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SQUALICUM SMALL BOAT BASIN:

Flushing Characteristics by Hydraulic Model

By

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Mr. Norman H. Smith, graduate student Department of Civil Engineering was the Research Assistant on the project and carried out the model construction and testing program in the Harris Hydraulic Laboratory with the assistance of Bradley Fristoe, Civil Engineering student (senior class). Mr. Vernon E. Cook was the Contracting Officers Representative and Mark Ekman his project engineer.

Several meetings with representatives of the project sponsor, the Port of Bellingham, and of governmental agencies interested in the project, were held during the course of the study to demonstrate operational procedures, to discuss results of plans tested, and to formulate possible design improvements.

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INTRODUCTION

The plans for a small boat basin (marina) proposed as an extension of existing facilities in Squalicum Harbor, Bellingham, Washington, as described in the Detailed Project Report (Seattle District June 1975) presented some questions regarding the consequential impact of the development upon water quality. One imput to the impact evaluation was this study of physical model for the purpose of evaluating certain hydraulic characteristics for the following configurations:

(a) The proposed plan including the existing basin, new basin, and I and J Street Waterway as shown in the Detailed Project Report.

(b) The proposed plan, except with the breakwater between the existing and new basins left in place.

(c) The proposed plan, with the addition of a training wall at the entrance to the interior of the new basin.

(d) An additional variation of the new basin as determined by the contractor and agreed to by Seattle District.

An important issure implicit in the configurations (a) and (b) above is whether the least impact on water quality would follow the layout with the proposed new basin interconnected with, or separated from, the existing basin.

The "certain hydraulic characteristics" of a marina as relating to water quality have three interdependent components. The tidal prism ratio, the ratio of volume between low and high tide to the basin volume, is a measure of the potential exchange of basin water with each tide, and can be computed from geometric data. A second component or parameter that has been developed to quantify the actual exchange with each tide is the exchange coefficient. This coefficient can be evaluated by flourescent dye techniques as a gross measure of the entire basin, or for a coarse grid by dividing the basin into a few sections and determining the "local" exchange coefficient for each.

If the waters coming into the basin on each tide were completely mixed with the ambient waters, the tidal prism ratio and the exchange coefficient essentially would be the same. However, the effects of rotational flow, the separation of flows from boundaries, the formation of individual circulation cells or gyres within the basin, the differences between ebb and flood flows, all have a bearing upon how completely the mixing may take during a series of tides. Without adequate mixing, local regions of quiescent water may develop, especially at basin extremities, even though the overall tidal prism ratio and exchange coefficients appear to be favorable. The mixing parameter is purely a qualitative one, but can be judged from observations and photographic records.

A physical model was constructed to a distorted scale of 1:600 for horizontal dimensions and 1:48 for vertical ones, and tested for the range of configurations listed above, as well as several others that developed during the course of the study.

LOCALE

Bellingham Bay is about 70 miles north of Seattle, Washington and is a part of the Strait of Juan de Fuca-Puget Sound complex (see Figure 1). The planform area covered by the model is shown on Figure 2. Major bathymetric and oceanographic features are described in a report by Collias and Barnes (1966). A later report (Seattle District, Corps of Engineers 1977) summarizes features of more local concern to bellingham Bay, including current measurements for a tidal series in March 1977. The currents in Bellingham Bay and the associated salinity and dissolved oxygen levels are the result of the interplay among the tidal forces (the dominant feature), salinity gradients, freshwater inflow from the Nooksack River, and, locally, the flow from Squalicum and Whatcom Creeks, and wind stresses.

Both referenced reports show counterclockwise "inferred" current patterns on the flooding tide. The 1977 report gives much greater detail, as reproduced in Figures 3 through 8. Under the southwesterly wind, a clockwise ebb current developed, whereas the shallow flood tended to move against the wind, with a weak counterclockwise current in front of the existing boat basin. The deep flood showed the stronger counterclockwise current. The special attention to the currents in front of the basin entrances is given here because their direction with respect to the entrances influences the strength of the flow into the marina on the flood and the fate of the water from the marina on the ebb.

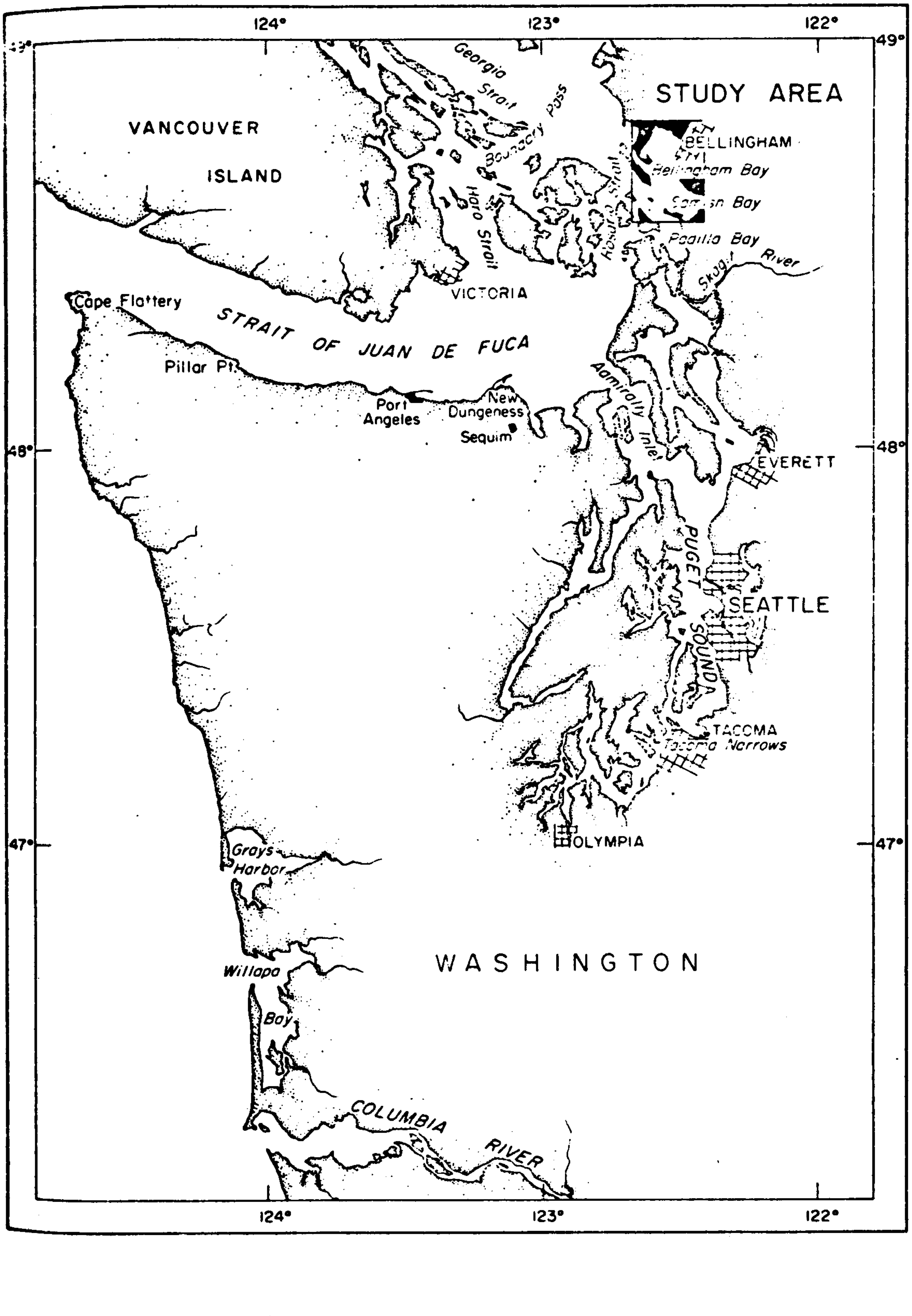

Figure 1 - Location of Bellingham Bay

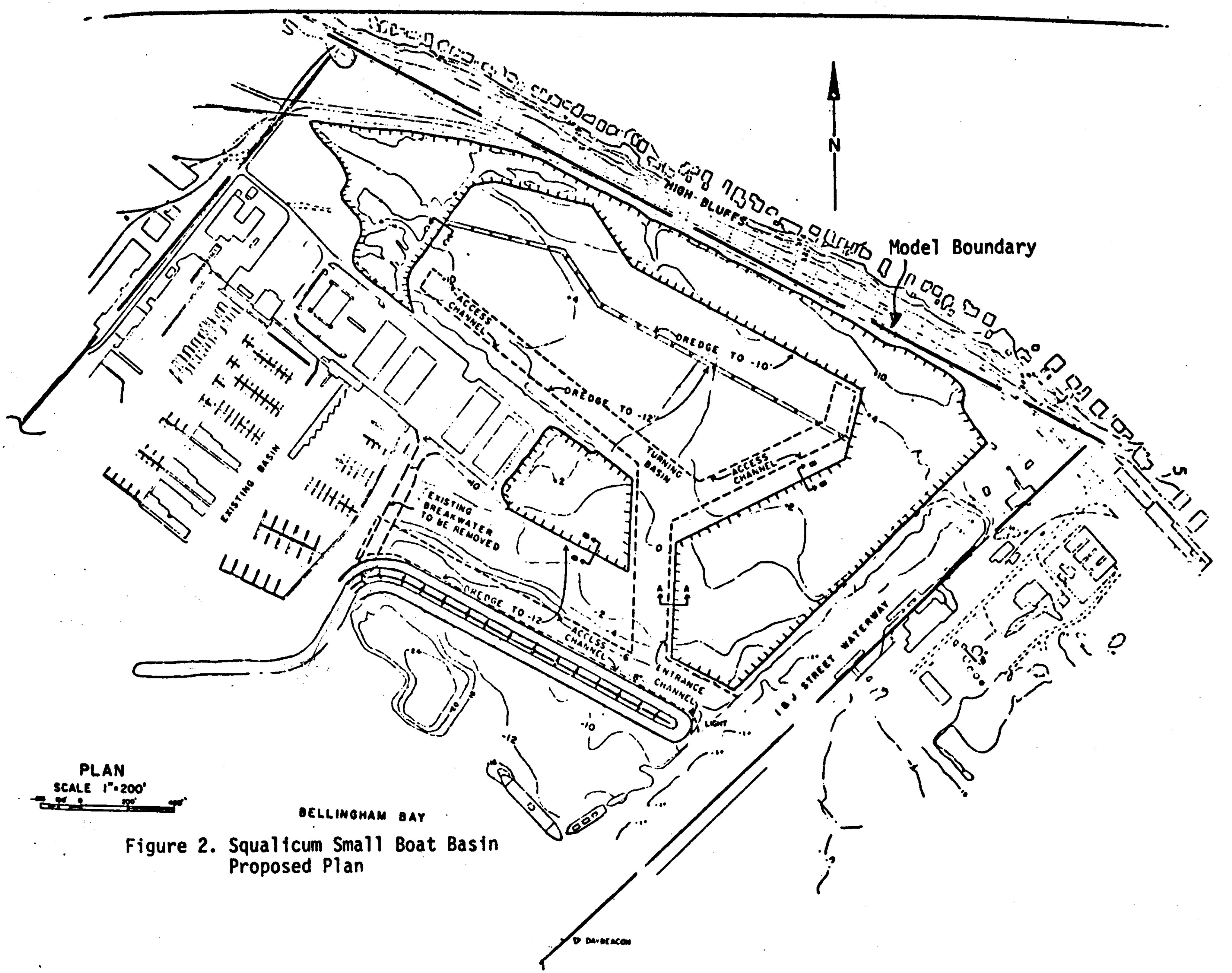

Figure 2. Squalicum Small Boat Basin
Proposed Plan

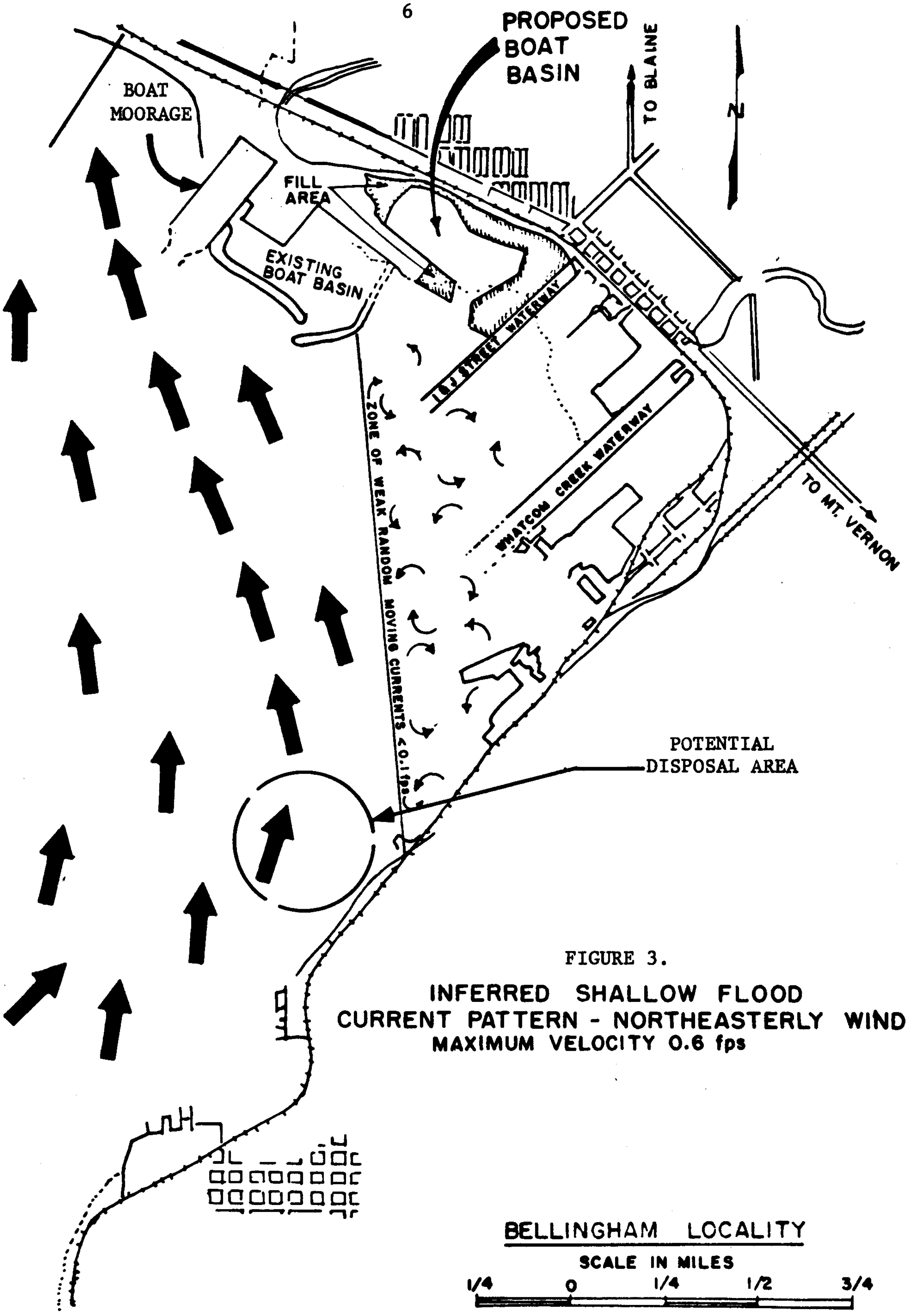

FIGURE 3.

