FINAL PROJECT REPORT
HYDRAULIC MODEL STUDY
TAWAS BAY MARINA
SCALE MODEL TESTS

Report UMCEE 94-39

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Tawas Bay Marina Scale Model Tests

EXECUTIVE SUMMARY

A scale model of the Tawas Bay Marina was tested. Wave periods inducing the greatest wave activity within the marina were observed to be around 4.0 seconds. The waves were tested at 90 degrees (from the southeast) and 45 degrees (from the east) incident to the marina entrance. Various modifications were tested for the marina including added gabions, riprap wedges, a riprap breakwater (for 45 degree incident waves only), and an angled armor stone extension. These modifications were tested in various combinations to determine the effects on relative wave heights within the marina for wave periods near 4.0 seconds. A combination of adding gabions along interior docks and side docks is recommended. Extending the gabions along the entrance of the marina has only slight wave reduction potential. The use of riprap wedges, a riprap breakwater, or an armor stone extension is not recommended as the wave reduction benefits are negligible or non-existent.

INTRODUCTION

Tawas Bay Marina is located on Lake Huron near Tawas City, Michigan. The marina has dimensions of about 600 ft by 600 ft and is protected by seawalls and beaches, see Figure 1. The marina was dredged such that the current depth in the marina is about 11 feet. A fetch of up to 90 miles across Lake Huron can produce significant wave activity causing undesirable wave action within the marina under even mild weather conditions. The marina has experienced wave heights inside the marina between one and three feet with a period around 4.0 seconds under normal weather conditions. A range of realistic wave periods (between 3.5 and 5.0 seconds) were tested. Modifications such as additional gabions or riprap extensions were tested to evaluate relative changes in wave height in the marina. The results show a general trend in wave height reduction for various marina modifications.

PROCEDURE

The model was set up at a scale of 1 to 30, i. e., all prototype physical dimensions were scaled 1 to 30 while prototype periods are scaled 1 to $(30)^{1/2}$. The prototype modeled had a water depth of 11 feet which corresponded to conditions with the current lake level. A dredged channel extended beyond the marina entrance for sufficient navigation depth of 11 feet; water depth on either side of the dredged channel was 5 to 6 feet. Changing the depth modeled would change the specific period at which high wave activity would be observed, but should not otherwise influence the test results. The waves were generated using a plunger type wave machine that could be adjusted to various frequencies. As repeatability of a specific frequency is difficult, data sets with a specific frequency were collected by running the wave machine in a locked position (i. e., without readjusting the period). The incident waves were measured for 90 degrees (direct from the southeast) and 45 degrees (from the east) of the entrance.

Five points in the marina were selected as having the most observable wave activity in the marina, Figure 1a. Point gauges were installed at these locations for the measurement of wave heights in the marina. Measurements reported for point 2 were collected at either point 2 or 2a, depending on which had a larger wave amplitude. A sixth point, 4a, was added to later studies at the request of the marina. As different frequencies resulted in different incident wave heights, wave activity in the marina was judged by normalizing interior wave amplitudes to incident wave heights. Thus, wave activity is often referred to as the ratio of the marina wave height to the incident wave height. A ratio allows for direct computation of the wave height in the marina at a given incident wave height. From the Corps of Engineers Report wave heights on Lake Huron at Tawas City have the following wave height/wave period correlation:

1 ft wave for a 3.5 second period

2 ft wave for a 4.5 second period

3 ft wave for a 5.0 second period.

These conditions are for waves from the east-south-east.

Various modifications (addition of gabions, riprap, etc.) were tested for the marina. See Figures 1a and 1b for the locations of the modifications in addition to the locations of point gauges. It should be noted that when dock gabions are referred to, both 60 foot long interior dock gabions are in place. Likewise, when side gabions are mentioned for a test, both side gabions are in use.

RESULTS

• multi-period wave testing

The *no gabion* scenario was tested for wave periods between 3.5 and 5.1 seconds at 0.1 second intervals to determine the periods with the most wave activity which was done by comparing marina wave activity to incident wave height. All of the waves tested were 90 degrees incident into the marina. Five periods (3.6, 3.9, 4.1, 4.3, and 5.1 seconds) were chosen for further analysis. These periods were tested with different modifications and are tabulated in Table I. The testing condition with the greatest wave activity appears to occur for periods close to 4.0 seconds. The location of greatest wave action is at point gauge 5 for most periods.

• modifications for 90 degree incident waves

Further testing was done specifically for 90 degree incident waves of period 4.0 seconds. Various modifications were tested to observe the effect on wave activity within the marina. The modifications tested were as follows:

1. *no gabions.* This was tested to see wave action due to the marina geometry alone.
2. *short gabions.* This is the existing condition at the marina. .
3. *extended gabions.* This was tested as an inexpensive improvement to the short gabions by extending the gabions along the entire length of the entrance.
4. *extended gabions with dock gabions*. Dock gabions were tested as if mounted to the ends of two floating docks within the marina; this scenario was tested because of this alternative's effectiveness as a head-on energy dissipater of waves entering the marina.

5. *extended gabions with dock and back gabions (configuration 1, see Figure 1).* Back gabions were tested at the request of the Marina for additional wave reduction at the back of the marina.
6. *extended gabions with back gabions (configuration 2).* Back gabions were tested to determine their effectiveness at wave reduction independent of dock gabions.
7. *extended gabions with side gabions.* Side gabions extending perpendicular to the marina walls were tested as if mounted to floating docks on the sides of the marina; this scenario was tested to determine the effects of side gabions in reducing the wave action of standing waves.
8. *extended gabions with riprap wedges in the entrance.* Riprap wedges were tested at the request of the Marina to determine their wave reduction effect.
9. *short gabions and dock gabions.* This was tested to determine the effectiveness of extended gabions.
10. *extended gabions with side and dock gabions.* This was tested to observe the net wave reduction accrued by the placement of both side and dock gabions.

The results of these tests are tabulated in Table II. To facilitate easier comparison, the last two rows are normalized to the incident wave (point 1). As before, the location of the greatest wave activity (as measured in amplitude) is at point gauge 5. The placement of the back gabions was done either as configuration 1 or 2. Configuration 1 was used when the dock gabions were concurrently tested; this configuration consisted of 60 feet of gabions on the back wall. Configuration 2 was used when the dock gabions were not being concurrently tested; this configuration consisted of a total of 180 feet of gabions on the back wall. The most effective wave energy reducing modification is the use of the dock gabions coupled with the side gabions. Back wall gabions and extending entrance gabions made no appreciable wave reduction within the marina.

Wave activity at point gauge 4a was specifically requested by the Marina for testing, see Table VII. A range of wave periods were tested comparing the existing condition (short gabions) to short gabions with the two dock gabions. The purpose of these tests was to determine a relative magnitude of wave activity at point 4a compared to the other five points. The magnitude of wave activity at point 4a was similar to that measured at point 5. Relative changes in wave height with period is part of the harbor resonance phenomenon and indicates that unless the period is specified, one cannot make a definite statement about where the wave activity is worst. The length of the floating finger piers in the marina will contribute to a sense of greater wave activity if this length is close to one-half the wavelength. As the pier length near point 4a (40 ft) is closer to half the wavelength of a 4.0 second wave than the pier length near point 5 (60 ft), wave activity at point 4a will appear larger in magnitude than at point 5.

Further studies of the 90 degree incident waves of periods 3.9, 4.0, and 4.1 seconds were studied with additional modifications involving the dock gabions in addition to the existing condition (short gabions). The modifications tested were as follows:

1. *short gabions*. The existing condition was tested.
2. *short gabions and both dock gabions*. This is the condition previously tested in the 4.0 second study described above.
3. *short gabions and both dock gabions submerged.* The low water condition in the marina is 3 feet below the current 11 foot depth. This alternative was tested to compare the results of dock gabions set for low water conditions during the event of high water conditions.
4. *short gabions with south dock gabion only*. This was tested to determine how much worse this alternative was to modification 2.
5. *short gabions with extended south dock gabion only.* This modification involved extending the lone south dock gabion an additional 15 feet.

The raw data of these modifications is listed in Table V. The results of these tests indicate that placement of the south dock gabion without the north dock gabion will result in less wave attenuation within the marina than the condition in which both dock gabions are in place. However, extension of a lone south gabion an additional 15 feet (from 60 ft to 75 ft) results in wave attenuation on par with wave attenuation from two 60 foot dock gabions. Dock gabions below the water surface will not reduce wave activity nearly as effectively as dock gabions at the surface; however, some wave reduction will occur.

• modifications for 45 degree incident waves

All of the previous tests were done for 90 degree incident waves from the southeast. Further testing for a 3.9 second wave incident 45 degrees from the east were tested. The modifications tested were as follows:

1. *extended gabions, 90 degrees incident.* This was tested as a comparison for the 45 degree results.
2. *extended gabions, 45 degrees incident.* This scenario compared with the 90 degree results yields the relative magnitude of waves impacting the marina at an angle as opposed to head-on.
3. *short gabions, 45 degrees incident.* This was tested for comparison to the addition of a riprap breakwater in front of the marina entrance.

