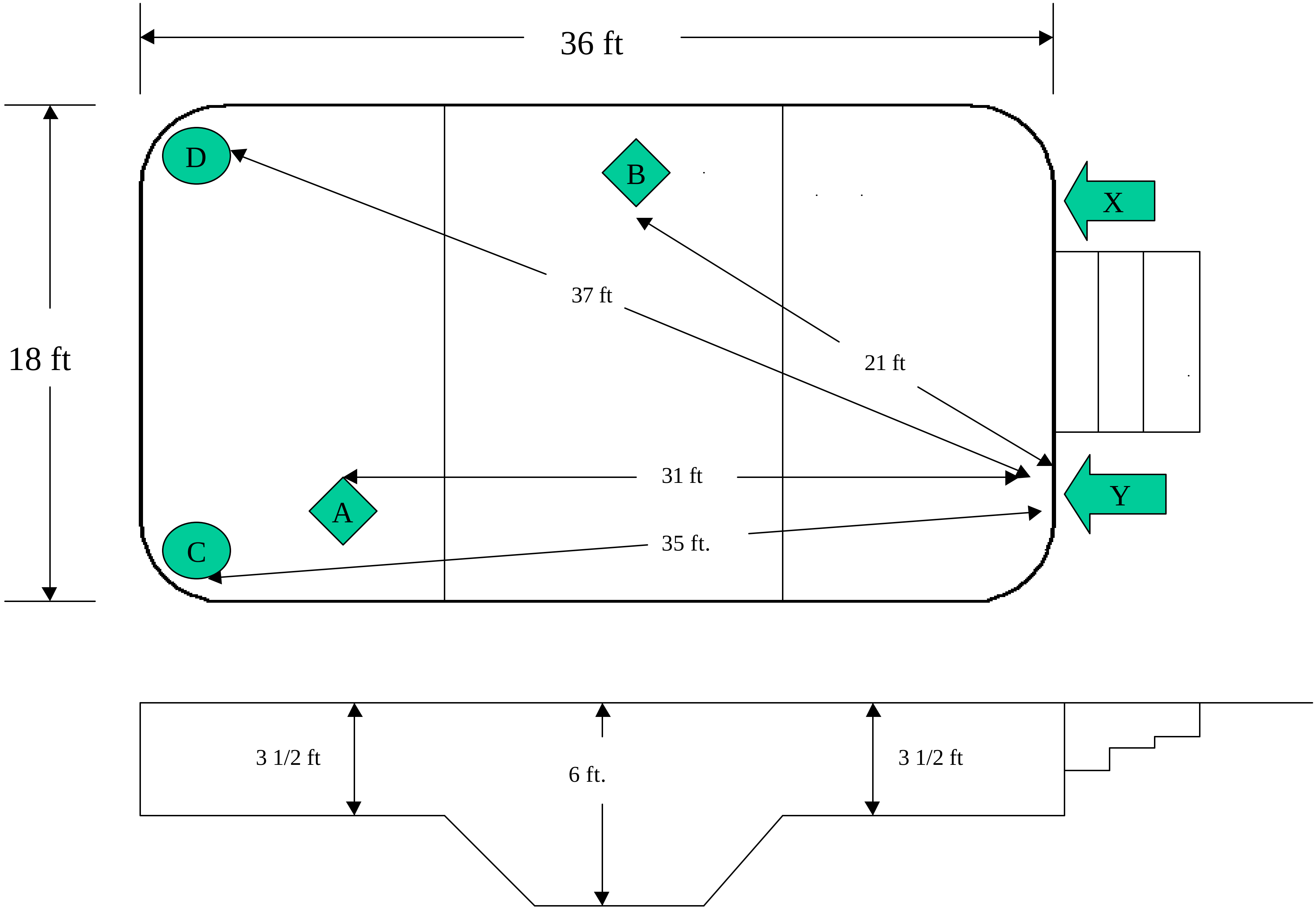


Figure B2. Sensor Locations and Water Entry Points

TABLE B1
DETECTION RESULTS FROM WATER ENTRY POINTS "X" AND "Y"
Three Gallon Test Weight

Sensor	Distance to Water Entry Point "X"	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	34 ft	100	High	19.1 to 22.4
B	16 ft	100	Highest	7.6 to 9.7
SUBSURFACE WAVE SENSORS				
C	35 ft	100	Mid-Range	15.1 to 15.7
D	38 ft	100	Mid-Range	15.7 to 20.5