INFERRED SHALLOW FLOOD CURRENT PATTERN - NORTHEASTERLY WIND
MAXIMUM VELOCITY 0.6 fps

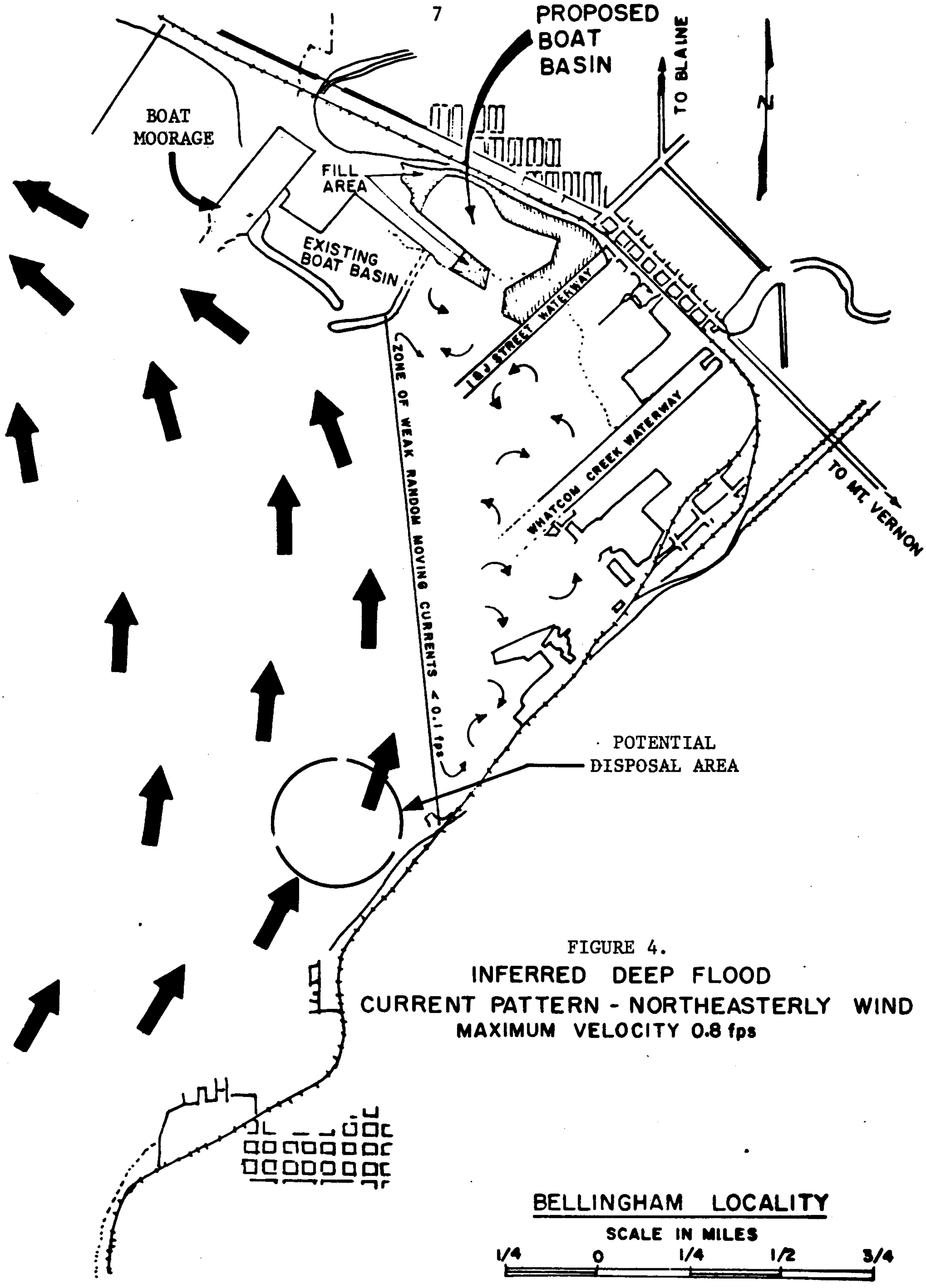

FIGURE 4.
INFERRED DEEP FLOOD CURRENT PATTERN - NORTHEASTERLY WIND
MAXIMUM VELOCITY 0.8 fps

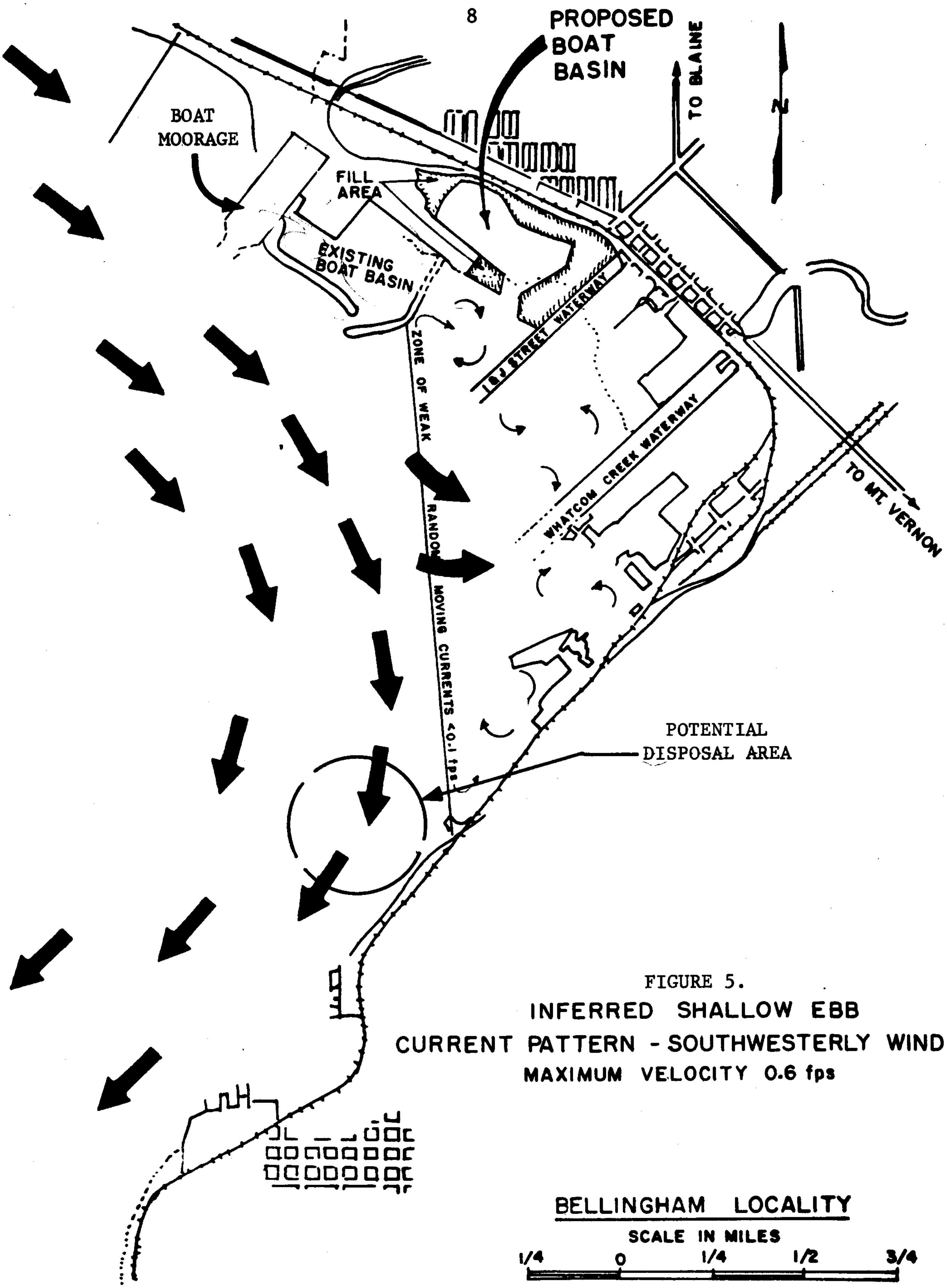

FIGURE 5.
INFERRED SHALLOW EBB CURRENT PATTERN - SOUTHWESTERLY WIND
MAXIMUM VELOCITY 0.6 fps

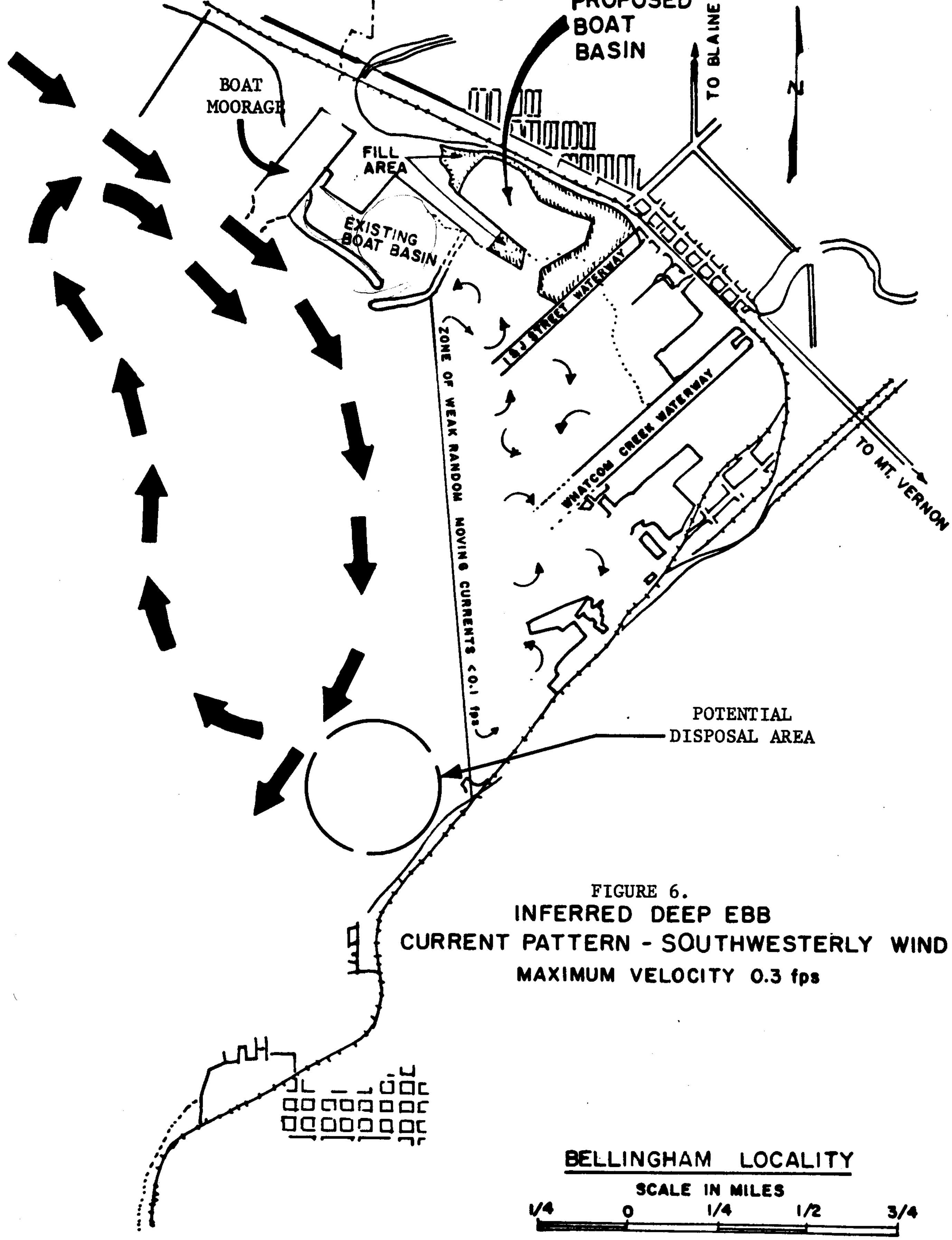

FIGURE 6.
INFERRED DEEP EBB
CURRENT PATTERN - SOUTHWESTERLY WIND
MAXIMUM VELOCITY 0.3 fps