4. *short gabions with breakwater, 45 degrees incident.* The breakwater was added as it is a possible option being considered by the Marina; the effect of waves approaching the breakwater at an angle were measured.
5. *angled 200 ft long armor stone extension out of harbor.* This is another possibility being considered by the Marina. It was tested at 90 degrees and 45 degrees incidence.

The results of these tests are tabulated in Tables III and VI. Further testing of 45 degree incident waves (3.9, 4.0, and 4.1 second periods) were made for *short gabions with dock gabions* compared to *extended gabions with dock gabions,* see Table IV. This was done to determine the effect of extended gabions on waves approaching the marina at an angle. The results show that for extended gabions only wave activity in the marina was slightly less for waves at 45 degree incident angles as opposed to 90 degree incident waves. The addition of a breakwater results in increased wave activity within the marina for 45 degree incident waves. The angled armor stone extension for 90 degree incident waves resulted in significant wave height reduction, except at some points where the geometry of the marina controlled. A 45 degree incident wave from the east into the armor stone extension results in a significant wave height increase within the marina.

DISCUSSION

From the results there becomes apparent trends in the use of the various modifications. Discussed below are the nature of the modifications, the expected results from such modifications, and the actual test results of such modifications. It should be noted that the model testing was an evolved process that was conducted over a time frame of about four weeks; this discussion is intended to synthesize all of the test results into one comprehensive study.

• point gauge wave heights

All of the raw data is tabulated in the Appendix Tables. In order to communicate the effect of various modifications in the marina simple bar graphs will be used for select points. The relative wave heights of the point gauges are graphed in Figure 2 for representative wave periods of 3.9 seconds and 4.1 seconds. Point gauge 5 experiences the most wave activity under both periods with significant activity at point 2 for 3.9 seconds and point 4a at 4.1 seconds. Points 3 and 4 are both relatively calm in respect to the other points. The graphs discussed in this section are comparisons between wave activity at points 3 and 5. Point 5 is chosen due to large wave activity while point 3 is chosen as a representative point of the marina that does not experience significant wave activity.

Again, it should be noted that most of the graphs are of the wave height ratio to the incident wave (point gauge 1). This is done to demonstrate more easily a percentage change in wave height to the incident and to provide a common baseline for different measurements. Note that the actual wave height in feet is plotted for measurements involving 45 degree incident waves. This was done because many factors can affect the incident wave height (shoaling, refraction, reflection) for angled waves of the same period. Hence, when comparing 90 degree incident waves with 45 degree incident waves a direct ratio of wave height to incident wave height is not appropriate.

• extended gabions along the entrance of the marina

This modification was tested as an inexpensive modification to aid in wave energy attenuation. The idea is that an additional length of gabion will damp out a significant proportion of the wave energy before entering the marina. Wave energy was indeed damped out in the tests, but not as effectively as hoped. As can be seen in Figure 3, the wave height reduction due to extended gabions is 40 % for point 5 and nonexistent for point 3. When other modifications are used along with or instead of extended gabions, the benefit of extended gabions is again nonexistent for point 3 and 50% for point 5, Figure 3. Figure 4, shows graphically that extended gabions reduces wave heights at point 5 for 3.9 and 4.0 second waves but not for 3.6 seconds, 4.3 seconds and 5.1 seconds. Therefore, extended gabions are not a consistently effective wave reduction modification.

• back wall gabions

This modification was tested at the request of the Marina. Gabions can remove greater amounts of wave energy from larger as opposed to smaller oncoming waves. For back wall gabions the height of the striking wave is much smaller than wave heights entering the marina due to wave diffraction. Therefore, the anticipated wave energy reduction due to the placement of gabions along the back wall would be negligible. The results of the testing shows that this occurs in the model, i. e., there is no significant wave height reduction due to the placement of back wall gabions in either configuration 1 or 2. Figure 5 illustrates the ineffectiveness of back wall gabions with and without the placement of dock gabions.

• riprap wedges in the entrance

This modification was also tested at the request of the Marina. Wave energy reduction would be expected with this alternative, however, once waves are inside the marina, wave height attenuation will be less as it is more difficult for the wave energy to exit the marina due to a more restricted channel. This is not to mention the navigational difficulties posed due the presence of these wedges. Figure 6 shows that wave height reduction of up to 25 % at point 5 occurs due to the addition of the riprap wedges for a 4.0 second wave. However, under the same testing conditions the presence of dock gabions reduced wave activity much more effectively.

• breakwater and armor stone extension

Waves incident to the marina at 45 degrees as opposed to 90 degrees were studied to examine the effects of this type of wave action on structures designed for 90 degree incident waves, i. e., breakwaters and armor stone extensions. Figure 7 shows a plot of 45 and 90 degree incident wave activity under existing conditions (short gabions only). Wave heights are slightly smaller for the 45 degree incidence case.

The use of a 200 foot long breakwater 120 feet outside of the marina entrance was tested for 45 degree incident waves. The 90 degree scenario was not tested as it is assumed that wave activity in the marina would be greatly reduced under these conditions. Waves incident to the marina at an angle have a significantly greater wave height when the breakwater is present, Figure 7. Wave activity increases by 50% at point 5 and by a small amount at point 3.

The use of a 200 foot long armor stone extension was tested for both 45 and 90 degree incident waves. Figure 8 shows that armor stone extensions will incur greater wave activity in the marina for 45 degree incident waves. This is due to an amplification of wave energy as it enters the constrained entrance. Another interesting result is that for 90 degree incident waves wave activity in the marina is not reduced as much as would be liked. This is due to multiple reflections within the marina and the fact that wave energy builds up inside the marina until it is able to leave in the same amount that enters. Altering the entrance conditions influences both the wave energy that enters and leaves and so may not affect a reduction in wave height as much as might be expected.

• dock gabions and side gabions

The dock gabions in question are the two 60 foot long gabions that are positioned along two of the floating docks near the entrance of the marina, Figure 1a. The gabions could be mounted to posts near the floating docks. The idea of this modification is direct wave energy (or wave height) reduction as the waves enter the marina. Along with wave energy reduction, the gabions would diffract the waves entering the marina. Figure 9 shows that the two dock gabions acting alone reduce wave activity at point 3 by 70 % and at point 5 by 40 % for 4.0 second waves.

Side gabions extending perpendicularly (as opposed to along the seawalls as is the case for back wall gabions) from the interior marina seawalls can reduce the wave activity due to standing waves rocking back and forth along the sides of the seawalls. These are more for local wave reduction and should be used in conjunction with another wave reducing modification. In the model the side gabions were tested in conjunction with dock gabions. Figure 9 shows that the addition of side gabions to the dock gabion modification results in a wave reduction of 65 % at point 3 and 80 % at point 5 (percentage compared to existing conditions). Hence, the side gabions in addition to dock gabions did not affect wave activity at point 3 but did affect wave activity significantly for point 5 when compared to the use of dock gabions alone.

• **dock gabion modifications**

Dock gabions are the preferred wave reducing modification. Therefore, further study was done for dock gabions under different configurations and different conditions. All of the dock gabion conditions previously described involved both north and south dock gabions, Figure 1a. Further consideration was given to studying only the south dock of 60 feet, a lone south dock extended to 75 feet (the additional 15 feet added to the northern end), and the presence of both north and south docks submerged by three feet of water.

The south dock alone would reduce wave activity as it nearly completely faces the entire entrance of the marina. Wave activity with a 60 foot south dock results in less wave activity in the marina than would occur under existing conditions, but does not work as well as both the north and south docks together, Figure 10. An extended south dock of 75 feet results in similar wave reduction as both the north and south (60 ft long) in conjunction (wave height is less for some points and higher for others).

The present water level of 11 feet is 3 feet higher than the expected low water condition. If both the north and south dock gabions were installed to be at the water surface under low water conditions, the gabions would presently be under three feet of water. This scenario was tested to determine what sort of wave reduction potential the submerged gabions would have. Figure 10 shows that submerged dock gabions would indeed reduce wave activity in the marina, but not as much as surfaced dock gabions. Wave reduction is about the same at point 3, but not nearly as effective at point 5.

• **experimental error**

The model results are subject to some uncertainty. The point gauges have a reading error of about 10%. Problems with determining steady state conditions is a source of error. As indicated by the problems of repeating 4.0 second period runs, several factors seem to influence wave behavior in the model. Slight changes in water depth and wave period can have significant effects on results. A change in the plunger setting on the wave generator can also have a significant impact (this happened for the 3.9 second wave in Table IV). With due consideration for the ability to control all test variables, the results seem relatively consistent with each other. Hence, reasonable confidence in these results exists for estimating relative wave heights and general trends within the marina.

CONCLUSIONS AND RECOMMENDATIONS

The scale model tests for the Tawas Bay Marina has given results that allow for the following conclusions:

1. The worst wave conditions for Tawas Bay Marina under normal conditions are at around 4.0 seconds.
2. The point with the most wave activity in Tawas Bay Marina is in the northeast corner of the marina, point gauge 5.
3. Extended gabions alone have negligible effect on reducing wave activity for waves directly incident to marina or incident at an angle.
4. Short entrance gabions in combination with either side gabions, dock gabions, or riprap wedges appear to reduce wave activity for 4.0 second period waves.
5. The use of gabions on the back wall has a negligible effect on wave action in the marina.
6. The use of a riprap breakwater outside the marina has negligible effects on wave activity within the marina for waves 45 degrees incident to the entrance.
7. The use of a breakwater or an armor stone extension significantly increases wave activity in the marina under 45 degree incident waves.
7. The single most effective modification to marina wave height reduction is the addition of dock gabions inside the marina.