Sensor	Distance to Water Entry Point "Y"	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	31 ft	100	High	17.7 to 40.7
B	21 ft	60	Highest	12.6 to 13.3
SUBSURFACE WAVE SENSORS				
C	37 ft	100	Mid-Range	7.4 to 12.0
D	35 ft	100	Mid-Range	16.9 to 17.6

TABLE B2
DETECTION RESULTS FROM WATER ENTRY POINTS "X" AND "Y"
Two Gallon Test Weight

Sensor	Distance to Water Entry Point "X"	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	34 ft	100	High	21.3 to 24.7
B	16 ft	80	Highest	9.9 to 12.2
SUBSURFACE WAVE SENSORS				
C	35 ft	100	Mid-Range	15.0 to 19.6
D	38 ft	100	Mid-Range	20.4 to 23.5

Sensor	Distance to Water Entry Point "Y"	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	31 ft	100	High	11.3 to 20.7
B	21 ft	100	Highest	11.3 to 14.4
SUBSURFACE WAVE SENSORS				
C	37 ft	100	Mid-Range	12.9 to 20.1
D	35 ft	100	Mid-Range	16.6 to 27.6

TABLE B3
Three Gallon Test Weight

INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"											INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "Y"									
Trial	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	P	21.68	P	22.43	P	21.64	P	21.09	P	19.10	P	17.76	P	18.02	P	22.08	P	40.70	P	34.64
B	P	9.71	P	7.70	P	9.11	P	7.59	P	8.90	P	12.79	F	-	P	12.59	F	-	P	13.34
SUBSURFACE WAVE SENSORS																				
C	P	15.69	P	15.11	P	15.05	P	15.06	P	15.13	P	12.01	P	7.63	P	9.30	P	7.43	P	7.67
D	P	18.43	P	20.53	P	17.63	P	15.71	P	15.97	P	17.62	P	16.87	P	17.45	P	17.40	P	17.60

TABLE B4
Two Gallon Test Weight

INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"											INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "Y"									
Trial	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	P	21.25	P	24.69	P	23.18	P	21.37	P	24.25	P	18.27	P	17.90	P	16.94	P	20.70	P	11.31
B	P	10.11	P	9.86	F	-	P	11.03	P	12.18	P	12.79	P	13.93	P	14.39	P	12.55	P	11.31
SUBSURFACE WAVE SENSORS																				
C	P	15.04	P	15.16	P	19.64	P	15.10	P	15.00	P	15.87	P	12.94	P	20.06	P	13.07	P	16.71
D	P	20.56	P	22.31	P	22.06	P	23.47	P	20.38	P	20.01	P	19.37	P	27.64	P	19.65	P	16.61

TABLE B5
FALSE ALARM TEST RESULTS

SENSOR	Simulation		Objects	Actual Weather		Sensitivity	Comments
	Wind	Rain		Wind	Rain		
SURFACE WAVE SENSORS							
A	Alarmed	N/A	N/A	N/A	N/A	High	Affected by surface conditions
B	Alarmed	N/A	N/A	N/A	N/A	Highest	
SUBSURFACE WAVE SENSORS							
C	Silent	N/A	N/A	N/A	N/A	Mid-Range	Unaffected by conditions
D	Silent	N/A	N/A	N/A	N/A	Mid-Range	Affected in rainstorm only