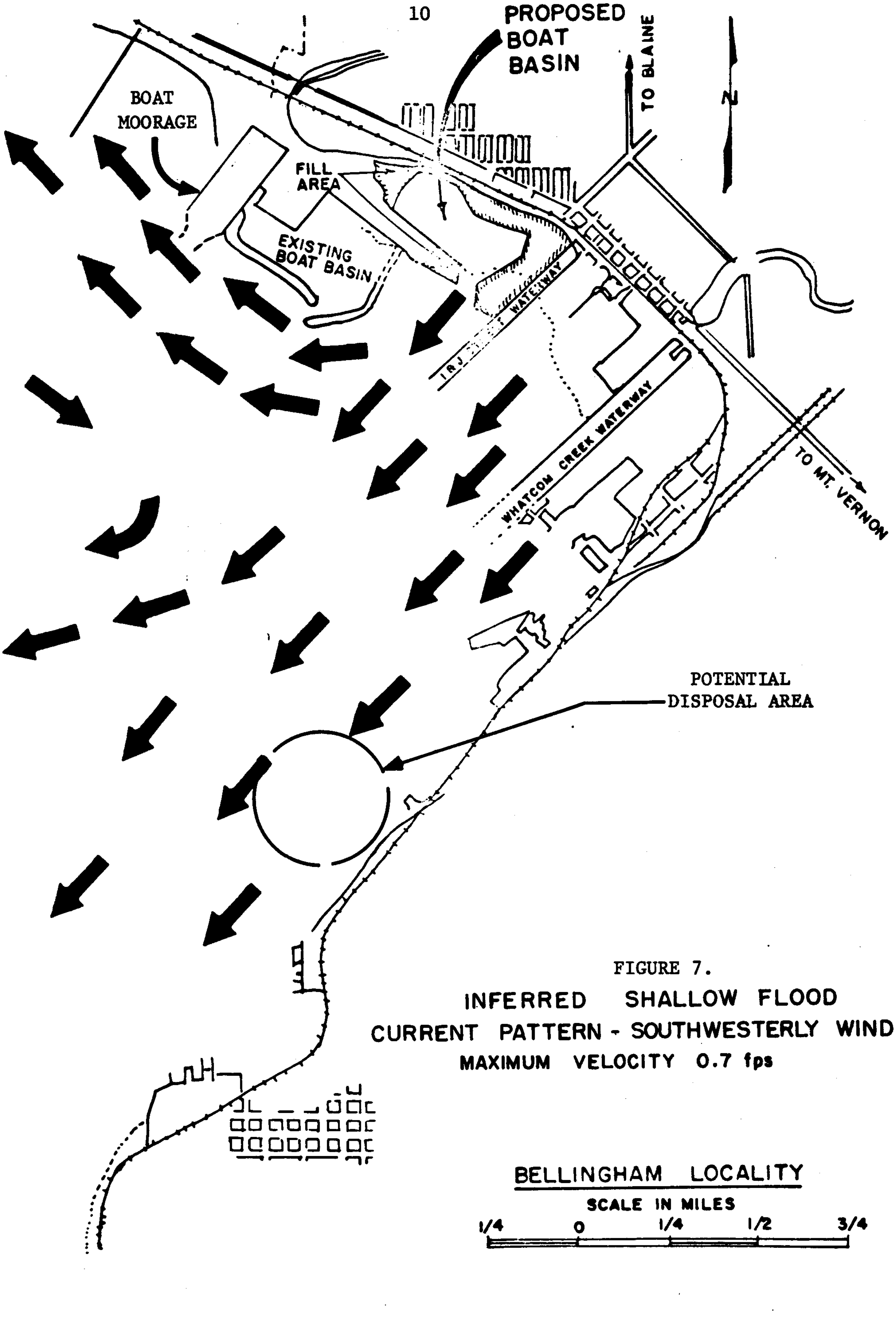

FIGURE 7.

INFERRED SHALLOW FLOOD CURRENT PATTERN - SOUTHWESTERLY WIND

MAXIMUM VELOCITY 0.7 fps

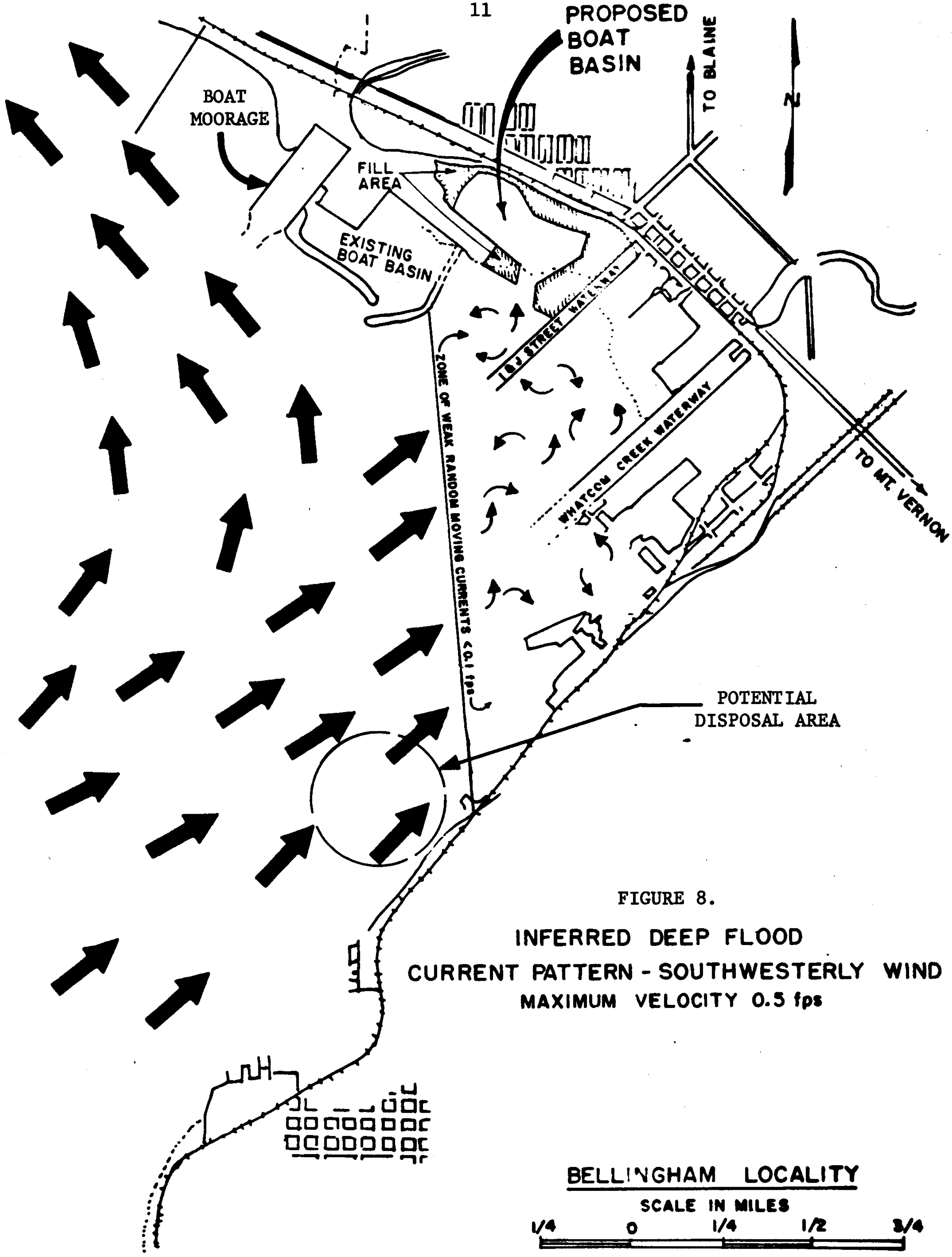

FIGURE 8.

INFERRED DEEP FLOOD CURRENT PATTERN - SOUTHWESTERLY WIND MAXIMUM VELOCITY 0.5 fps

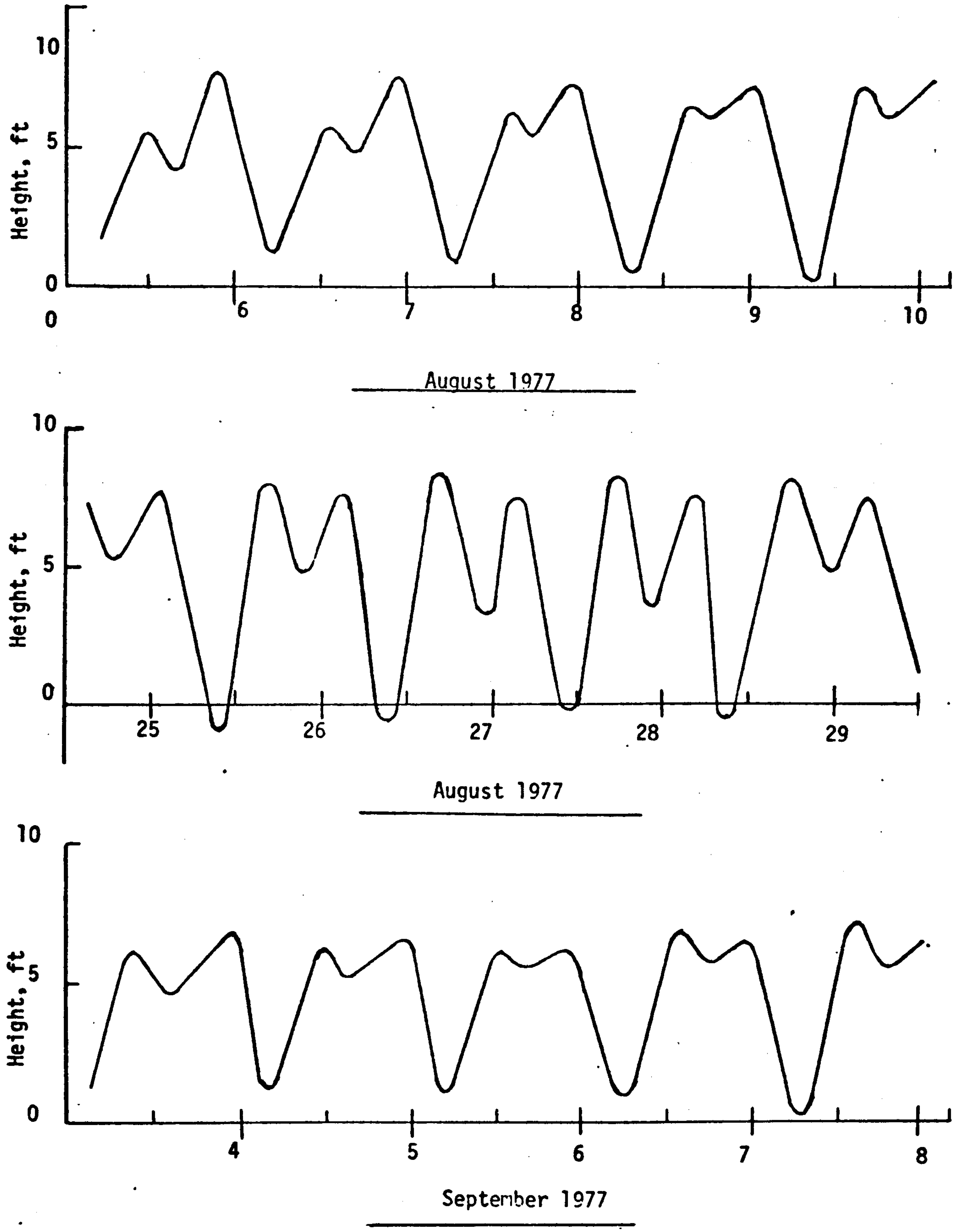

Figure 9. Tides in Bellingham Bay

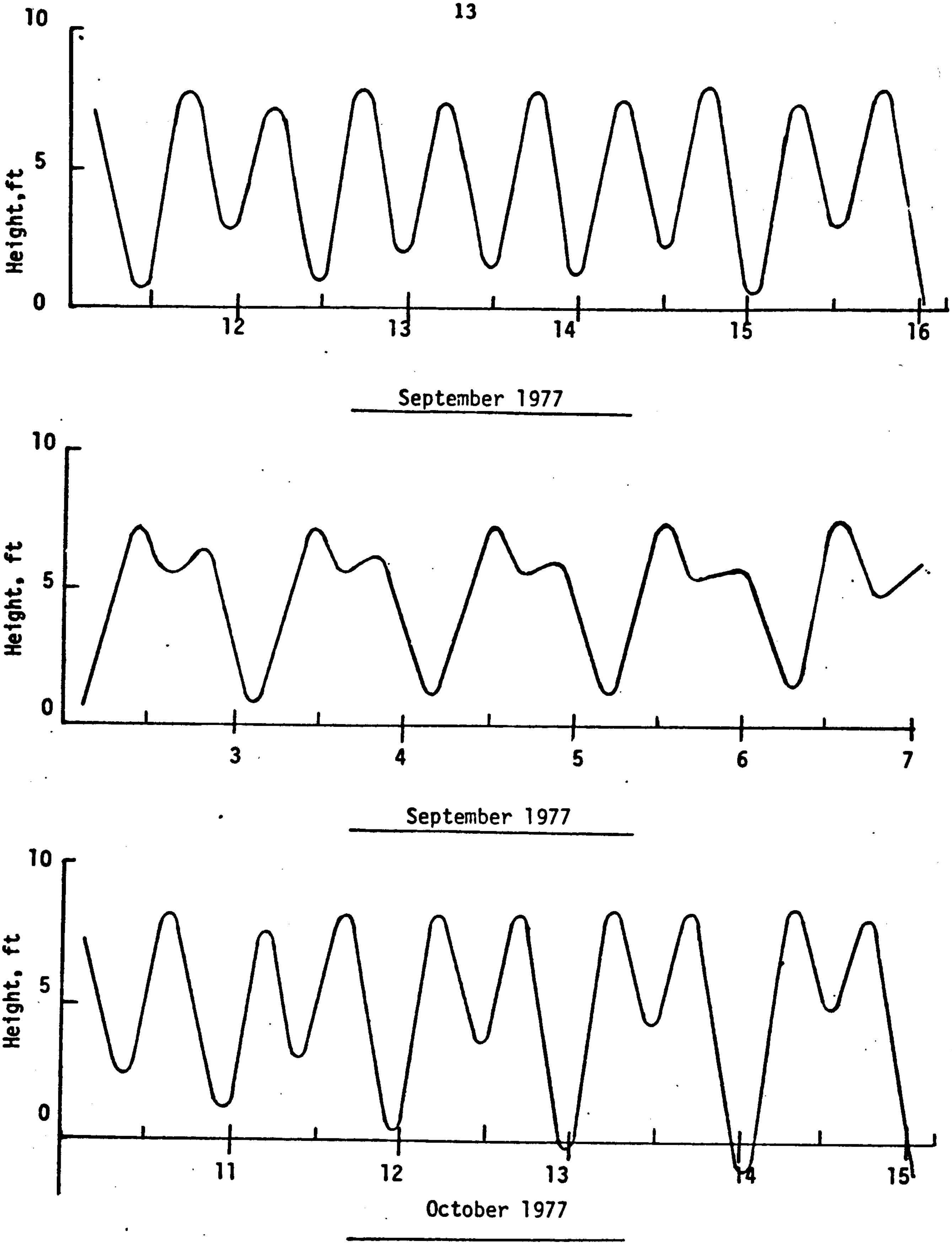

Figure 10. Tides in Bellingham Bay

Table 1. Bellingham Bay Tidal Statistics
Reference: MLLW
(USCGS Tide Tables and Collias 1966)