In regard to the above conclusions, *it is recommended that either the existing gabions in conjunction with dock gabions alone or in conjunction with dock and side gabions be used.* A combination (i.e., short, dock and side gabions) would produce the most favorable results. Submerged dock gabions will not be as effective as surfaced gabions. The use of only the south gabion will not be as effective as both the north and south gabions unless the south gabion is extended. If only one side gabion is to be placed, the more effective wave reduction location is along the 60 ft. slips in the northeast corner (near point gauge 5). Extended entrance gabions and back wall gabions may be added for aesthetic purposes but will not significantly reduce wave action. Riprap extensions into the entrance reduce wave action for 4.0 second waves but could increase navigational dangers for water vessels using the marina. A riprap breakwater's use is not recommended, nor is the use of armor stone extensions as waves approaching the marina at an angle would actually increase the wave activity within the marina.

Appendix A: Figures and Tables

Figure 1a. Gabion and breakwater configurations in Tawas Bay Marina and the location of point gauges

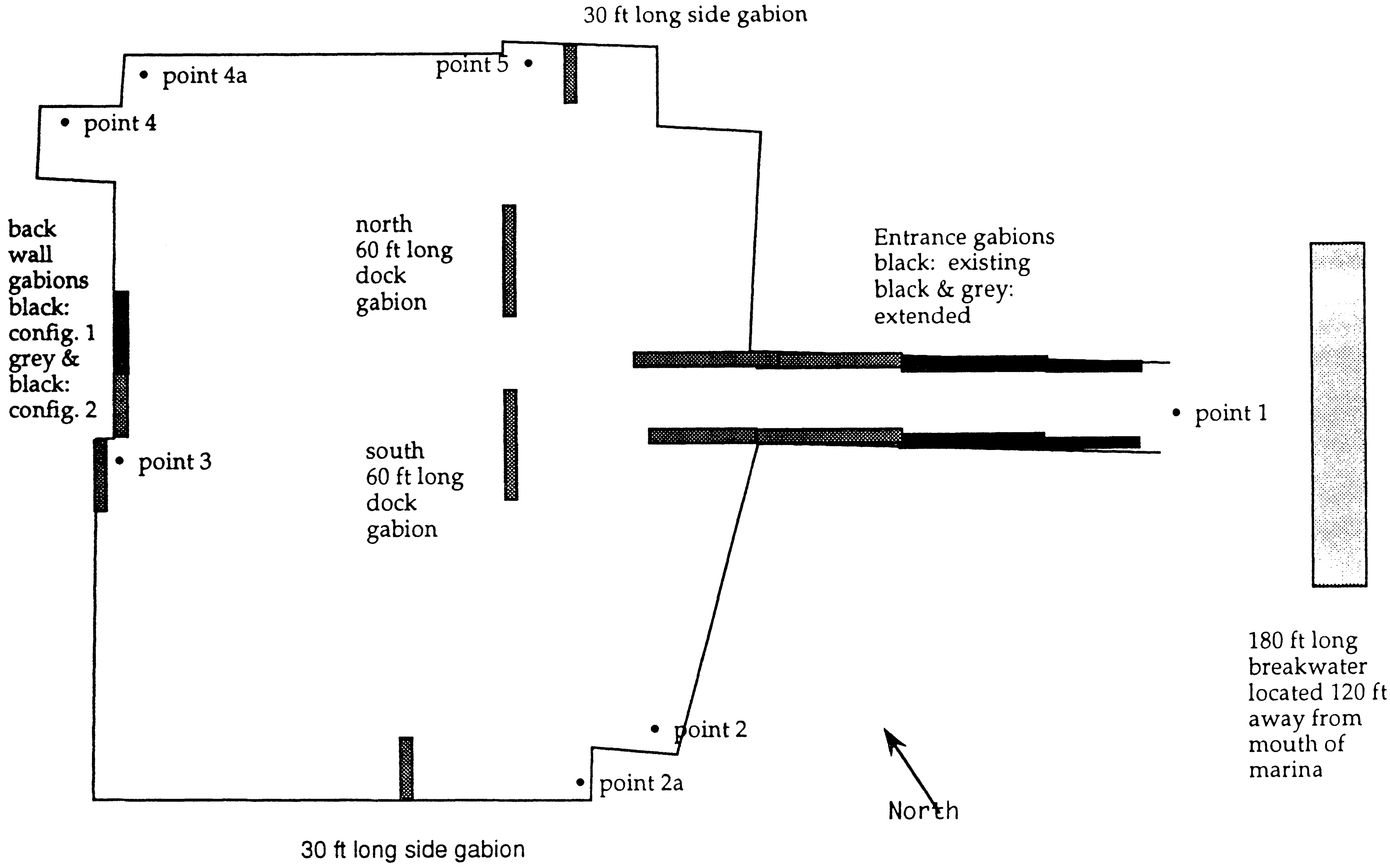

Figure 1b. Other structural configurations in Tawas Bay Marina

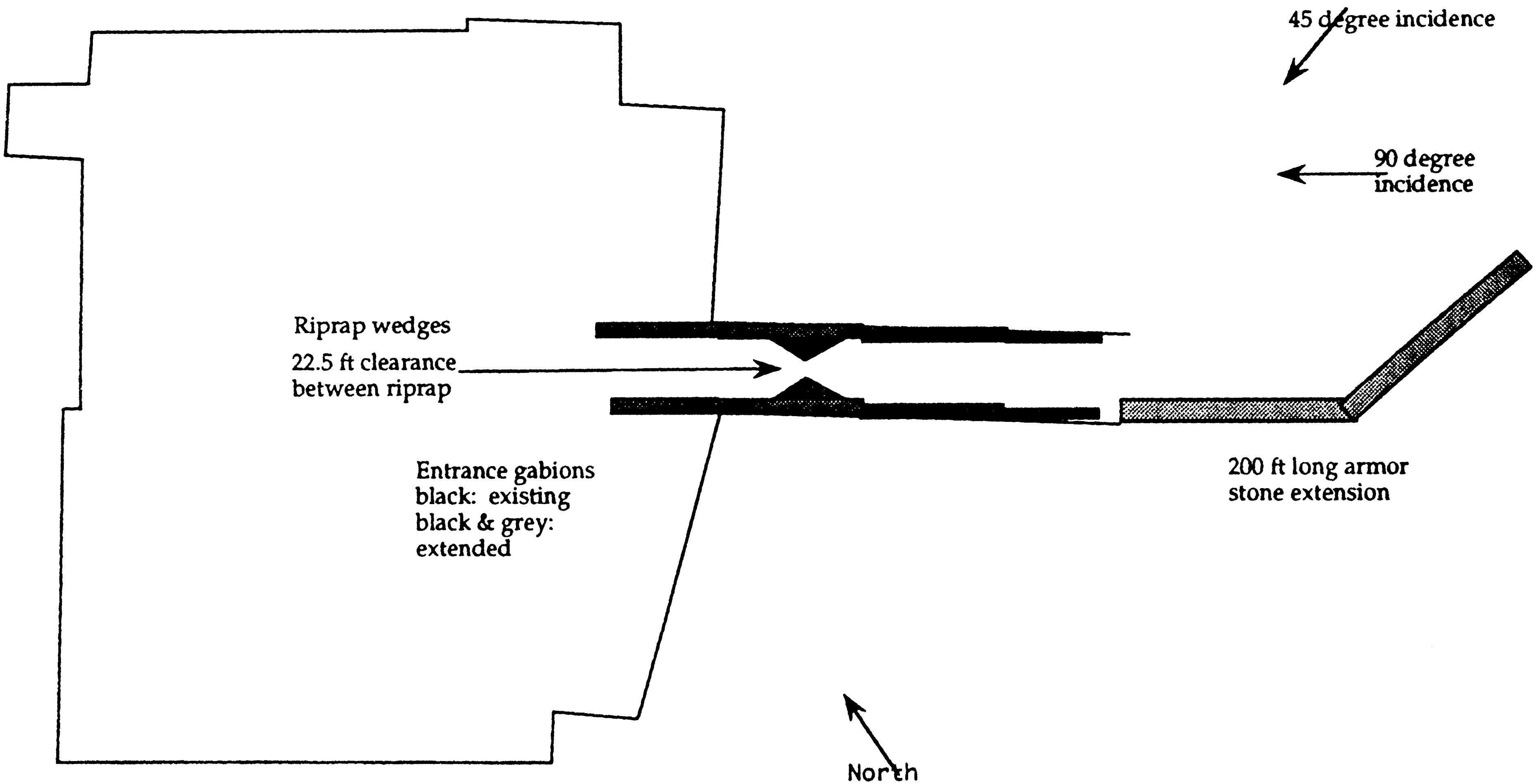

Figure 2. Relative point gauge wave ht

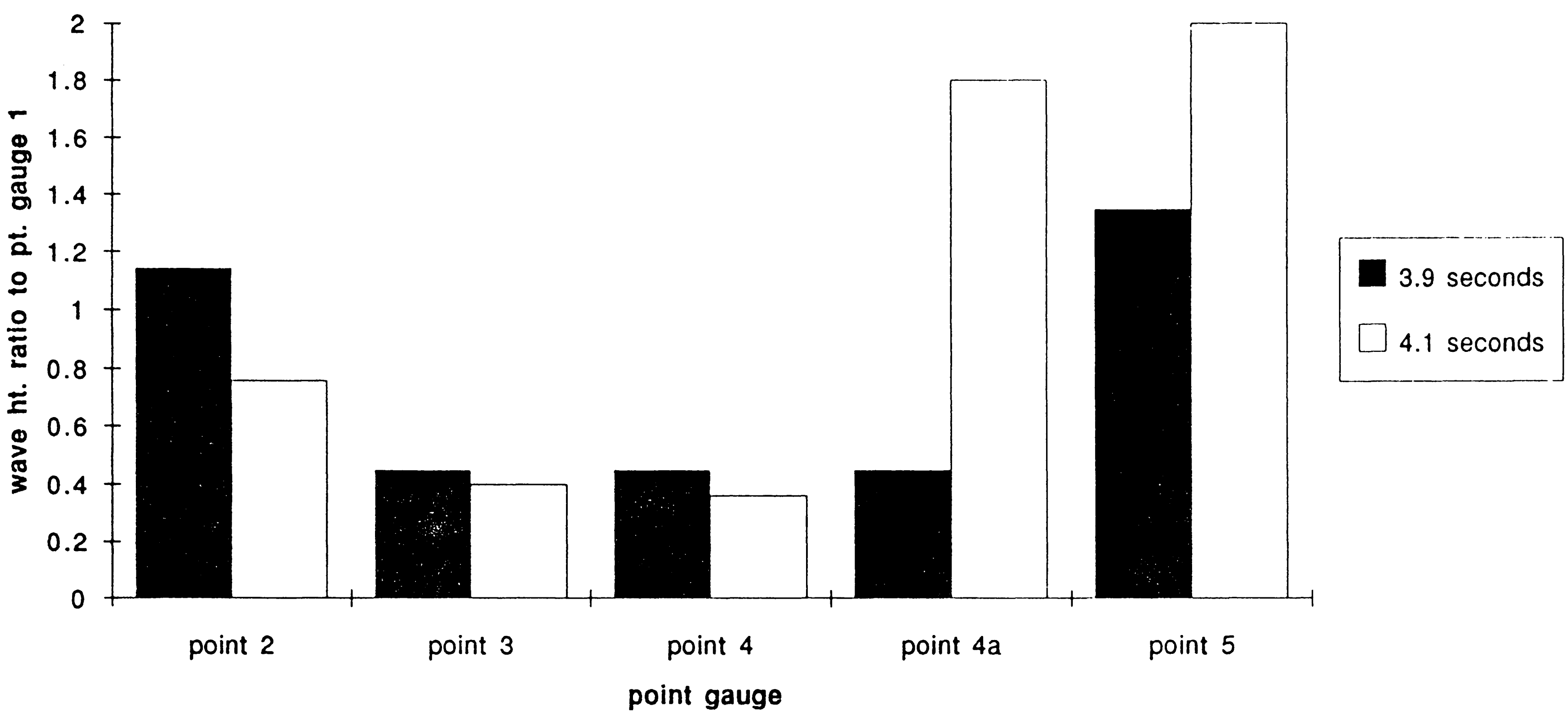

Figure 3. Existing condition vs. extended gabions, 4.1 second wave

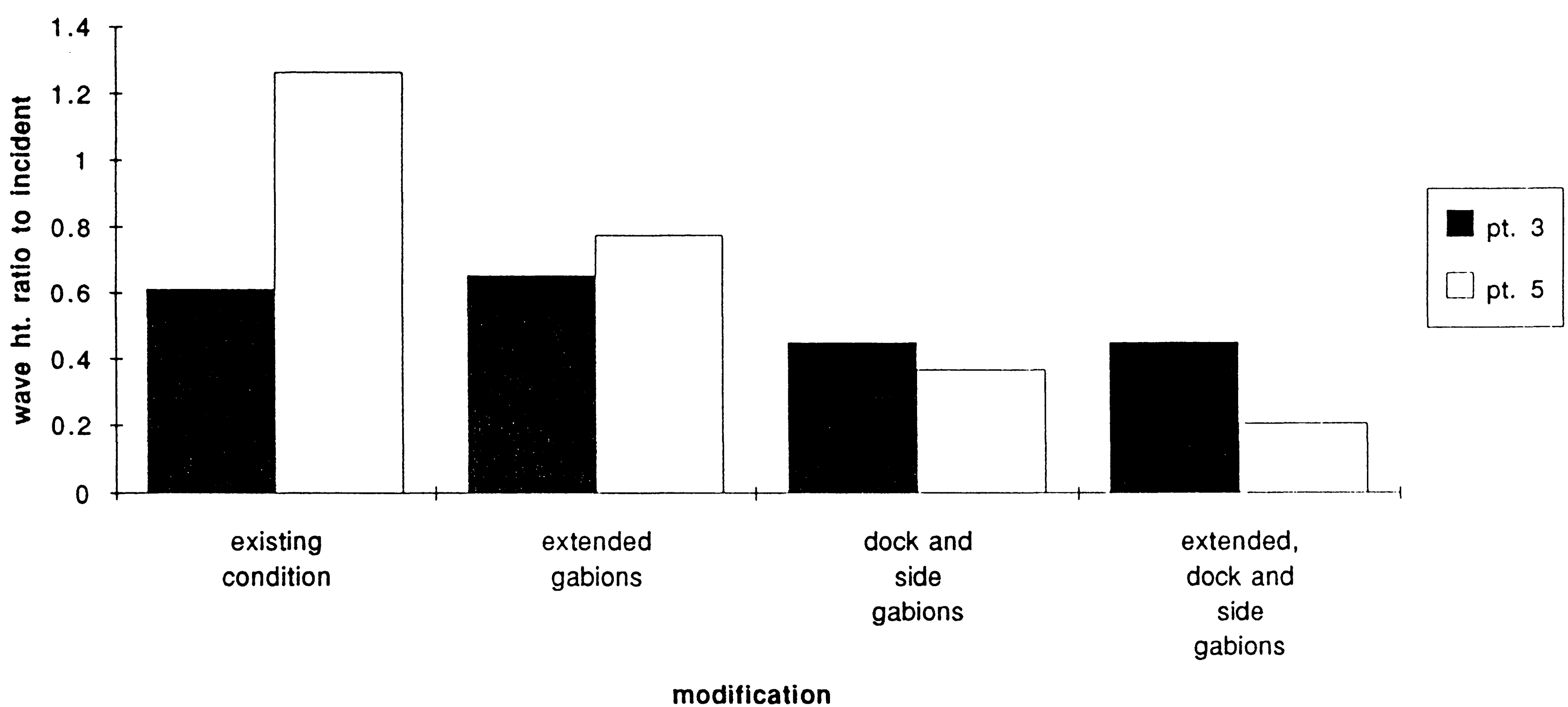

Figure 4. Effect of modifications to point gauge 5

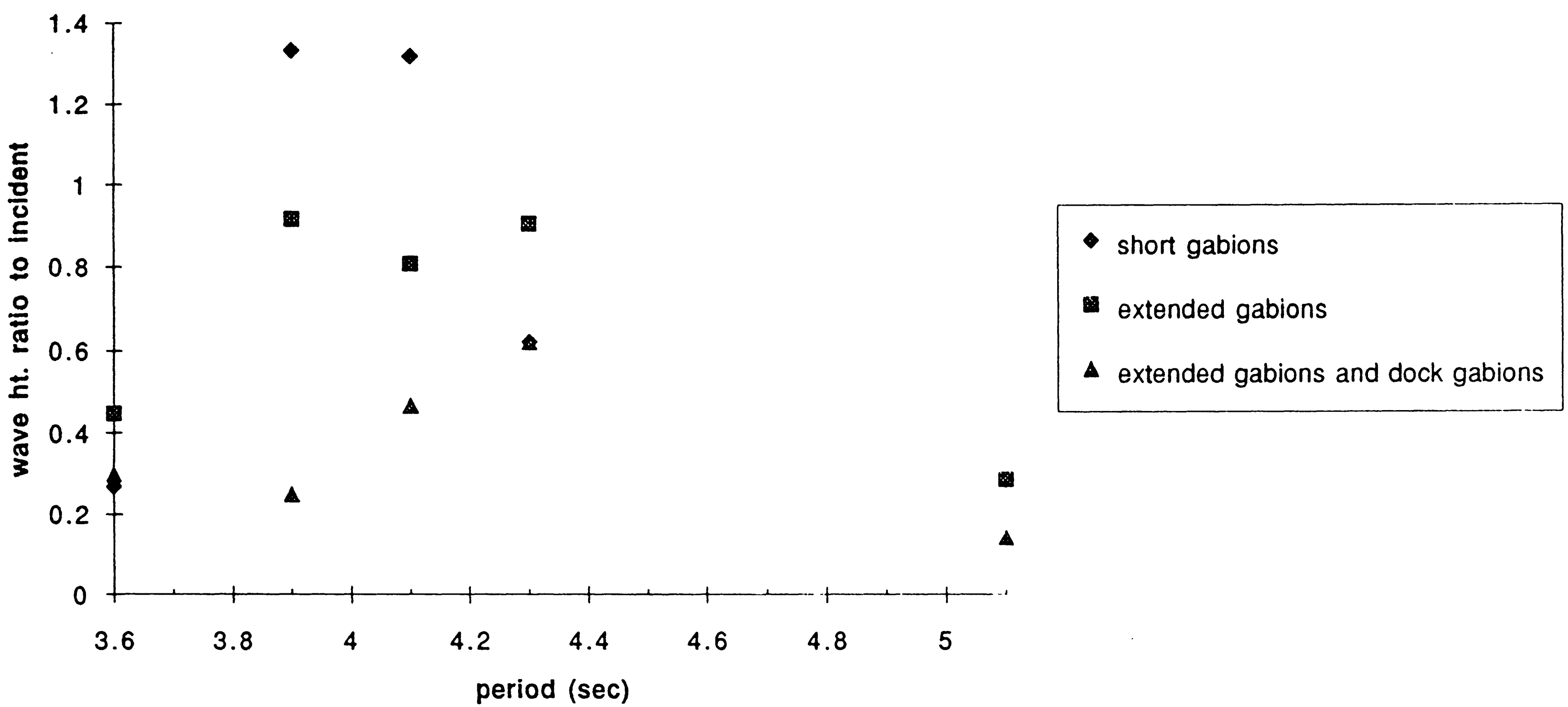

Figure 5. Effect of back wall gabions, 4.0 second wave

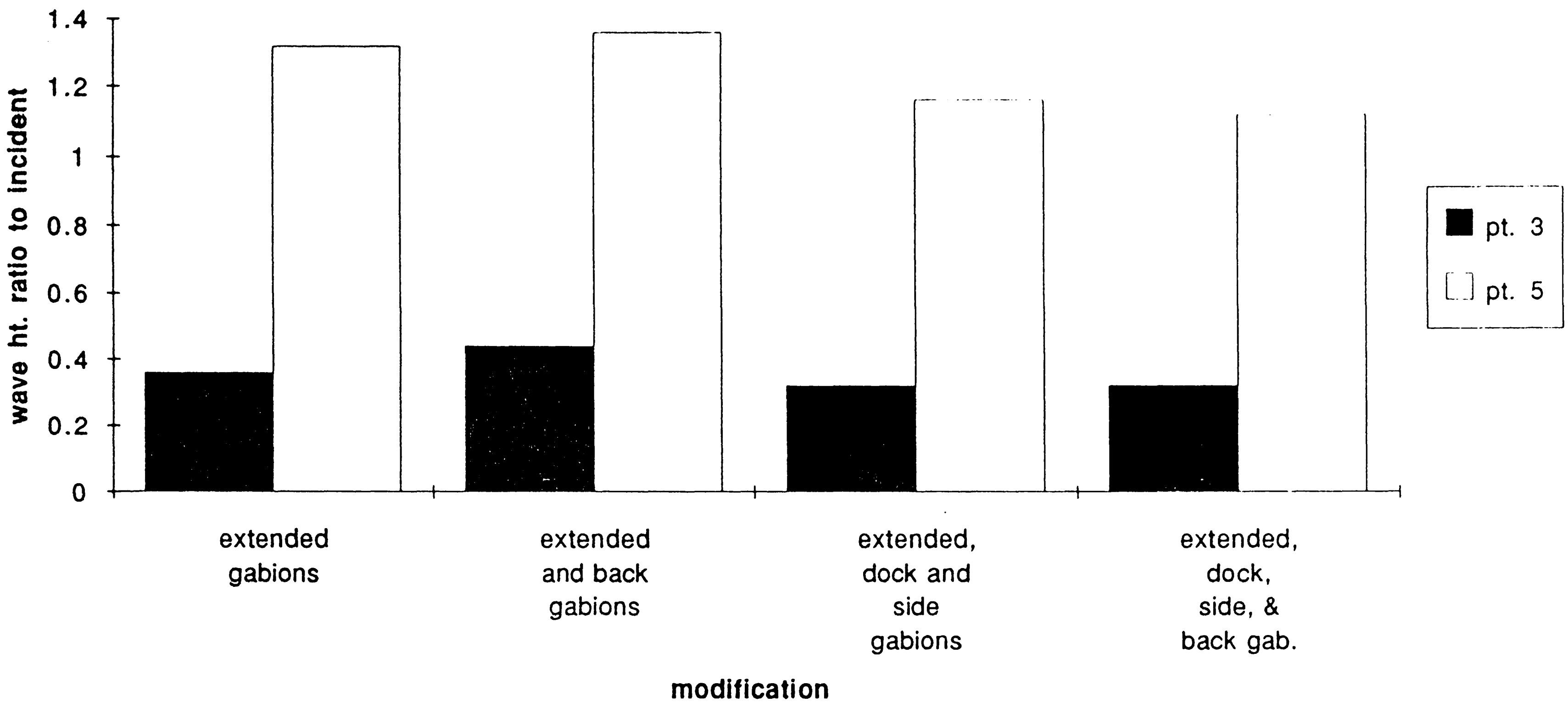

Figure 6. Rip rap wedges vs. dock gabions, 4.0 second wave

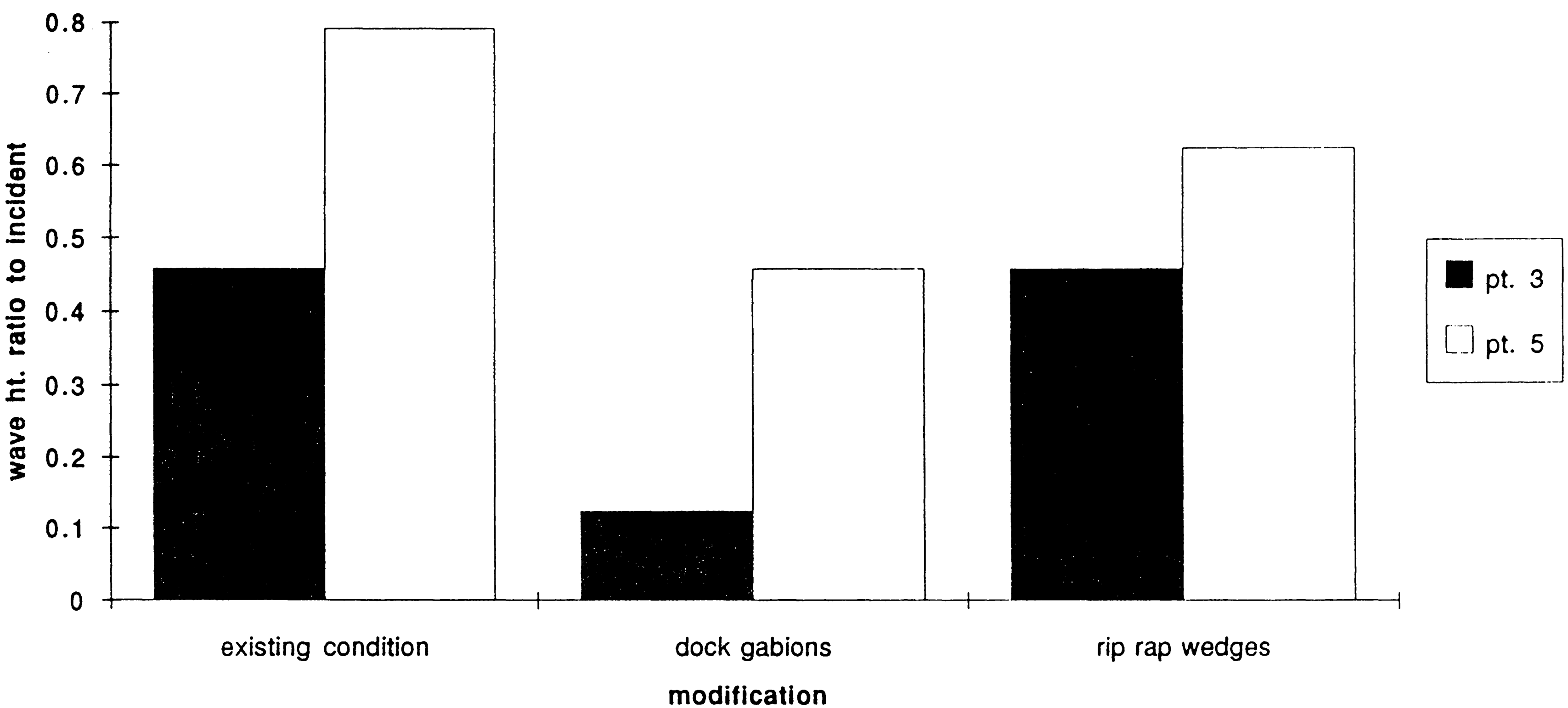