Appendix C

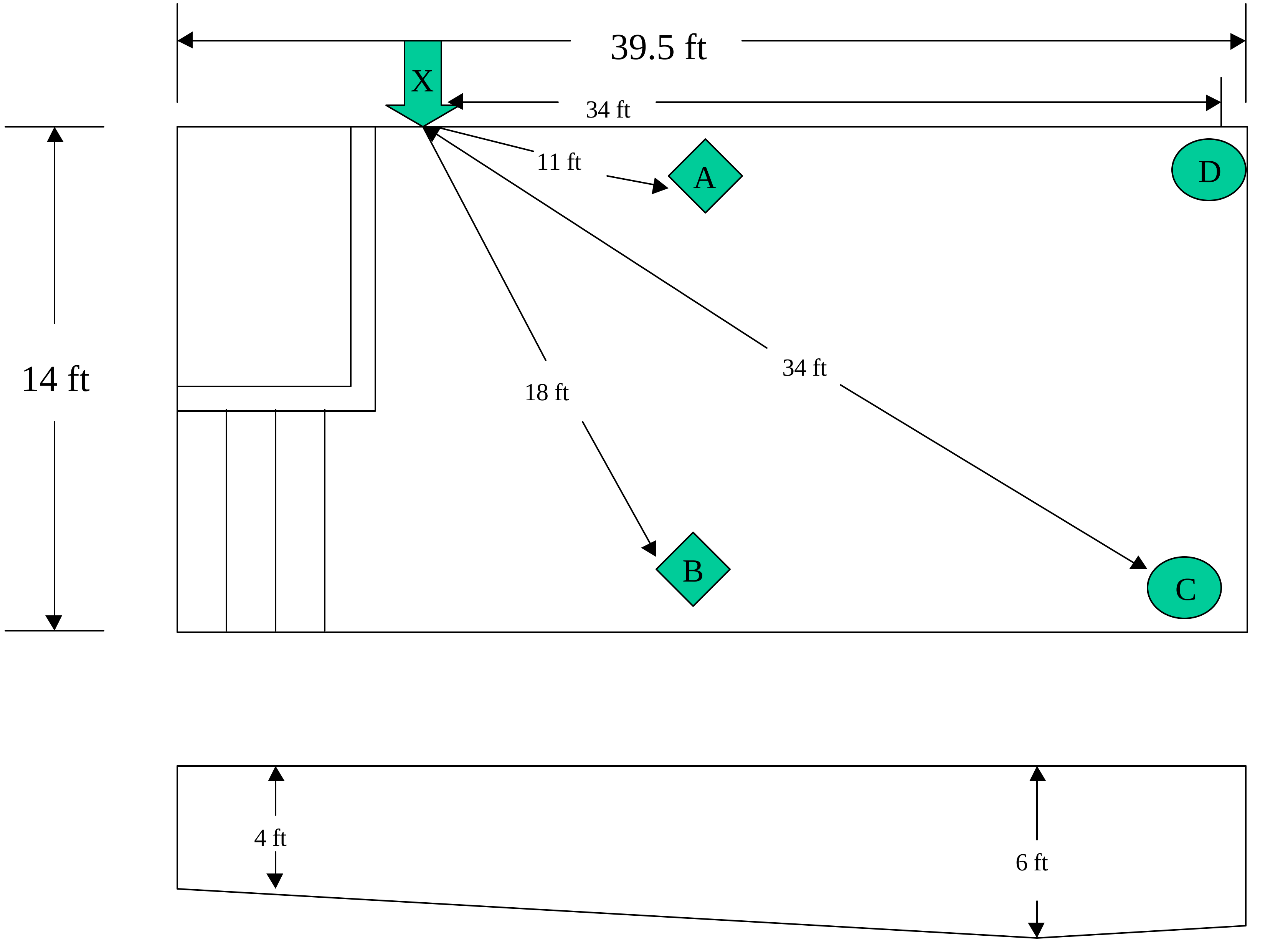


Figure C1. Sensor Locations and Water Entry Point

TABLE C1
Detection Results from Water Entry Points “X”
Three Gallon Test Weight

Sensor	Distance to Water Entry Point “X”	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	11 ft	100	High	7.1 to 29.8
B	18 ft	100	Highest	9.7 to 15.1
SUBSURFACE WAVE SENSORS				
C	34 ft	100	Mid-Range	5.8 to 15.7
D	34 ft	100	Mid-Range	15.9 to 19.0

Two Gallon Test Weight

Sensor	Distance to Water Entry Point “X”	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	11 ft	100	High	7.4 to 27.0
B	18 ft	100	Highest	8.8 to 12.8
SUBSURFACE WAVE SENSORS				
C	34 ft	100	Mid-Range	8.8 to 22.1
D	34 ft	100	Mid-Range	16.6 to 20.6

TABLE C2
Three Gallon Test Weight

INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"																				
Trial	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	P	7.09	P	25.10	P	27.12	P	9.67	P	29.81	P	19.10	P	10.30	P	24.42	P	7.32	P	10.40
B	P	10.07	P	10.90	P	15.10	P	9.67	P	9.59	P	12.27	P	10.30	P	11.59	P	11.72	P	10.40
SUBSURFACE WAVE SENSORS																				
C	P	7.96	P	5.81	P	15.67	P	9.42	P	14.68	P	7.71	P	7.62	P	5.81	P	6.00	P	7.93
D	P	17.53	P	17.71	P	17.94	P	17.45	P	17.96	P	18.97	P	16.35	P	17.56	P	17.47	P	15.90