Mean Range	5.2 feet	Normal Max Tide range	13.0 ft.
Diurnal Range	8.6	" High Spring	9.5
Mean Tide Level	5.2	Extreme heights	+11.5 and -4.5

Selected Data 1977

	August	September	October
Highest 20 consecutive Tides	25th-30th	12-17	11-16
Average High ft.	8.62	7.59	8.08
Average Low	2.21	1.68	1.72
Average Range	6.42	5.81	6.36
Lowest 20 consecutive Tides	6th-11th	4-9	5-8
Average High ft.	6.82	6.65	6.72
Average Low	3.16	2.99	3.11
Average Range	3.66	3.66	3.41

THE MODEL

The boundaries of the model (Figure 2) were fixed in the east-west direction by the I and J Street Waterway and Squalicum Creek, and in the other direction by the northern limit of the harbor and a line about 2000 feet south of the existing breakwater. This expanse the size of the model basin, 8' x 12', and Froude Law modeling criteria led to the following scale ratios:

Length, horizontal	X_r	1:600
Length, vertical	Z_r	1:48
Velocity	$Z_r{}^{1/2}$	1:6.93
Time	$X_r/Z_r{}^{1/2}$	1:86.6
Tidal cycle	12.4 hours	8.63 minutes

The tide generator in the model basin can generate only sinusoidal tides, with an amplitude fixed for any one series. Statistical data for the tides in Bellingham Bay are given in Table 1, with data for the highest 20- and the lowest 20 consecutive tides in the period August-October 1977. Sets of these are graphed on Figures 9 and 10 to show the "mixed tide" supplying the driving force for the water exchange and circulation in the marinas. The model would duplicate quite closely only the near-sinusoidal tides of September 13-15. The low high-tide and the high low-tide of September 5-6 results in a period of about 12 hours in which the tidal range is only about a foot.

The average tidal height in the Bay is 5.2 feet, and average range, coincidentally, is also 5.2 feet. This height and range were used in the model for basic comparison runs and photographic records. Other ranges of 3.0 and 9.5 feet were used for determining the effect of range on performance characteristics. These two ranges are not to be taken as avarages for any particular tides. So far as exchange coefficients are concerned Lewis (1972) showed that the values from the average range was equal approximately to the coefficient average from the set of tides composing the average tides.

The single-density, distorted model successfully represents major tidal circulation effects, but does not correctly duplicate features like point-source pollutants; the effects of water density stratification and wind stress on the movement and mixing of local waters are not modeled by this method, so they must be assessed separately.

OPERATING PROCEDURES

Two of the characteristics employed to describe the hydraulic characteristics of the marina, the exchange (flushing) coefficient and the internal mixing, found experimentally, the former by a fluorescent dye technique and the mixing by using both still- and cine photography. Separate runs are required for each procedure, since ordinary photographic film is not responsive to the fluorescent dye colors.

EXCHANGE COEFFICIENT

The exchange coefficient is a measure of the fraction of the water in a basin that is exchanged on each tidal cycle. The fluorescent dye technique used to determine this coefficient leads to values averaged over a series of tidal cycles and for an isolated basin, or segment of basin; point values are not obtained. The coefficient is best defined through its derivation:

Let
C_o = initial spatial average dye concentration
C_i = spatial average dye concentration after i cycles (i is commonly 4)
R = average, per cycle retention coefficient (the fraction retained)
E = average, per cycle, exchange coefficient

then

$$R = (C_i/C_o)^{1/i}$$
$$E = 1 - R$$

The retention coefficient was determined in the laboratory model using Rhodamine WT, a dye whose fluor~~escent propert~~ies can be used as an index of relative concentration. A 20% solution of this dye. Dams were installed at the high water slack tidal position to isolate a particular basin, and to this basin volume and tidal range so that an initial reading could be positioned on the instrument used to measure the fluorescence, a Turner Model 110 Fluromenter. The dye was thoroughly mixed and samples withdrawn from which the initial concentration C_o was determined. The tide generator was started and at the same time, the dam was removed. After four complete cycles, the generator was stopped, the dams again installed to isolate the sections being tested. Usually samples were withdrawn from critical areas in the basin to explore for local spots of high or low concentration, then the basins were thoroughly mixed and samples withdrawn to determine the final concentration, C_i. Special care was taken with each run to eliminate effects of temperature, sunlight and chlorine. The model was filled with city water, and free chlorine even in small amounts will quench fluorescence, so a solution of sodium thiosulfate was added to the influent water to remove the chlorine. Dosage rates amounted to about 2 milligrams of the sodium thiosulfate per litter of water to remove a chlorine content of 0.4 ppm. The exchange coefficient is a useful term, but should not be considered a factor isolated from general planform layouts and circulation features.

The exchange coefficient determiened for the various basin configurations defined on Figures 11 and 12 and section "Photographic Techniques" and three tidal ranges 3.0, 5.2, 7.0 and 9.5 feet are plotted in Figure 13 against the background of those determined for other marinas of record (listed in references).

The coefficients for the inner basin (C) with or without the breakwater between A and B were essentially the same. It should be noted that the inner basin was exchanging with basin B whether or not the breakwater was present. The photo sequences discussed next, show that water from Basin A moved into B, thence into C when there was no breakwater between A and B.

The data scatter on the Series F and G has been difficult to trace down, but does appear to be closely associated with just how internal circulation develops on the individual run. For example, on three runs for a tide range of 3 feet, the following values were obtained:

Average C_o	Average spot reading at far end	Average C_i	Exchange Coefficient
78.7	73.7	49	.11
85	70.5	45	.15
81	6	20	.24