Figure 7. Change of wave direction and breakwater addition, 3.9 second wav

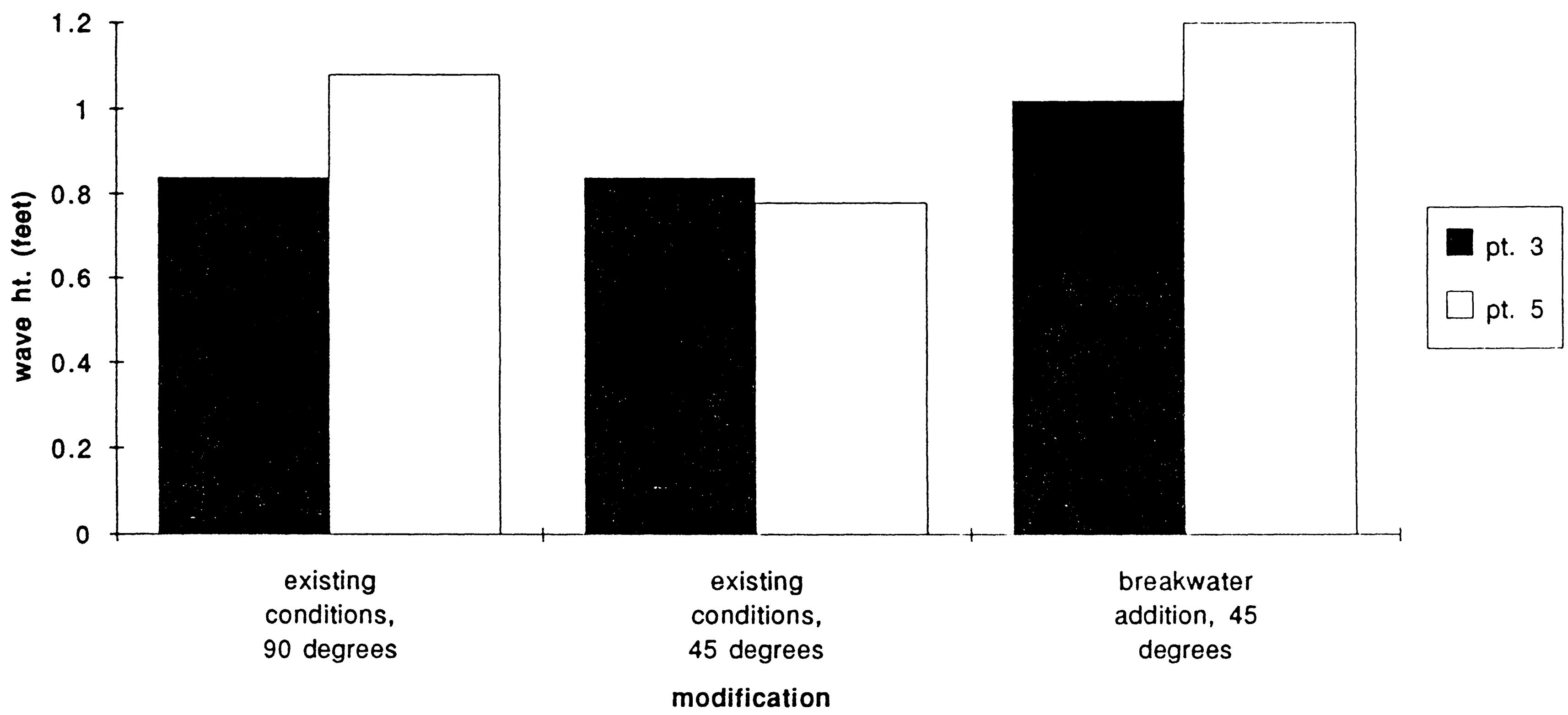

Figure 8. Effects of armor stone extension, 4.1 second wave

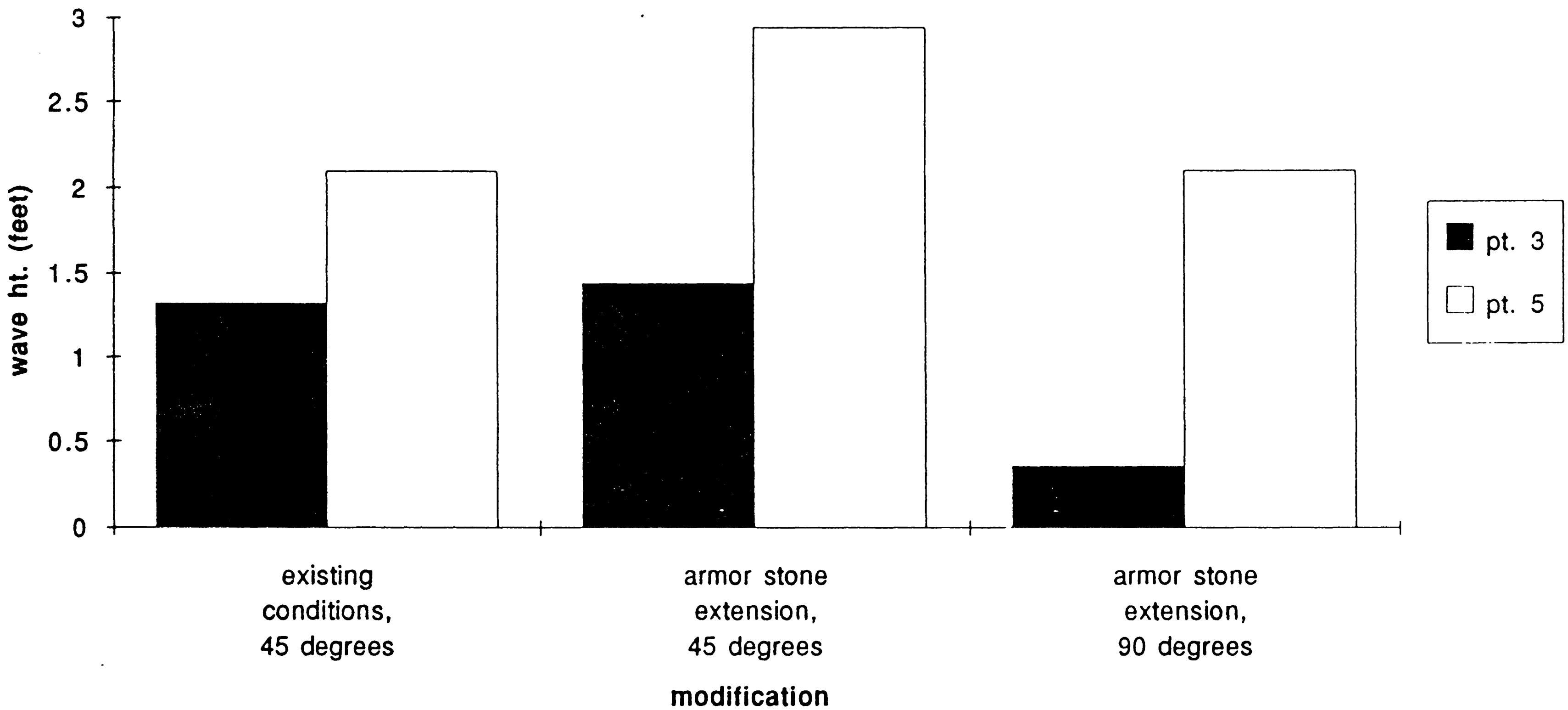

Figure 9. Effect of dock and side gabions, 4.0 second wave

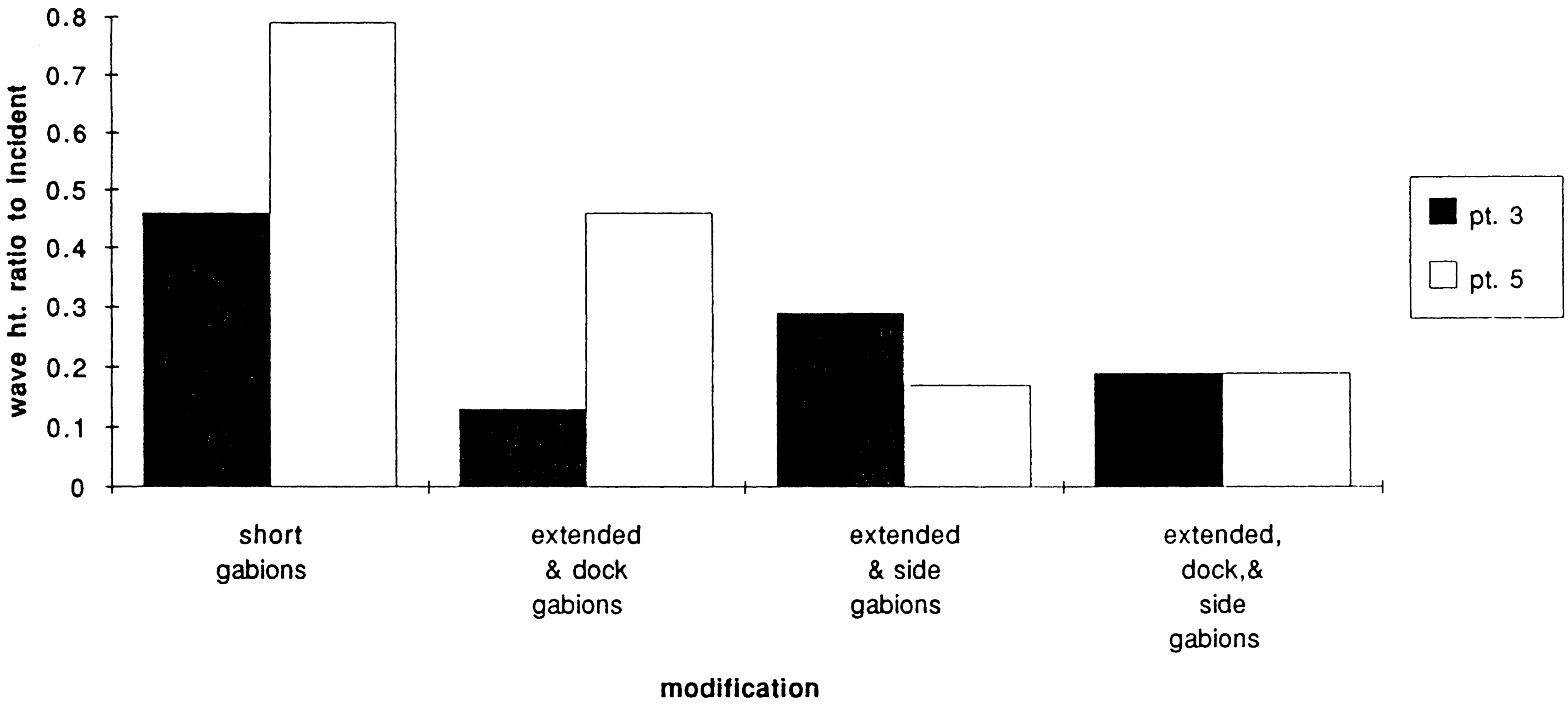

Figure 10. Dock modifications, 3.9 second wave

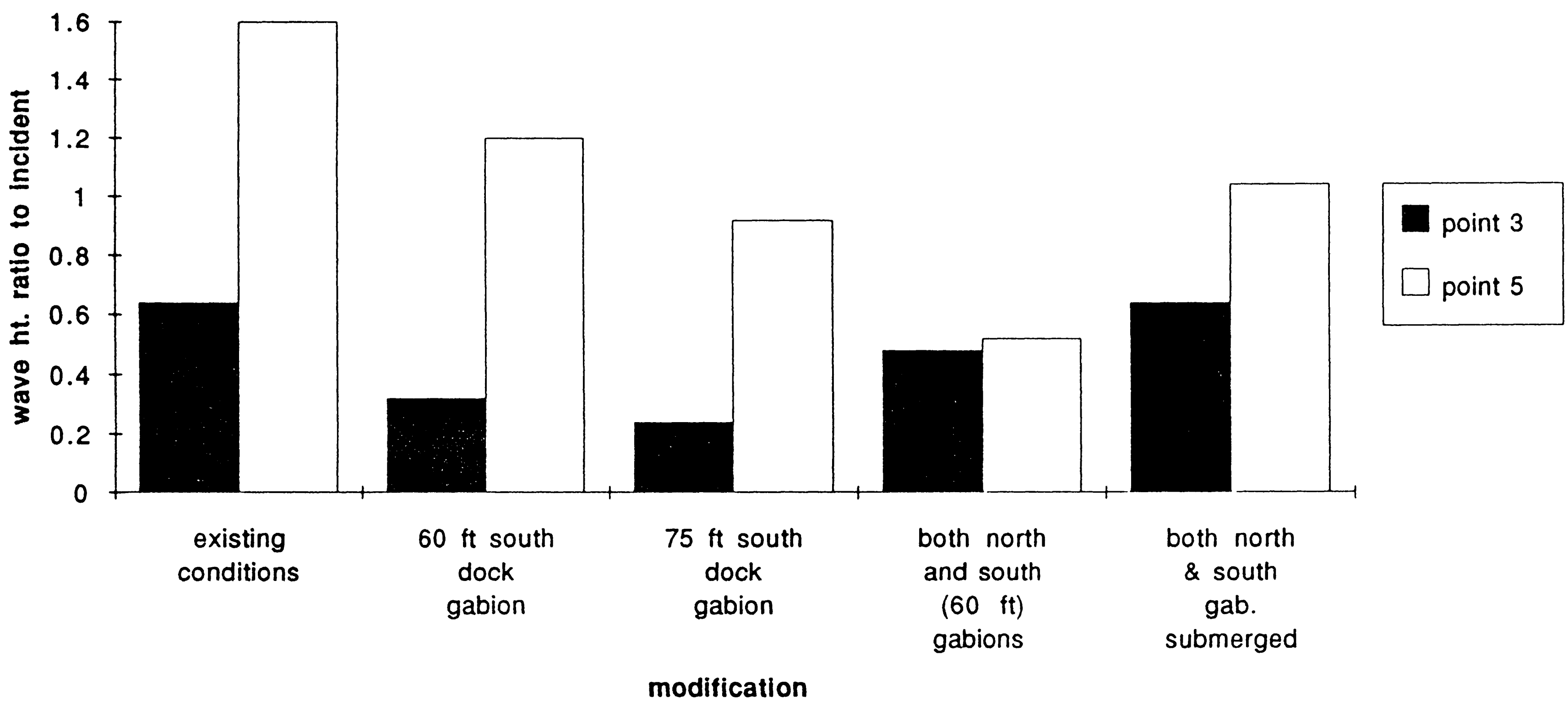

Table I. Real Wave Heights (in feet) of selected periods, 90 degrees incident

3.6 seconds

	no gabions	short gabions	ext. gabions	ext gab + dock gab
1	2.01	2.01	2.01	2.01
2	0.72	1.02	0.48	0.18
3	1.92	0.6	0.48	0.36
4	1.62	1.14	0.9	0.6
5	0.48	0.54	0.9	0.6

3.9 seconds

	no gabions	short gabions	ext. gabions	ext gab + dock gab	ex,side,dock	short,side, dock	riprap
1	1.48	1.48	1.48	1.48	1.48	1.48	1.48
2	1.8	1.38	1.32	1.08	0.72	0.72	0.66
3	1.5	1.2	1.2	1.08	0.36	0.6	0.78
4	1.02	0.72	0.66	0.78	0.36	0.6	0.3