TABLE C3
Two Gallon Test Weight

INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"																				
Trial	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	P	20.68	P	22.28	P	13.37	P	12.80	P	26.97	P	9.38	P	13.68	P	8.68	P	7.35	P	8.00
B	P	10.71	P	11.30	P	9.93	P	12.79	P	9.37	P	9.38	P	9.15	P	8.78	P	11.57	P	10.53
SUBSURFACE WAVE SENSORS																				
C	P	22.16	P	17.60	P	17.75	P	9.59	P	9.41	P	20.58	P	19.96	P	8.80	P	19.60	P	18.40
D	P	17.59	P	17.62	P	17.77	P	19.28	P	19.09	P	20.56	P	16.57	P	20.18	P	20.59	P	18.34

TABLE C4
FALSE ALARM TEST RESULTS

SENSOR	Simulation		Objects	Actual Weather		Sensitivity	Comments
	Wind	Rain		Wind	Rain		
SURFACE WAVE SENSORS							
A	Alarmed	N/A	N/A	N/A	N/A	High	
B	Silent	N/A	N/A	N/A	N/A	Highest	
SUBSURFACE WAVE SENSORS							
C	Silent	N/A	N/A	N/A	N/A	Low	
D	Silent	N/A	N/A	N/A	N/A	Mid-Range	