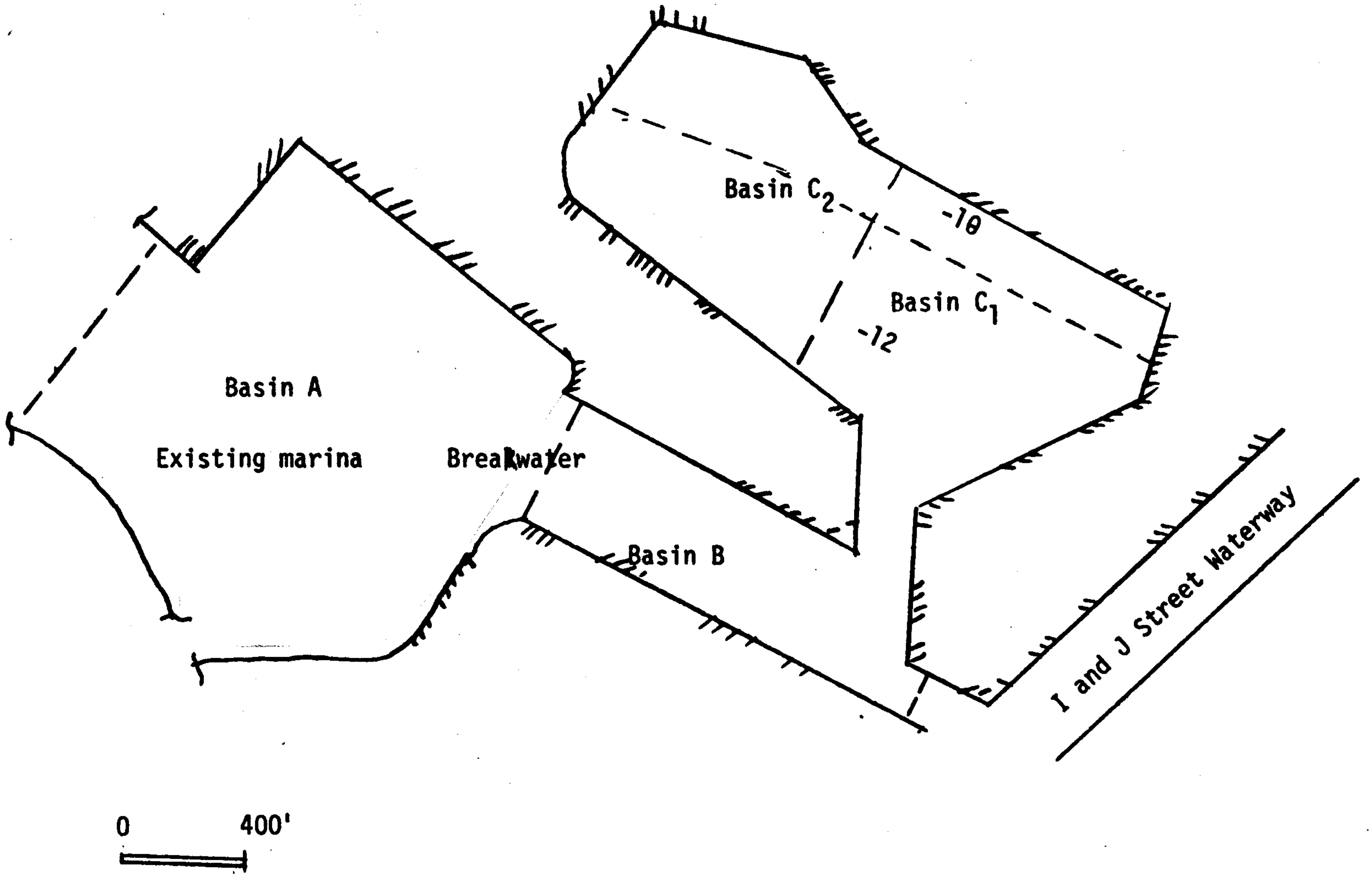

Figure 11. Initial Plan

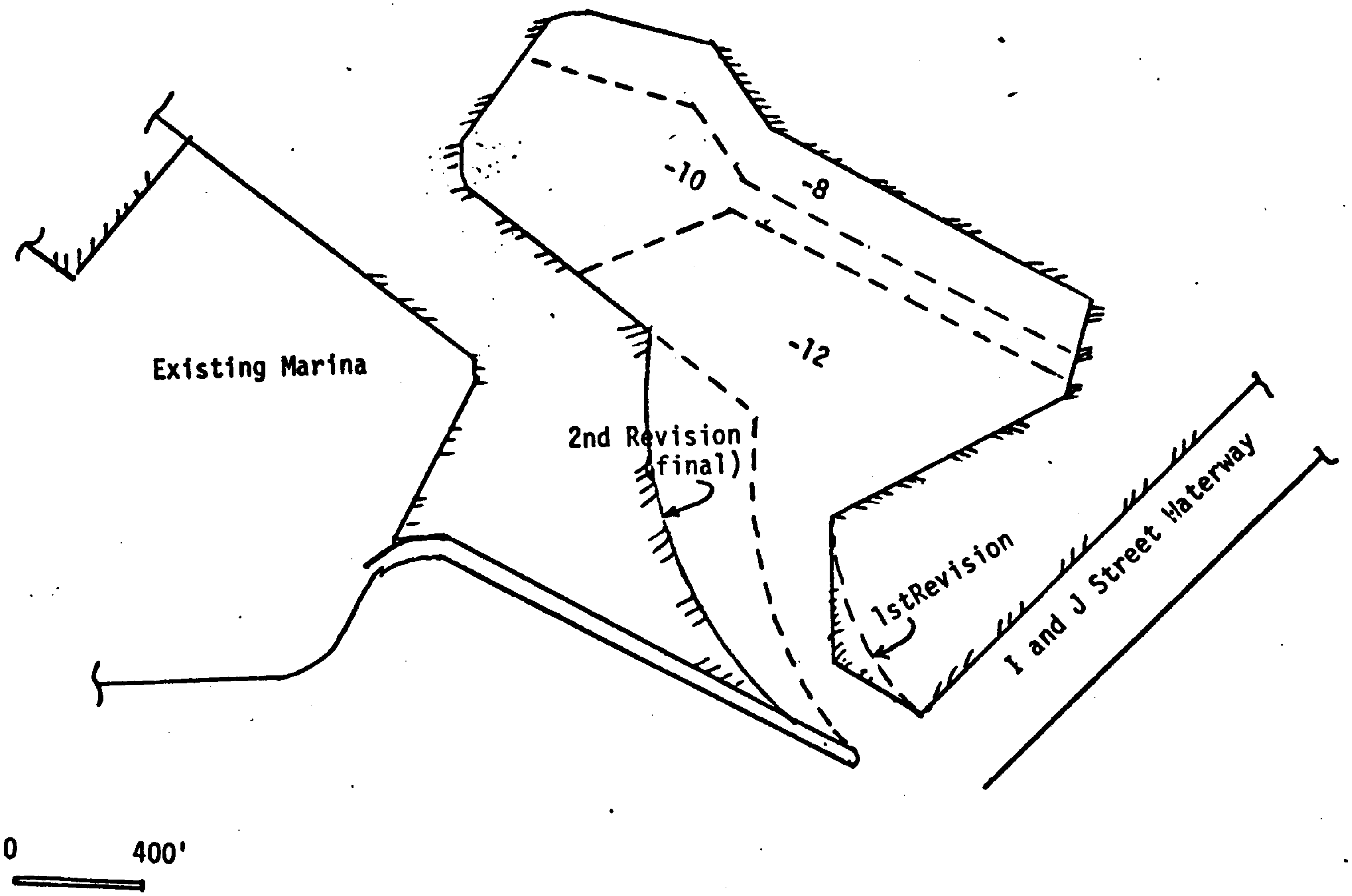

Figure 12. Final Plan

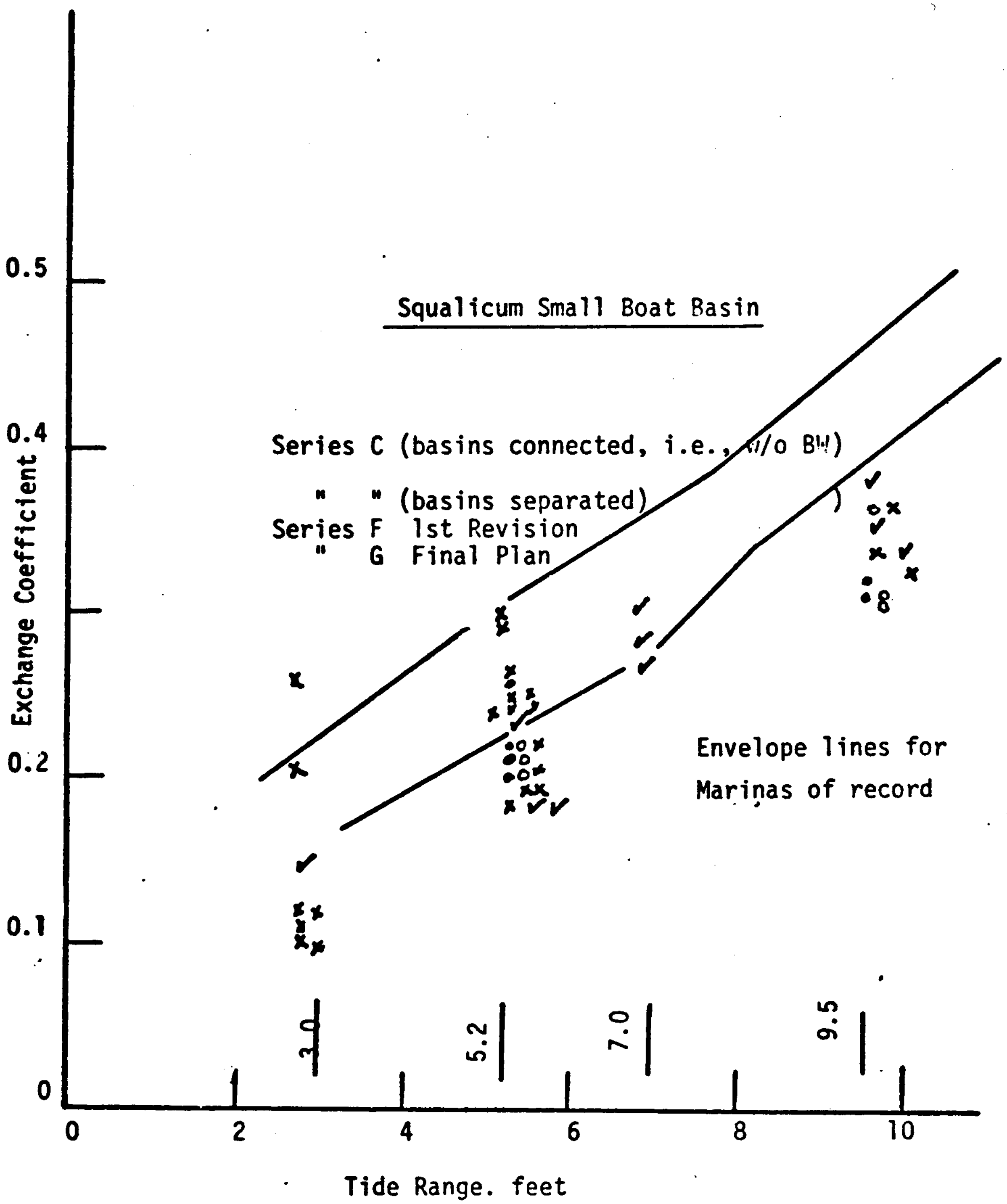

Figure 13. Exchange Coefficient vs Tide Range

Other runs show similar patterns. The motion in the "far ends" of basin C is rather weak, and will be pointed out in the discussion for the photographic series. It appears that if the slight difference in density between clear and the dyed water and a behavior of the jet along the outer curved channel boundary are favorable, the exchange coefficient is relatively high; if these conditions are not present, then the coefficient is relatively low. Although there were not as many runs taken at the higher range (9 feet), the scatter was less than at the two lower ranges. The three runs at the 7-foot range were about the last ones taken, and the utmost care was exercised to eliminate density effects, with the resulting small scatter present.

Based upon the exchange coefficient rating, the Squalicum basin lies along the lower envelope line bounding the performance of referenced marinas, with a susceptibility to both lower and higher values depending upon random jet actions and small density differences. There was not as much affect of removing the basin B from the system as might have been expected, but a companion change in design was made simultaneously, viz., the enlarging and curving the channel leading into the inner (C) basin, with the attendent reduction in momentum into that basin. These appear to be offsetting features, so far as exchange coefficient of the inner basin is concerned.

PHOTOGRAPHIC TECHNIQUE

The internal circulation, zones of separation, and local motions all contributing to the mixing process can be recorded photographically for subsequent assessment. As already mentioned, the ordinary film is not sensitive to the light associated with the fluorescent dye, so separate runs are needed for the photographic sequence. Mother Stewarts bluing, available at most grocery stores, has been found to be well suited for the purpose. It is stable, mixes easily, and can be washed out of the model readily. A concentration is chosen which will provide a very apparent reduction in color density after one or two cycles; this concentration is carefully repeated for each run. The basin is dyed with retention dams in place; after the dye is mixed uniformly, and residual currents have damped out, the dams are removed at the time the generator is started. A cine record is kept with a Super-8 camera mounted directly above the model. The normal laboratory procedure was to photgraph the basin at each quarter cycle, run for 4 cycles, then to inject dye or extra drogues to illustrate special features. To keep the number of photographs for the report within resonable limits, each flood tide and one set of supplemental quarter-cycle photos were reproduced for inclusion in the Appendix. The photographs form a vital record of the current patterns and general hydraulic features of the several plans investigated; the full 35-mm series is considered a part of the report, along with the companion 8-mm cine films. The following discussions highlight the principal features appearing in the 35-mm series.

Series	Basin Layouts
A	Initial Plan, w/o breakwater, Basins A, B and C dyed.
B	Initial Plan, w breakwater, Basins A, B and C dyed.
C	Initial Plan, w/o breakwater, Basin A dyed.
D	Initial Plan, w/o breakwater, Basins C_1C_2 dyed.
E	Curved Channel, Basin B omitted, depths decreased.
F	Enlarged curved channel.
G	Final Plan, inner curve of channel linearized.

Notation on 35-mm slides: Series Cycle Number/number of quarter cycles.

Example: F 3/2 is Series F, 3rd cycle, second quarter (ebb slack).

SERIES A, all basins dyed, no breakwater:

With all the basins dyed, contrasts from cycle to cycle were weak. Flood currents appeared to enter basin B from basin A as well as from the I-J Street entrance. In going from slide A 0/0 to A 4/0, there was a rather uniform dilution of color with some darker areas in the entrance of C_1 and C_2; drogues in the western end moved out only after 2-3 cycles.

SERIES B, all basins dyed, breakwater between A and B installed:

Flood currents appear to be a little more distinctive on slide B 4/0 than on A 4/0 and extend to the back of basin C. There is more contrast between basins A and B when the breakwater is present. The red drogue in the west side of basin C moves slowly along the southern boundary in B 1/1 to B 1/2, then follows a looping trajectory to B 4/0. The red drogue on the eastern boundary moves out of the basin from B 1/1 to B 1/0; the white drogue in B 2/1 makes a loop and is in position to exit at B 4/0.

SERIES C, w/o breakwater, only basin A dyed:

This sequence was run to examine the interchanges of basin A with B and C. The strength of the current inflow to A is sensitive to the directional components of surrents in Bellingham Bay. A flooding current toward the east would carry through the gap left by the removal of the breakwater and flow into B. The evidence from current measurements in the field as reported by Collias (1966) and Lucas and Ekman (1977) have shown a westerly current on the flood; hence, it does not appear that a flooding current can be exploited to improve the circulation through basin B. On the ebb flow, water from A entered B, thereby competing for exit rights through the I-J Street opening with water from basin C. On the flood, water from B joins with that from the main entrance to fill basin C. Slides C 0/3, C 1/0 and C 1/1 show the development of a gyre in the eastern part of the basin (note comment on drogue trajectory in Series B) and a cell in the western half that subsequently breaks into two cells. On successive tides, water from basin A is pumped into C so that after 4 cycles, B and C are only slightly lighter than A.

SERIES D, same layout as in Series C:

Only Basin C was dyed to illustrate its communication with B and A. The dye patterns showed some change into B, but very little into A. The hydraulic route for water from C to the exterior (Bellingham Bay) is more direct via the I-J Street opening than through the basin B-basin A route. A comparison of D 4/0 with D 0/1 shows that a fairly uniform dilution has taken place.

SERIES E:

The photosequences of Series A-D showed that the proposed inner basin would have more direct communication with the ambient waters of Bellingham Bay if it were isolated from the existing boat basin (A). The following changes in the initial design were made prior to running the E-series:

1. Northern boundary straightened to eliminate V-projection.
2. Depths decreased to improve the tidal prism ratio. The resulting steps, having depths of -8, -10 and -12 feet MLLW in progression from the northern boundary, are readily visible in E 2/0.
3. Basin B replaced by a curved channel to provide more direct communication of basin C with the ambient waters.

A distinctive feature of this layout is the tendency for the flooding jet to separate from the inner (northern side) boundary and then to extend almost to the center of the northern side) boundary and then extend almost to the center of the northern face, as evidenced on E 1/0. This entrance channel is like a nozzle, and on the ebb, waters near its mouth (trace the drogues beginning slide E 1/0) at high slack are swept out by low slack. On E 4/0, relatively clear water appears in the western side, with the flow sequences leading to this beginning to show in E 2/2. This pattern was found to be difficult to duplicate, however, on some runs the dye would be left in the western and eastern sections, whereas on others, it would be replaced by clear water. The only explanations of this behavior are first, possibly subtle density difference between the clear water and the dyed water, and secondly the randomness in how the incoming flood currents reacted with residual momentum cells in the basin.

SERIES F:

The planform of Series E was altered by increasing the radius of the outer (seaward) boundary to enlarge the entrance channel (entrace width not changed) as a partial compensation for the loss of mooring space through the deletion of Basin B. The general patterns were much the same as in Series E, except that with the wider channel there seemed to be more chance for separation from the inner boundary, with reverse currents developing along it. Drogues placed just right along the inner boundary on the flood would move toward the entrance. A typical erratic trajectory is shown by the white drogue in the sequence F 1/2 to F 4/0, where it arrived at the northern boundary after a looping route within the basin. The red drogue in front of the white one, however, moved into the main channel at F 2/2, to illustrate the mixing that goes on within the basin, resulting in the absence if any distinctive features at the end of 4 cycles, F 4/0.

SERIES G:

The inner radius of the entrance channel (series F) was replaced by two straight segments to meet harbor layout criteria; this modification was not expected to cause any significant change in basin characteristics, since the flood current had already shown the tendency to separate from the curved boundary. The separation appears to be at a more definite location now, i.e., at the intersection of the two segments as shown on G 0/3. Other patterns are much like those in the F-series. The flooding jet (G 1/0 and G 4/0) spreads out and extends close to the northern boundary, imparting motion, but not causing defined gyres in the western and eastern lobes of the basin. In the C-series with the narrower entrance, the motion (see C 0/3, C 1/0 and C 1/1) resulting in a well-defined gyre in the eastern lobe and a distinct cell in the western one. In the G-series, a reverse flow develops along the inner boundary during the flood flow where the main core of the current hugs the outer curve. This reverse flow can be identified by following the drogues in the sequence G 2/2 to G 3/0. The final result, as shown in G 4/0, is much like that of the F-series, with a fairly well mixed basin. In some runs, the eastern and western lobes cleared out quite well, but on others they did not, as discussed under Series E.

CONCLUSIONS FROM PHOTOGRAPHIC SERIES

The Series A-C showed that the waters from basin A would be pumped into the inner basin C if the breakwater between A and B were removed. The inner basin should communicate more directly with the ambient waters of Bellingham Bay, rather that with those from another boat basin. The flow into basin A could be altered significantly by directing a flooding current into its entrance. Available field data show a flooding current that is not favorable for enhancing the flow into A. Therefore water quality within Basin C would be better with the breakwater present so that it would exchange directly with the ambient waters of Bellingham Bay. The changes in design beginning with Series E were made to improve the exchange coefficient, and are discussed under that topic. What the photographs show is that show tradeoff has taken place between a gain from omitting the basin B, which acted as a damper on the communication between basin C and the outside water, and a lowering of the momentum into C as a consequence of the expanding-nozzle entrance into that basin. The lesser momentum does not create the district gyres that formed under the initial and discussed under Series C, yet a wider jet has enough momentum to impact some motion to the extremities of the basin.