5	2.4	1.92	1.32	0.36	0.36	0.48	1.02

4.1 seconds

	no gabions	short gabions	ext. gabions	ext gab + dock gab	ex,side,dock	short,side, dock	riprap
1	1.47	1.47	1.47	1.47	1.47	1.47	1.47
2	2.1	2.1	1.02	0.54	0.54	0.96	0.84
3	1.98	0.9	0.96	0.48	0.66	0.66	0.78
4	1.02	0.78	0.78	0.84	0.48	0.6	0.9
5	2.34	1.86	1.14	0.66	0.3	0.54	1.26

4.3 seconds

	no gabions	short gabions	ext. gabions	ext gab + dock gab
1	1.06	1.06	1.06	1.06
2	1.5	1.08	0.96	0.72
3	1.2	0.96	0.84	0.78
4	0.84	0.42	0.24	0.24
5	0.96	0.66	0.96	0.66

5.1 seconds

	no gabions	short gabions	ext. gabions	ext gab + dock gab
1	1.26	1.26	1.26	1.26
2	0.12	0.12	0.06	0.06
3	0.84	0.9	0.96	0.54
4	0.78	0.78	0.72	0.42
5	0.6	0.36	0.36	0.18

Table II. 4.0 second period, real wave height (in feet), 90 degrees incident

physical modification

1: no gabions
2: short gabions (existing condition)
3: extended gabions
4: extended gabions and dock gabions
5: extended gabions, dock and back gabions (configuration 1)