Appendix D

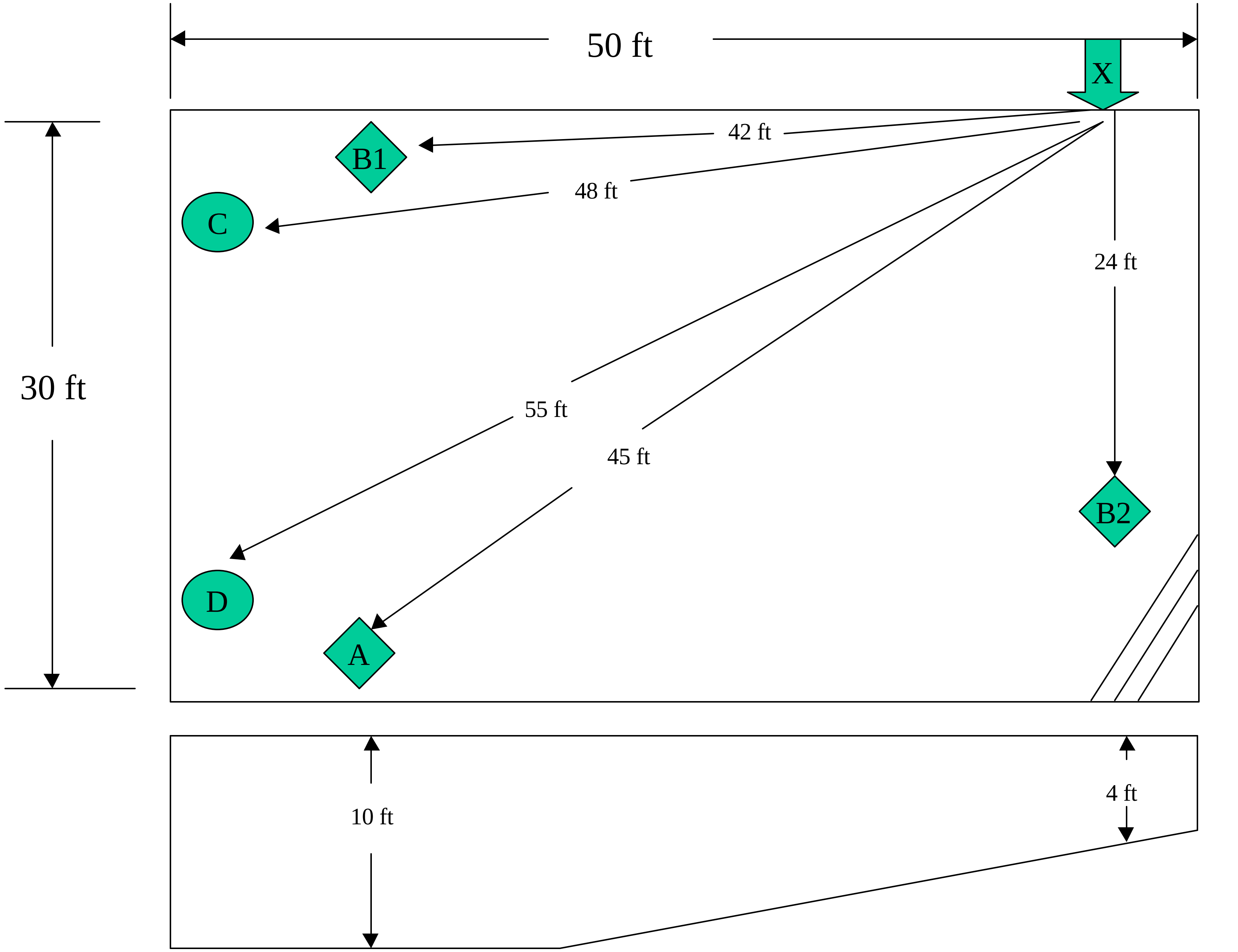


Figure D1. Sensor Locations and Water Entry Point

TABLE D1

Detection Results from Water Entry Points "X"
Three Gallon Test Weight

Sensor	Distance to Water Entry Point "X"	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	45 ft	100	High	25.0 to 33.4
B1	42 ft	10	Highest	1:02.
B2	24 ft	0	Highest	-
SUBSURFACE WAVE SENSORS				
C	48 ft	100	Mid-Range	10.1 to 24.5
D	55 ft	100	Mid-Range	24.8 to 2:27.

Two Gallon Test Weight

Sensor	Distance to Water Entry Point "X"	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	45 ft	90	High	14.1 to 54.6
B1	42 ft	20	Highest	7.2 to 54.1
B2	24 ft	20	Highest	33.2 to 53.2
SUBSURFACE WAVE SENSORS				
C	48 ft	80	Mid-Range	17.3 to 43.0
D	55 ft	70	Mid-Range	31.0 to 49.3

TABLE D2
Three Gallon Test Weight

INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"																				
Trial	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	P	28.21	P	24.98	P	35.37	P	25.29	P	27.14	P	33.44	P	30.61	P	29.08	P	27.28	P	27.53
B1	F	-	F	-	F	-	F	-	P	1:02.	F	-	F	-	F	-	F	-	F	-
B2	F	-	F	-	F	-	F	-	F	-	F	-	F	-	F	-	F	-	F	-
SUBSURFACE WAVE SENSORS											*									
C	P	16.03	P	21.15	P	16.26	P	10.12	P	19.11	P	10.28	P	21.06	P	19.32	P	21.62	P	24.45
D	P	29.72	P	2:27.	P	48.76	P	36.81	P	35.98	P	26.12	P	26.08	P	25.45	P	24.83	P	28.53

* Alarms C & D positions were switched

TABLE D3
Two Gallon Test Weight

INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"																				
Trial	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	F	-	P	32.47	P	23.85	P	37.64	P	38.40	P	52.00	P	14.12	P	25.39	P	54.59	P	35.00
B1	P	54.06	P	7.24	F	-	F	-	F	-	F	-	F	-	F	-	F	-	F	-
B2	F	-	P	53.21	P	33.18	F	-	F	-	F	-	F	-	F	-	F	-	F	-
SUBSURFACE WAVE SENSORS																				
C	P	43.02	P	25.00		**	F	-	P	22.96	P	32.01	P	23.22	P	21.33	P	31.35	P	17.33
D	P	31.00	P	32.57	P	33.65	F	-	P	46.65	P	49.06	P	49.33	F	-		**	P	34.65