All field data available showed that a counterclockwise current past the entrance to the existing marina (Basin A) developed on the flooding tide. If a clockwise current developed, likely it would have led to a stronger flow from Basin A to B when the breakwater was omitted, but without that favorable inflow should be expected.

SUMMARY AND CONCLUSIONS

The performance characteristics of the proposed inner basin (C) were impaired by the intermediate basin (B) just inside the new breakwater. Basin B tends to behave somewhat like an elastic damper in the circuit. Removal of the existing breakwater between Basin B and the existing boat basin (A) did not have a significant influence on the exchange coefficient from Basin C. In other words, removing the breakwater did not reduce the damping influence of Basin B. The characteristics in Basin A likely would be enhanced by the removal of the breakwater, since that would provide an additional entrance of significant size, but the improvement would be slight, since the exchange between A and B was weak and erratic.

FINAL PLAN

The revisions on the initial design, viz., eliminating the intermediate basin, reducing the dredged depths within the basin, and providing a more direct, curved entrance to the inner basin, produce only a small increase in exchange coefficients. However, these changes considered to provide the most direct communication between the inner basin and Bellingham Bay and the best internal geometry that is possible within the project constraints of breakwater location and basin boundaries. When compared with other Puget Sound boat basins of record, the model data from Squalicum lies along the lower envelope curve.

The reasons from the relative position of the basin's performance are believed to be:

1. Communication with Bellingham Bay is impared by the flow direction change at the I and J Street Waterway entrance.
2. Relatively long distance (about 2500 feet) from entrance to remote parts of the basin.
3. Weak circulation in the western and eastern lobes of the basin.

Although the tests showed the basin performance as gaged by the exchange coefficient to be on the lower envelope of comparative basins, other features need to be considered along with this coefficient. Flood in the entrance channel separated from the northern (straight) boundary, thus creating eddies which contribute to mixing. The main current penetrates well into the inner basin and initiates some motion in the waters in the extremities of the lobes. On the ebb flow, the nozzle-shape of the entrance channel is conductive to an ideal flow which carries along the eddy-mix cells created on the flooding tide.

The type of model used in the study approximated the tidal currents in Bellingham Bay and in the basin only for the simple, well-mixed case. Currents in the Bay are complex and dependent upon seasonal and daily weather conditions. The model encompasses only a small part of Bellingham Bay; the current patterns at the edges of the model would come closest to fitting those developed in the

Bay under no wind, no straitification and regular (sinusoidal) tide; the model, then, portrays a consecutive performance.

The final evaluation by the senior author of the model study and its projection to the phototype condition and comparison with other model studies and regional marinas, places the Squalicum Boat Basin in an acceptable category. The effects of tidal currents, salinity gradients, wind stress and inherent variability in the natural circulation processes in Bellingham Bay add enough to the tidal mixing and circulation within the marina to keep it from developing slack regions where water quality be depressed significantly.

The uncertain spots in the proposed design are the western and eastern lobes of the inner basin. As s conservative and precautionary measure, it is recommended that water quality monitoring stations in these lobes be a part of the initial construction plans, and that they be operated continuously during critical seasons until the uncertainties in the design performance predictions can be evaluated. With such a monitoring program, the development of any unfavorable water quality conditions can be detected and then reversed mechanically by, for example, utilizing the propellor thrust from one or two power boats placed to increase the circulation and mixing within the basin. The conditions that might give rise to the development of the unfavorable conditions would be a combination of low runoff from the Nooksack River, a neap tide sequence, low wind stress, and warm weather. Unfortunately, there is not enough field data available to form a basis for forecasting the frequency or probability of the occurrence of the adverse conditions. The impact of these conditions on the marina will be lower, of course, as the water quality in Bellingham Bay is improved; therefore, programs to implement such improvements should be encouraged.

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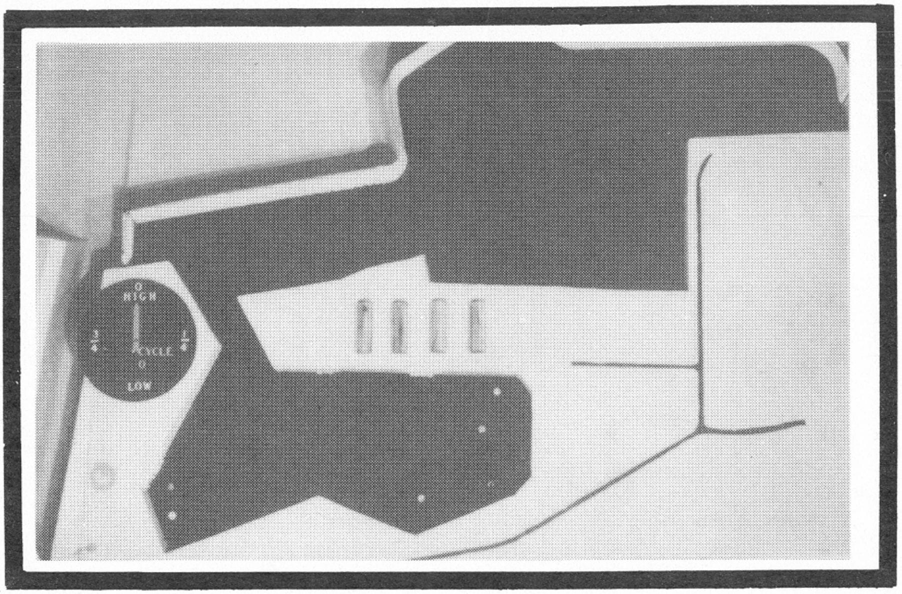
APPENDIX A

Photographic Series

Photo No.	Title	Page
A_{1-8}	Initial Plan, without Breakwater, Basins A, B and C Dyed	A-2
B_{1-8}	Initial Plan, with Breakwater, Basins A, B and C Dyed	A-4
C_{1-8}	Initial Plan, without Breakwater, Basin A Dyed	A-6
D_{1-8}	Initial Plan, without Breakwater, Basins C_1C_2 Dyed	A-8
E_{1-8}	Curved Channel, Basin B Omitted, Depths Decreased	A-10
F_{1-8}	Enlarged Curved Channel	A-12
G_{1-8}	Final Plan, Inner Curve of Channel Linearized	A-14

NOTE: A set of 8 black & white prints are included for each series at tidal cycles as shown below:

Tide Cycle	Photo Code
0	0/0
1	1/0
1-1/4	1/1
1-1/2	1/2
1-3/4	1/3
2	2/0
3	3/0
4	4/0



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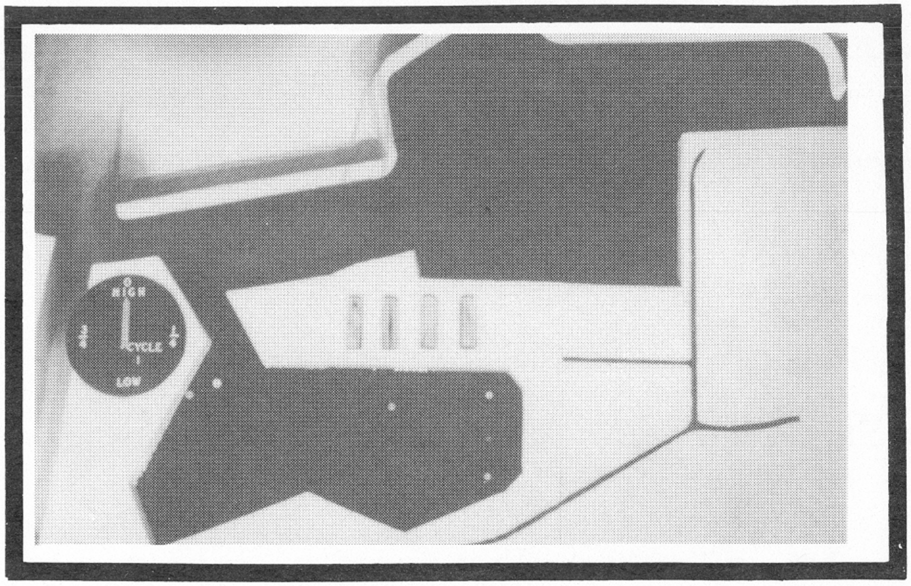

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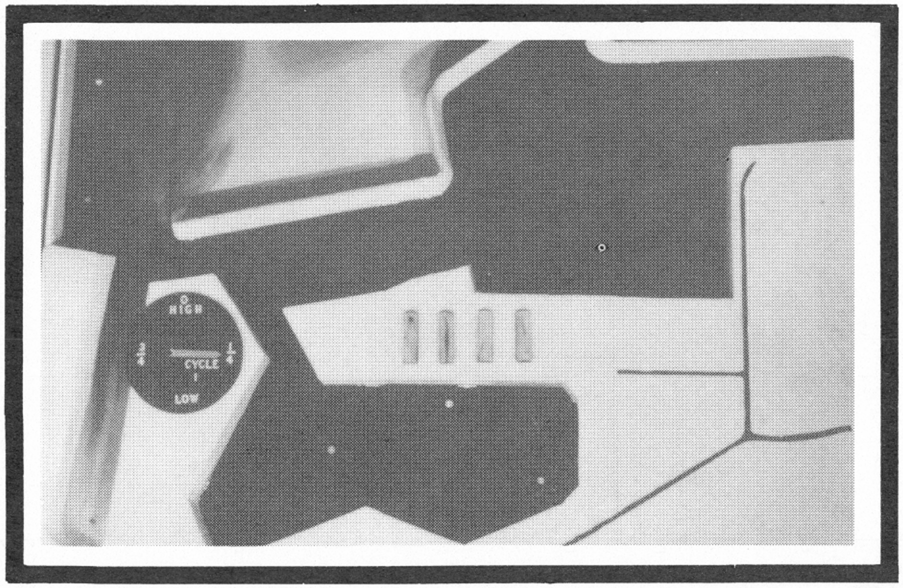

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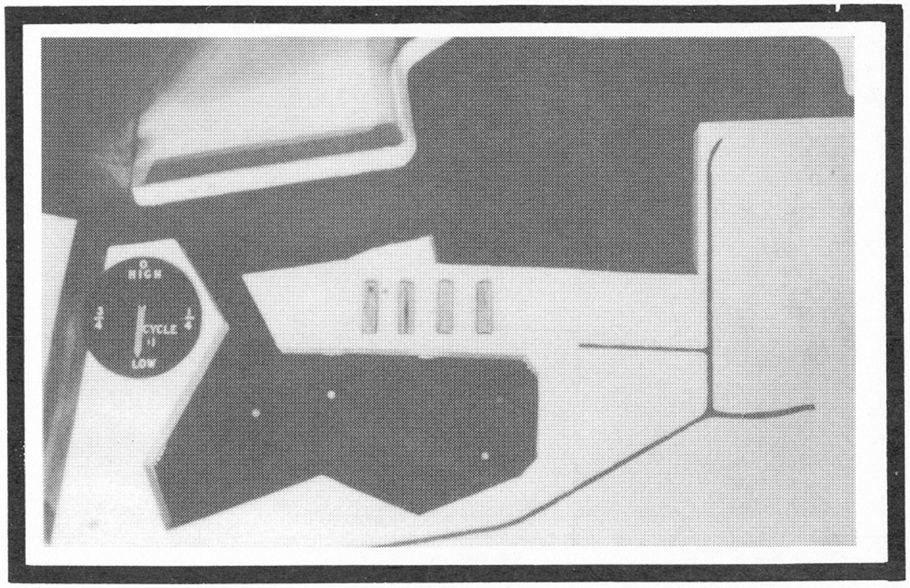

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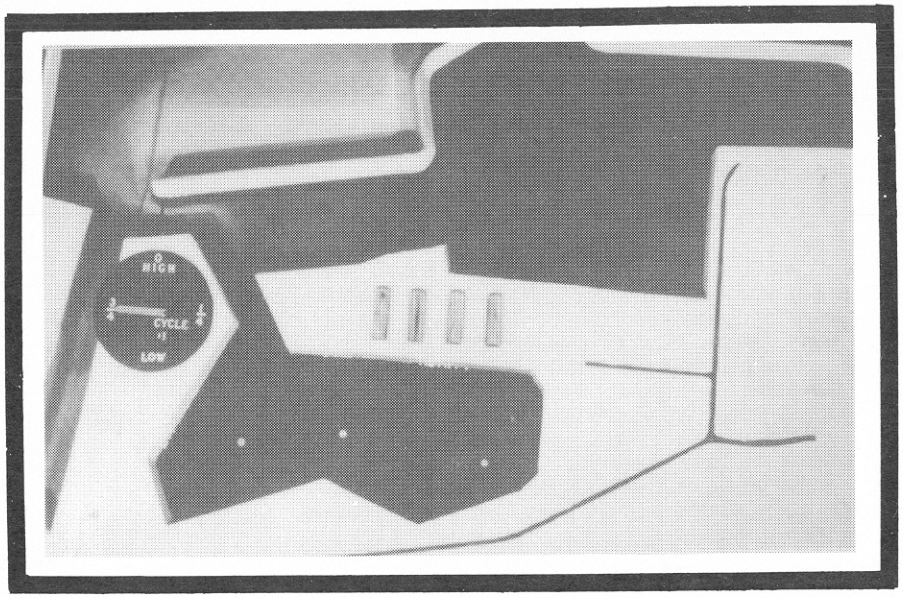
A1-A4 INITIAL PLAN, WITHOUT BREAKWATER, BASINS A, B AND C DYED