6: extended gabions and back gabions (configuration 2)
7: extended gabions and side gabions
8: extended gabions and riprap
9: short gabions and dock gabions
10: extended, dock, and side gabions

modification 5/4/94

point gauge	**1**	**2**	**3**
1	1.5	1.5	1.5
2	3.06	3.12	2.34
3	1.26	0.9	0.66
4	2.52	1.2	1.2
5	3.06	2.1	1.56

modification 5/5/94

point gauge	**3**	**4**	**5**	**6**
1	1.5	1.5	1.5	1.5
2	2.34	0.72	0.72	0.72
3	0.66	0.48	0.48	0.66
4	1.2	0.48	0.36	0.24
5	1.98	1.74	1.68	2.04

modification 5/5/94

point gauge	**3**	**7**
1	1.5	1.5
2	0.6	0.48
3	0.6	0.54
4	0.36	0.54
5	1.74	0.84

modification 5/6/94

point gauge	**2**	**3**	**4**	**7**	**8**
1	1.44	1.44	1.44	1.44	1.44
2	1.2	0.9	0.48	0.48	0.72
3	0.66	0.6	0.18	0.42	0.66
4	0.96	0.36	0.18	0.42	0.36
5	1.14	1.14	0.66	0.24	0.9

modification 5/10/94

point gauge	**2**	**9**	**10**
1	1.62	1.62	1.62
2	1.26	0.54	0.12
3	0.54	0.48	0.3
4	0.6	0.6	0.3
5	1.5	1.08	0.3