** Alarm activated after 2 minutes

Appendix E

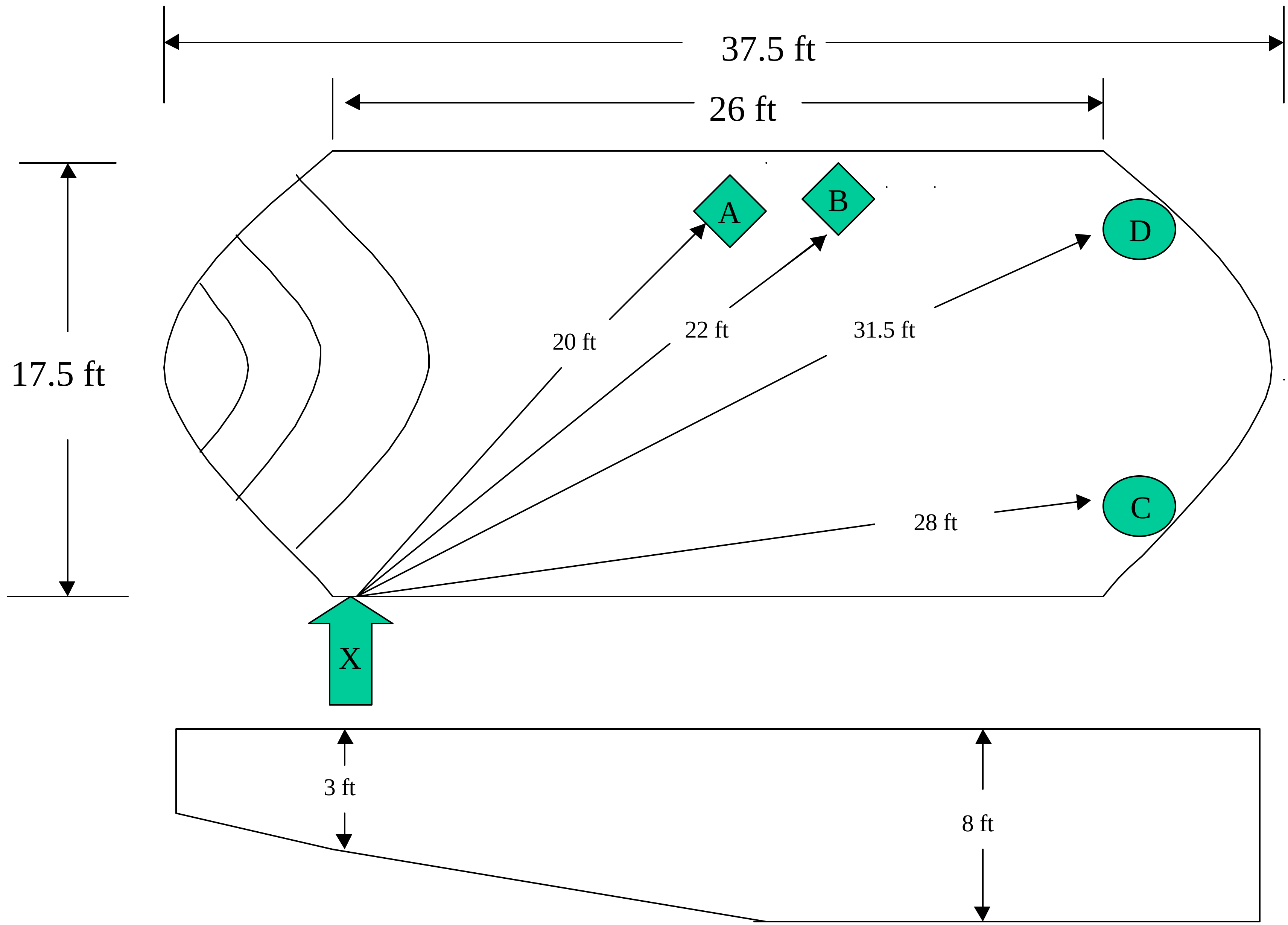


Figure E1. Sensor Locations and Water Entry Point

TABLE E1

Detection Results from Water Entry Points "X"
Three Gallon Test Weight

Sensor	Distance to Water Entry Point "X"	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	20 ft	100	High	14.1 to 21.4
B	22 ft	10	Highest	23.0
SUBSURFACE WAVE SENSORS				
C	28 ft	100	Mid-Range	6.3 to 10.6
D	31.5 ft	100	High	9.4 to 18.1

Two Gallon Test Weight

Sensor	Distance to Water Entry Point "X"	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	20 ft	90	High	15.1 to 20.2
B	22 ft	40	Highest	17.1 to 23.6
SUBSURFACE WAVE SENSORS				
C	28 ft	100	Mid-Range	6.9 to 13.6
D	31.5 ft	100	High	7.1 to 31.6