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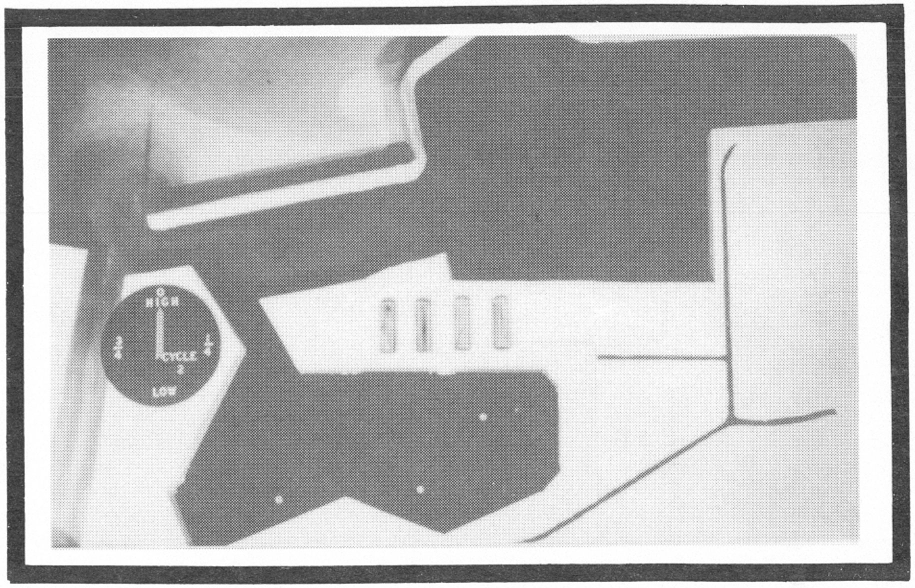

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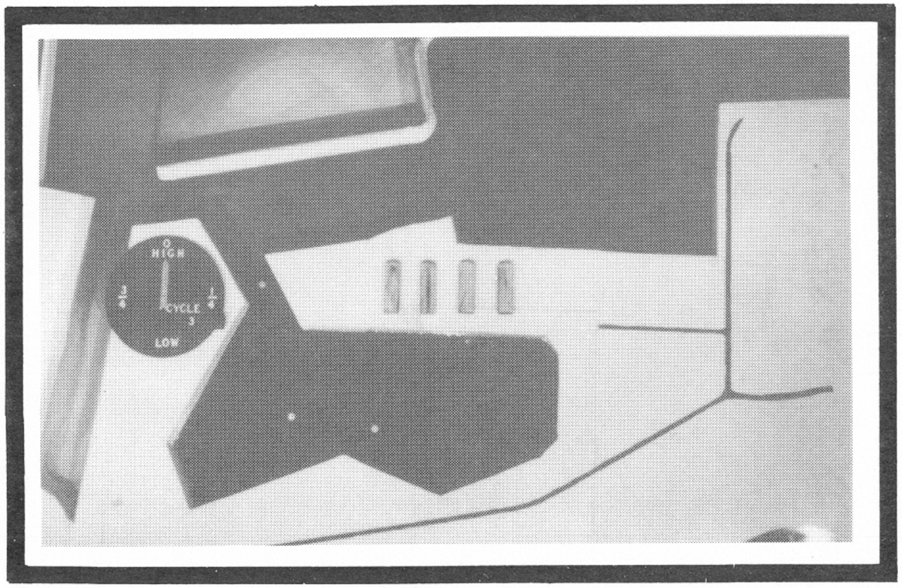

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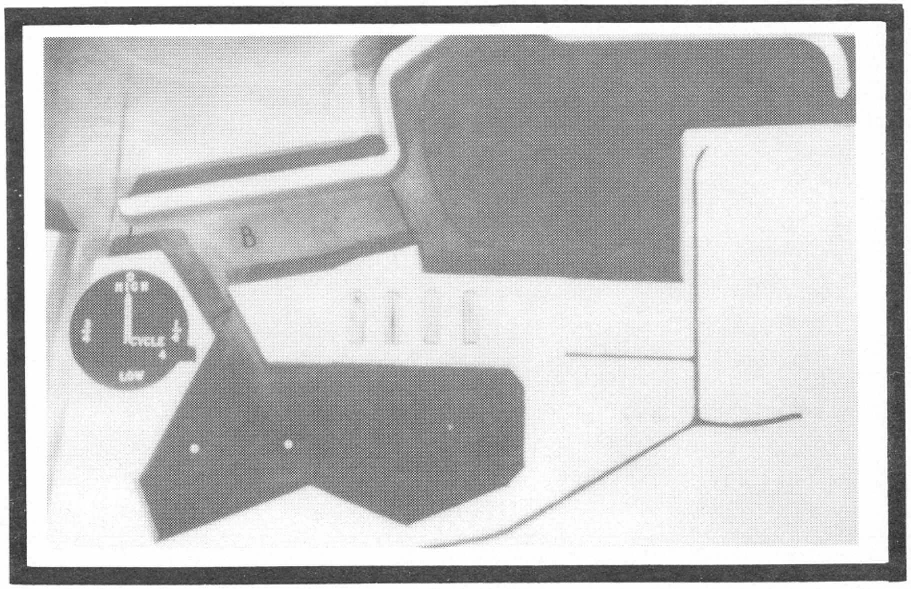

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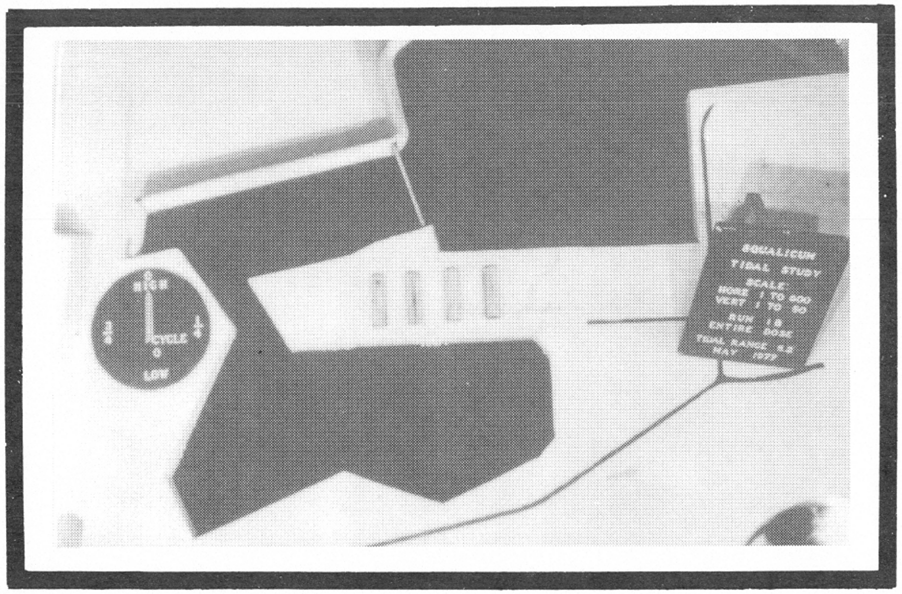

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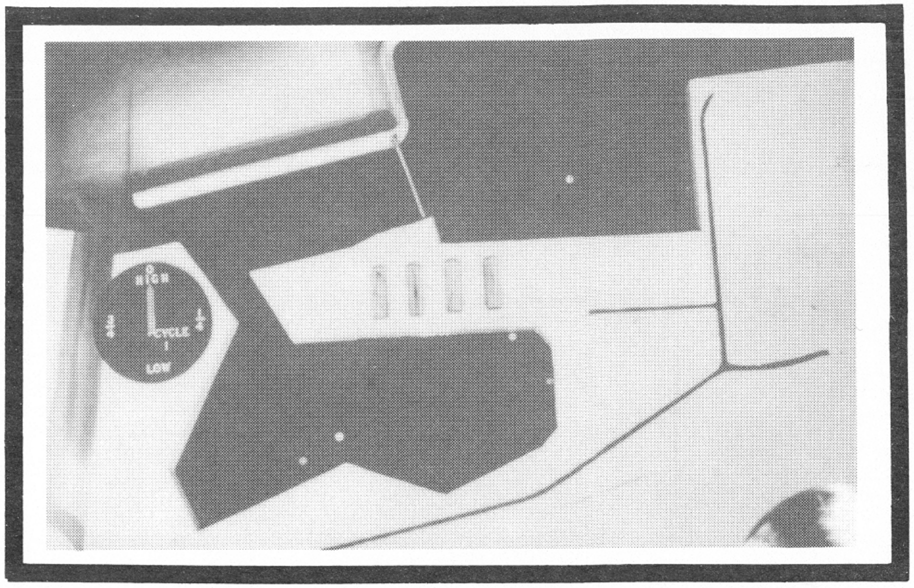

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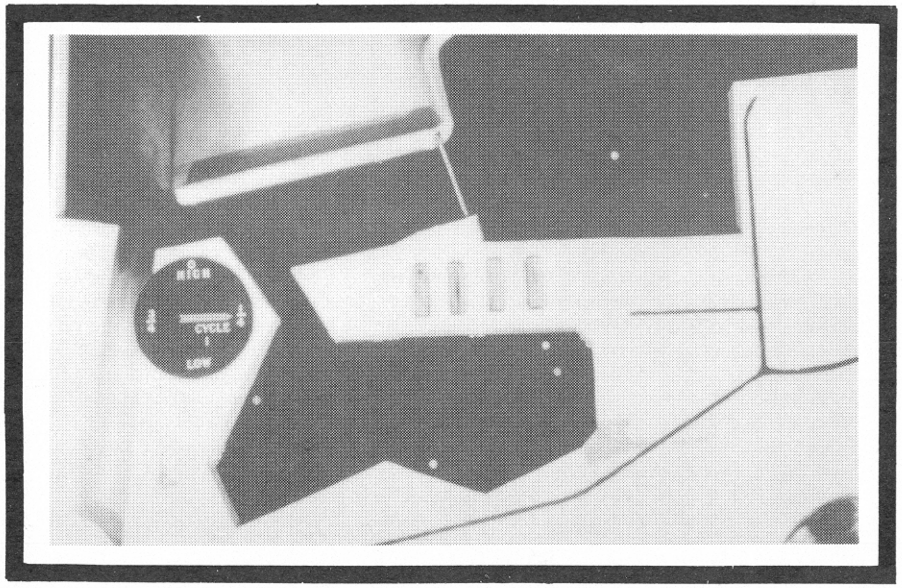

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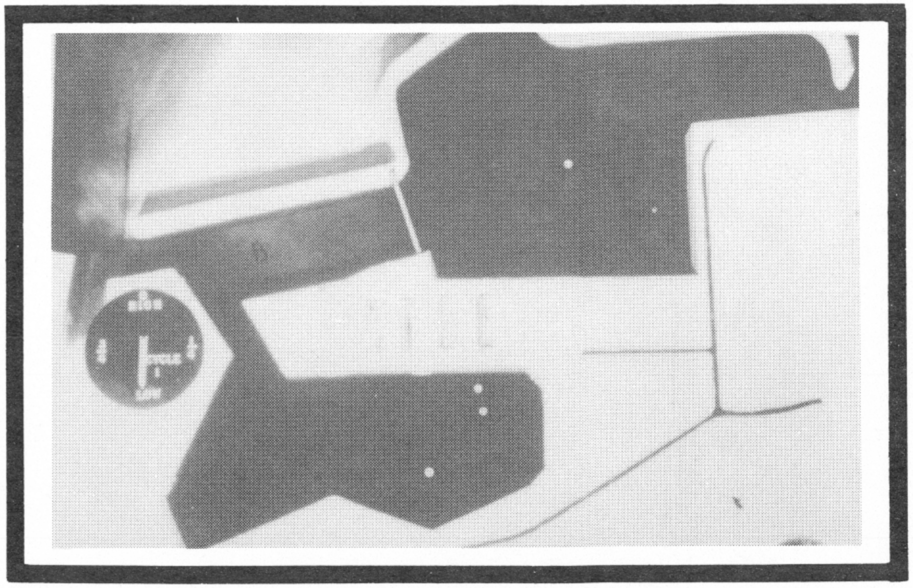

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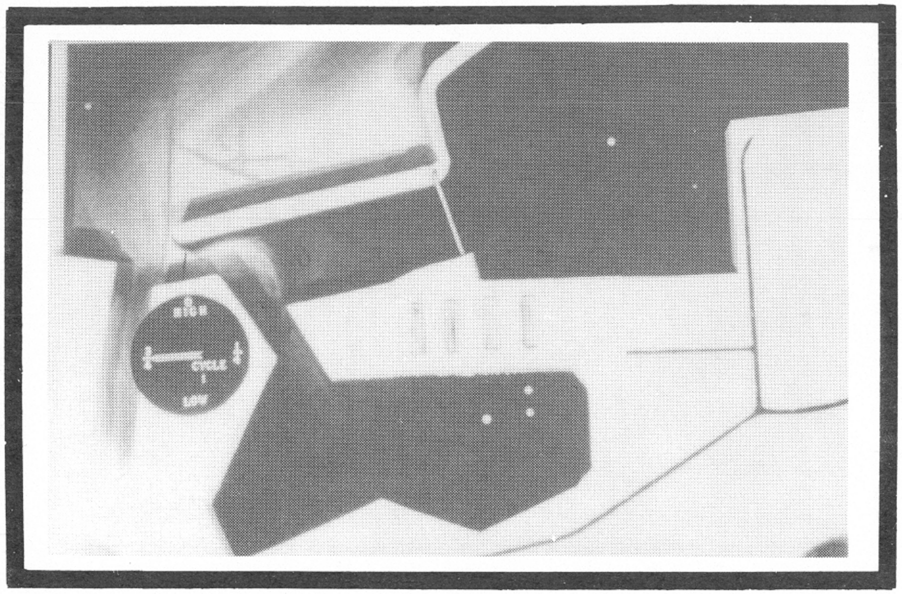