Table II (cont.). Data normalized to incident wave height

point gauge	*modification* 1	2	3	4	5
1	1.00	1.00	1.00	1.00	1.00
2	2.04	0.83	0.63	0.33	0.48
3	0.84	0.46	0.42	0.13	0.32
4	1.68	0.67	0.25	0.13	0.24
5	2.04	0.79	0.79	0.46	1.12
	6	**7**	**8**	**9**	**10**
1	1.00	1.00	1.00	1.00	1.00
2	0.48	0.33	0.50	0.33	0.07
3	0.44	0.29	0.46	0.30	0.19
4	0.16	0.29	0.25	0.37	0.19
5	1.36	0.17	0.63	0.67	0.19

physical modification

1: no gabions
2: short gabions (existing condition)
3: extended gabions
4: extended gabions and dock gabions
5: extended gabions, dock and back gabions (configuration 1)
6: extended gabions and back gabions (configuration 2)
7: extended gabions and side gabions
8: extended gabions and riprap
9: short gabions and dock gabions
10: extended, dock, and side gabions

Table III. 3.9 second period, real wave height (in feet) at 90 and 45 degree angle incident waves

physical modification

1: extended gabions, 90 degrees (head on)
2: short gabions, 45 degrees
3: extended gabions, 45 degrees
4: extended and dock gabions, 45 degrees
5: extended, dock and side gabions, 45 degrees
6: short gabions with breakwater, 45 degrees

	modification		
point gauge	**1**	**2**	**3**
1	1.56	2.76	2.76
2	1.02	1.32	0.96
3	0.84	0.84	0.48
4	0.72	0.3	0.3
5	1.08	0.78	0.84

	4	**5**	**6**
1	2.76	2.76	3.24
2	0.3	0.66	1.26
3	0.3	0.24	1.02
4	0.18	0.54	0.36
5	0.72	0.24	1.2

TABLE IV.

Table IV. Effect of extended gabions for 45 degree incident wa'
Real wave heights in feet

3.9 second wave

point gauge	modification short gab w/ dock	ext. gab w/ dock gab
1	5.16	5.46
2	0.72	0.84
3	1.08	1.08
4	0.96	0.6
5	1.08	0.9

4. 0 second wave

point gauge	modification short gab w/ dock	‹t. gab w/ dock gab
1	2.76	2.76
2	1.26	1.44
3	0.12	0.42
4	0.66	0.42
5	0.9	1.2

4.1 second wave

point gauge	modification short gab w/ dock	‹t. gab w/ dock gab
1	2.82	2.82
2	1.26	0.84
3	0.36	0.72
4	0.78	0.54
5	0.78	0.6

Table V. Real wave heights for dock modifications

3.9 seconds

point gauge	*modification* **existing**	**s. dock (60 ft)**	**s. dock (75 ft)**	**both docks**	**submerged docks**
1	1.5	1.5	1.5	1.5	1.5
2	1.5	1.38	1.08	1.08	1.38
3	0.96	0.48	0.36	0.72	0.96
4	0.48	0.48	0.18	0.3	0.9
4a	1.5	0.9	0.6	0.72	1.02
5	2.4	1.8	1.38	0.78	1.56

4.0 seconds

point gauge	*modification* **existing**	**s. dock (60 ft)**	**both docks**	**submerged docks**
1	1.74	1.74	1.74	1.74
2	0.84	0.78	0.66	0.78
3	1.38	0.36	0.6	0.78
4	0.3	0.24	0.24	0.3
4a	1.62	0.54	1.02	1.38
5	2.04	1.08	0.54	1.38

4.1 seconds

point gauge	*modification* **existing**	**s. dock (60 ft)**	**both docks**	**submerged docks**
1	1.74	1.74	1.74	1.74
2	1.98	1.2	1.44	1.5
3	2.4	1.68	0.96	1.8
4	1.08	1.08	0.48	1.08
4a	1.32	1.02	1.02	1.32
5	2.46	1.98	2.28	2.28

Table VI. Wave height (in feet) for armor stone extension

modifications
1: short gabions, 45 degree incident wave
2: short gabions & armor stone extension, 45 degrees
3: short gabions & armor stone extension, 90 degrees

4.1 seconds

point gauge	*modification* **1**	**2**	**3**
1	3.36	3.54	0.66
2	1.68	2.7	1.14
3	1.32	1.44	0.36
4	1.26	1.86	0.84
4a	2.4	3	1.8
5	2.1	2.94	2.1

Table VII. Tests with point 4a for 90 degree incident waves

	3.6 seconds *modification*		4.0 seconds *modification*	
point gauge	**short gab.**	**short & dock gab.**	**short gab.**	**short & dock gab.**
1	2.28	2.28	1.56	1.56
2	0.66	0.42	1.08	0.66
3	0.78	0.3	1.38	1.2
4	1.32	0.54	0.96	0.72
4a	1.5	0.6	1.98	1.86
5	1.38	0.42	2.16	1.68

	3.9 seconds *modification*		4.1 seconds *modification*	
point gauge	**short gab.**	**short & dock gab.**	**short gab.**	**short & dock gab.**
1	1.47	1.47	1.5	1.5
2	1.68	1.38	1.14	1.14
3	0.66	0.78	0.6	0.48
4	0.66	0.96	0.54	0.54
4a	0.66	0.24	2.7	1.32
5	1.98	1.5	3	2.1

AIIM SCANNER TEST CHART #2

Spectra

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Times Roman

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6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
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Century Schoolbook Bold

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6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
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News Gothic Bold Reversed

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6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
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Bodoni Italic

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Greek and Math Symbols

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6 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⋫⋪⋗⋜≡
8 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⋫⋪⋗⋜≡
10 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⋫⋪⋗⋜≡

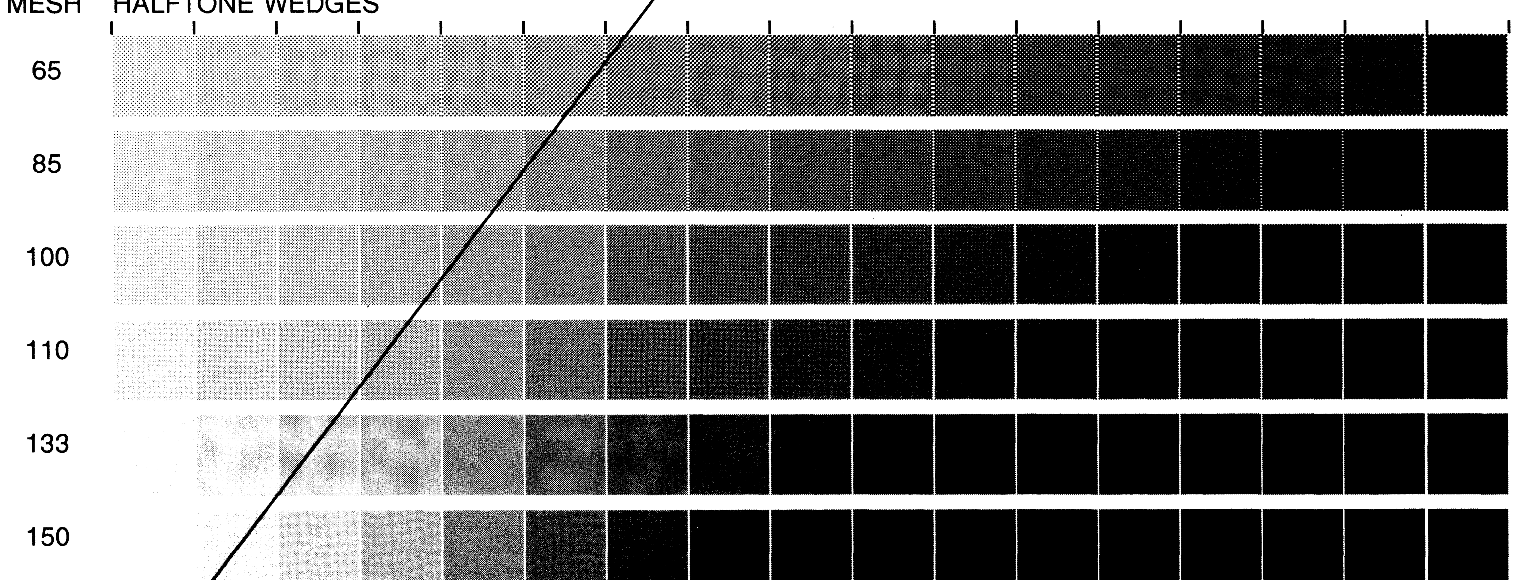
White

Black

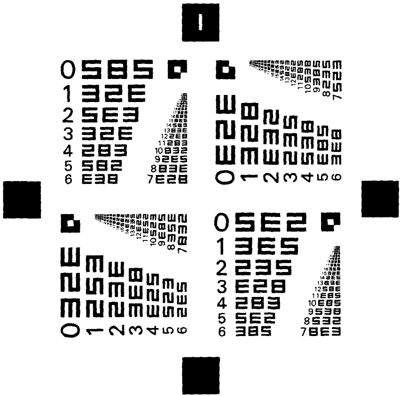
Isolated Characters

e	m	1	2	3	a
4	5	6	7	o	•
8	9	0	h	l	B

MESH HALFTONE WEDGES



RIT ALPHANUMERIC RESOLUTION TEST OBJECT, RT-1-71



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