TABLE E2

Three Gallon Test Weight

INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"																				
Trial	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	P	18.06	P	14.43	P	18.21	P	17.10	P	19.41	P	14.13	P	18.26	P	14.16	P	16.84	P	21.40
B	F	-	F	-	F	-	P	23.01	F	-	F	-	F	-	F	-	F	-	F	-
SUBSURFACE WAVE SENSORS																				
C	P	6.87	P	7.10	P	6.75	P	10.62	P	6.71	P	8.42	P	6.57	P	6.69	P	6.71	P	6.33
D	P	18.06	P	16.43	P	15.38	P	14.46	P	14.15	P	14.43	P	14.32	P	14.16	P	9.44	P	14.14

TABLE E3

Two Gallon Test Weight

INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"																				
Trial	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	P	15.12	P	19.56	P	18.63	P	17.14	F	-	P	20.20	P	15.21	P	16.81	P	15.44	P	17.25
B	P	23.56	F	-	F	-	P	17.14	F	-	F	-	P	23.31	P	22.25	F	-	F	-
SUBSURFACE WAVE SENSORS																				
C	P	8.79	P	11.28	P	7.09	P	9.48	P	8.22	P	8.12	P	6.94	P	8.50	P	13.55	P	9.50
D	P	31.56	P	25.15	P	15.65	P	17.14	P	20.44	P	7.12	P	17.15	P	16.81	P	17.14	P	20.55

Appendix F

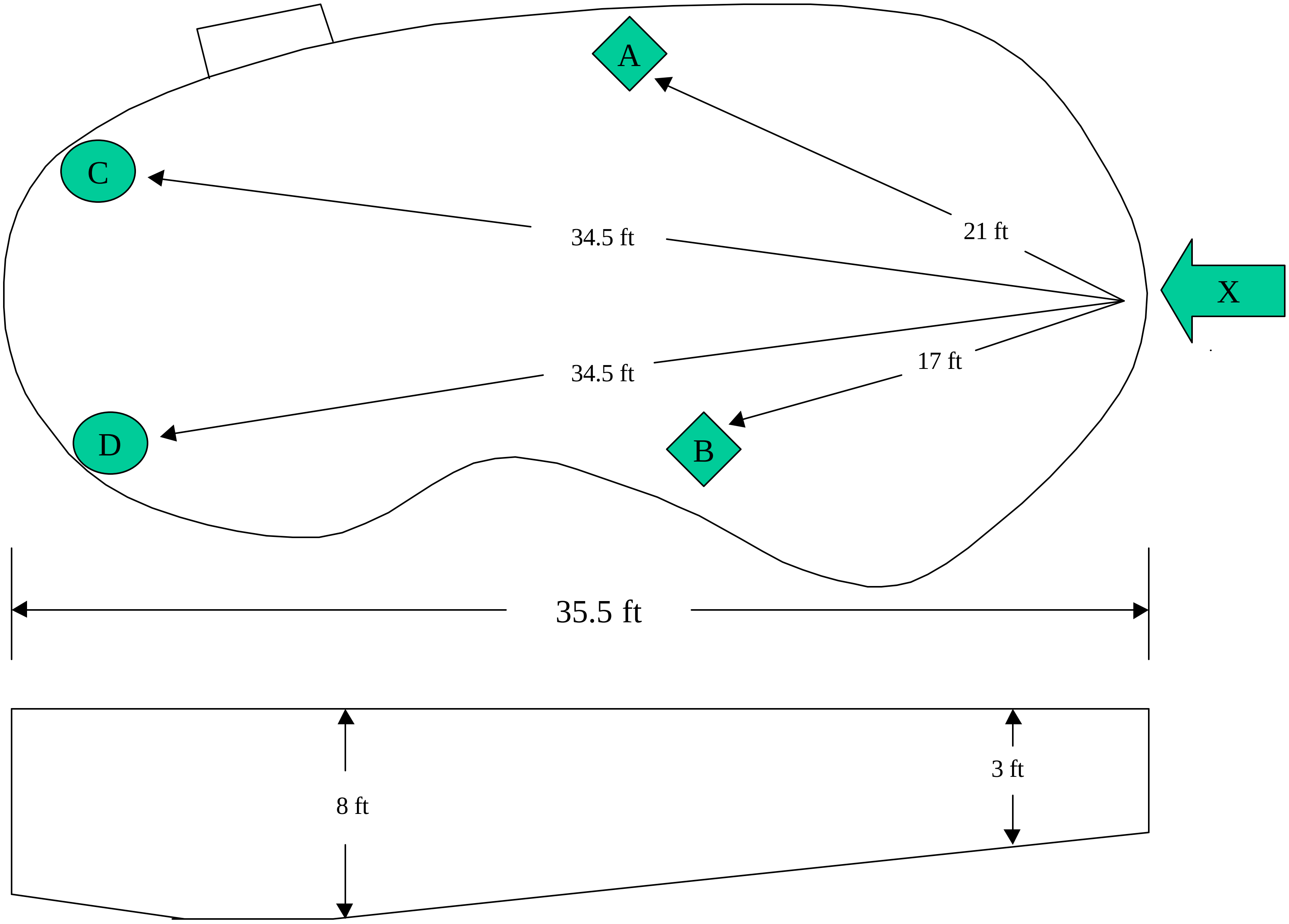


Figure F1. Sensor Locations and Water Entry Point

TABLE F1

Detection Results from Water Entry Points "X"
Three Gallon Test Weight

Sensor	Distance to Water Entry Point "X"	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	21 ft	100	High	10.9 to 21.2
B	17 ft	70	Highest	8.1 to 16.3
SUBSURFACE WAVE SENSORS				
C	34.5 ft	100	Mid-Range	9.7 to 19.7
D	34.5 ft	100	Mid-Range	11.2 to 25.8

Two Gallon Test Weight

Sensor	Distance to Water Entry Point "X"	Percent Detection	Sensitivity Setting	Response Time to Alarm (sec)
SURFACE WAVE SENSORS				
A	21 ft	80	High	12.8 to 25.1
B	17 ft	50	Highest	9.7 to 11.1
SUBSURFACE WAVE SENSORS				
C	34.5 ft	100	Mid-Range	8.8 to 22.2
D	34.5 ft	100	Mid-Range	16.6 to 20.6

TABLE F2
Three Gallon Test Weight

INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"																				
Trial	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	P	10.86	P	13.11	P	14.09	P	13.58	P	13.25	P	12.68	P	13.96	P	12.96	P	13.04	P	21.15
B	P	9.34	P	12.11	F	-	P	8.50	P	9.28	P	9.04	P	8.13	F	-	P	16.34	F	-
SUBSURFACE WAVE SENSORS																				
C	P	9.86	-	*	P	15.82	P	15.94	P	15.87	P	14.87	P	19.71	P	15.88	P	9.69	P	12.48
D	P	11.21	P	18.16	P	21.17	P	19.04	P	17.28	P	19.61	P	25.09	P	25.61	P	25.79	P	18.85

TABLE F3
Two Gallon Test Weight

INDIVIDUAL TRIAL RESULTS FROM WATER ENTRY POINT "X"																				
Trial	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Sensor	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)	P/F	T (sec)
SURFACE WAVE SENSORS																				
A	F	-	P	15.32	P	12.84	F	-	P	12.76	P	13.20	P	25.14	P	14.17	P	15.02	P	15.30
B	P	9.67	F	-	F	-	-	-	P	10.23	F	-	P	11.07	P	10.23	F	-	P	10.84
SUBSURFACE WAVE SENSORS																				
C	P	22.16	P	17.60	P	17.75	P	9.59	P	9.41	P	20.58	P	19.96	P	8.80	P	19.60	P	18.40
D	P	17.59	P	17.62	P	17.77	P	19.28	P	19.09	P	20.56	P	16.57	P	20.18	P	20.59	P	18.34

TABLE F4
FALSE ALARM TEST RESULTS

SENSOR	Simulation		Objects	Actual Weather**		Sensitivity	Comments
	Wind	Rain		Wind	Rain		
SURFACE WAVE SENSORS							
A*	N/A	N/A	N/A	Silent	N/A	High	
B	N/A	N/A	N/A	Silent	N/A	Highest	
SUBSURFACE WAVE SENSORS							
C*	N/A	N/A	N/A	Silent	N/A	Low	
D	N/A	N/A	N/A	Silent	N/A	Mid-Range	

*During the weight test phase, the alarms were difficult to reset, possibly due to windy conditions. Additionally, the sensing mechanism of Sensor C was positioned at the minimum depth due to water level in the pool and the shape of the coping.

**At the conclusion of the weight tests, the alarms were left in the pool for 25 minutes to check for any false alarms due to windy conditions