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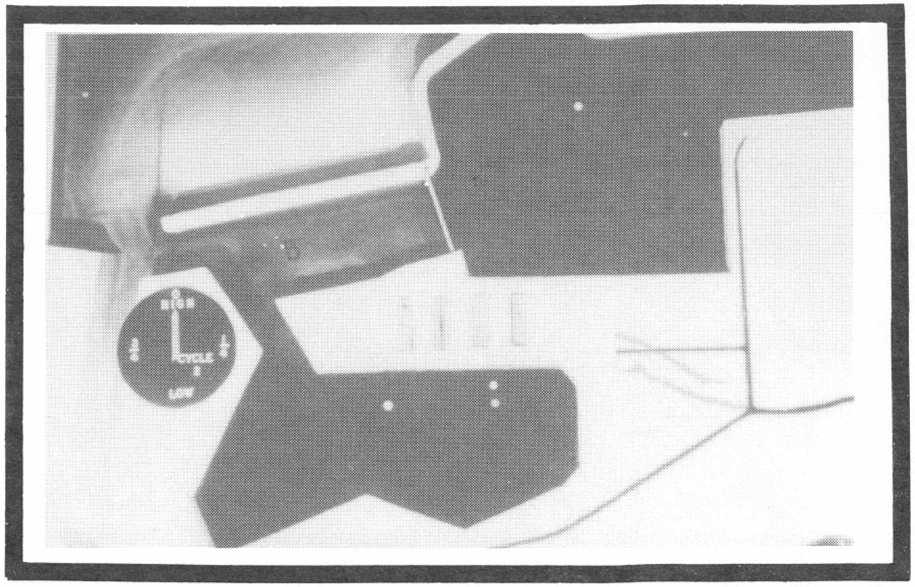

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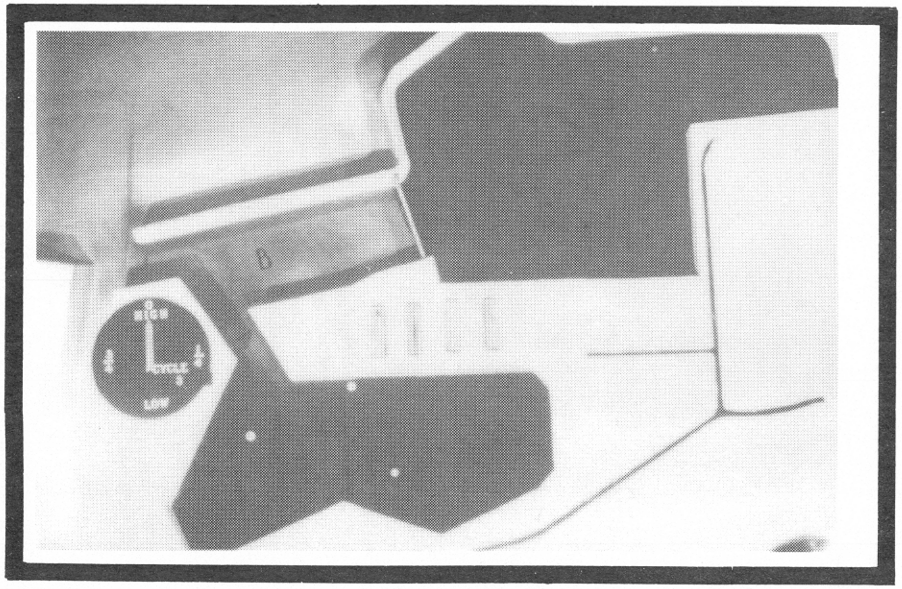

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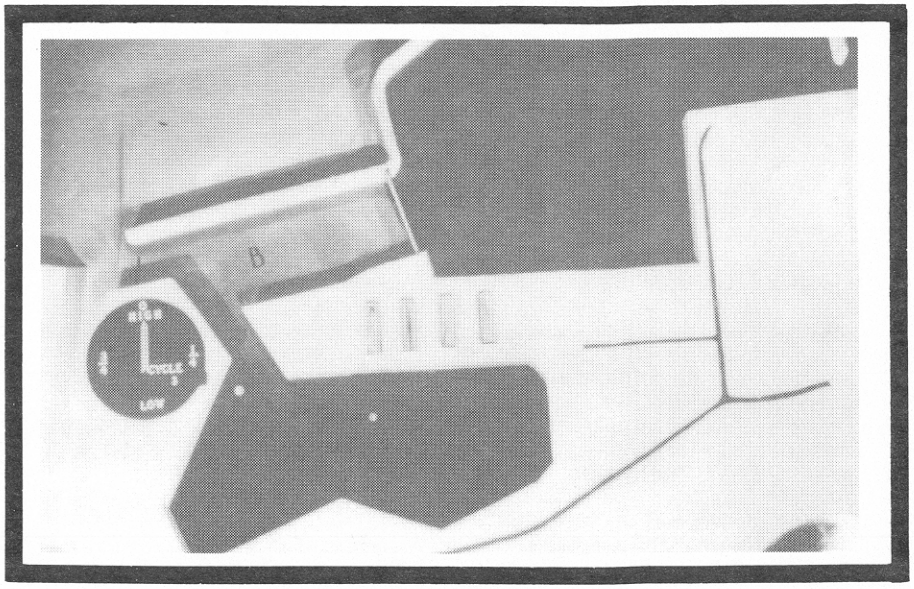

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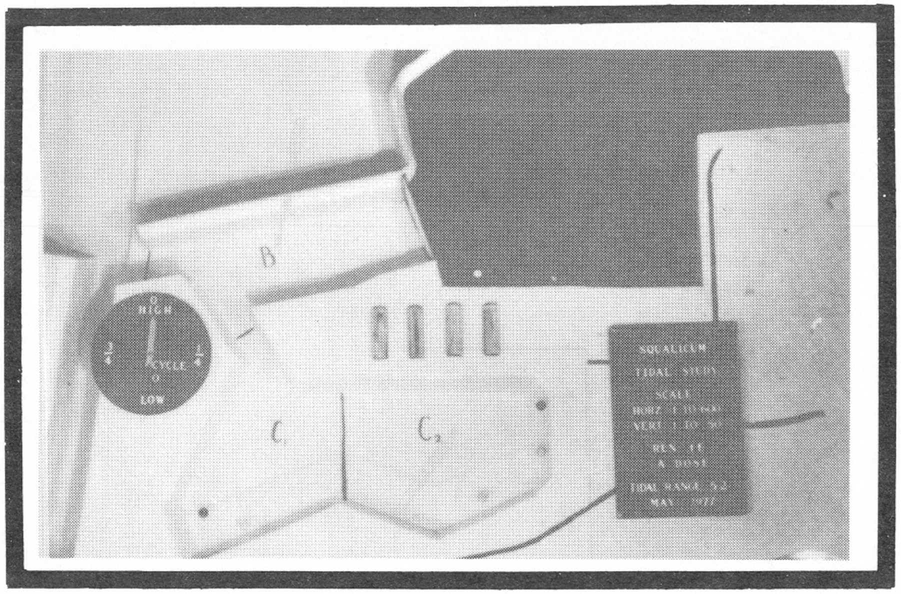

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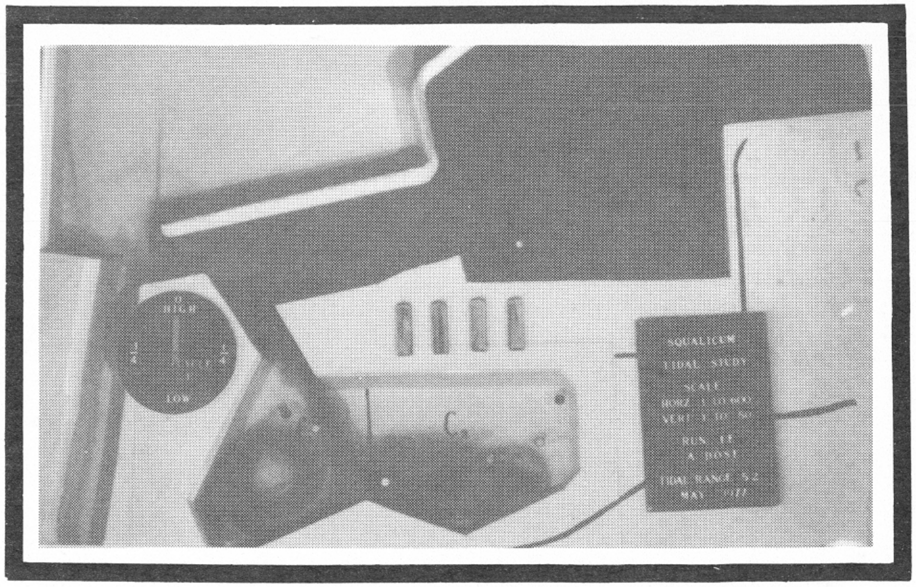

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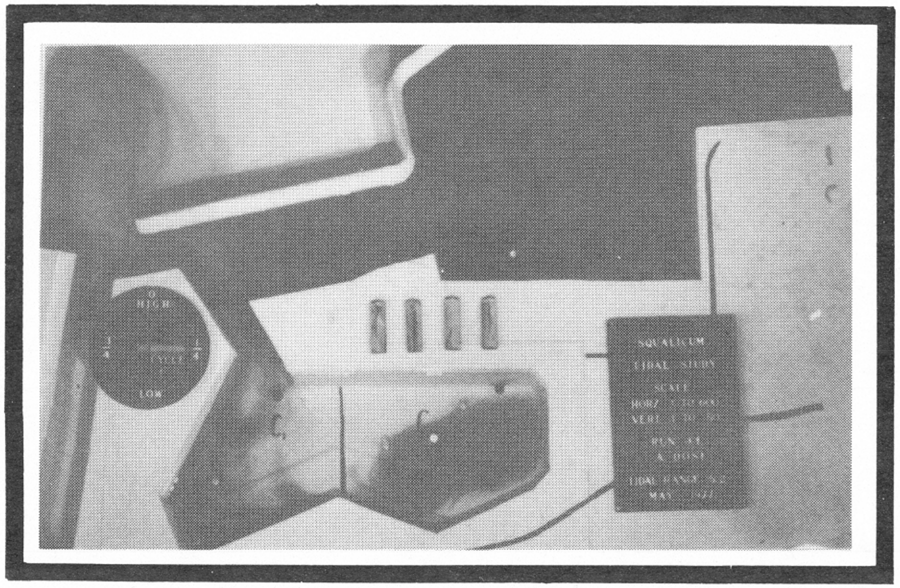

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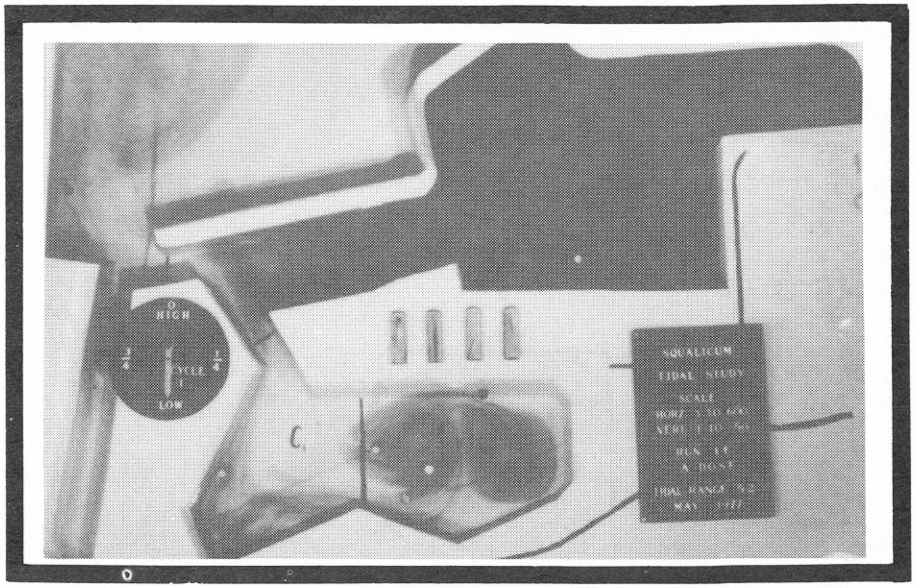

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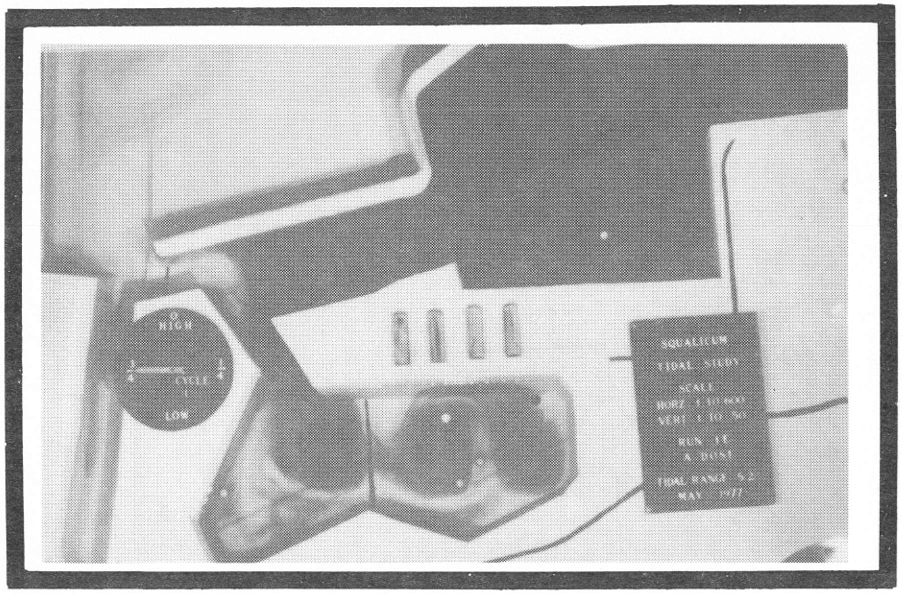

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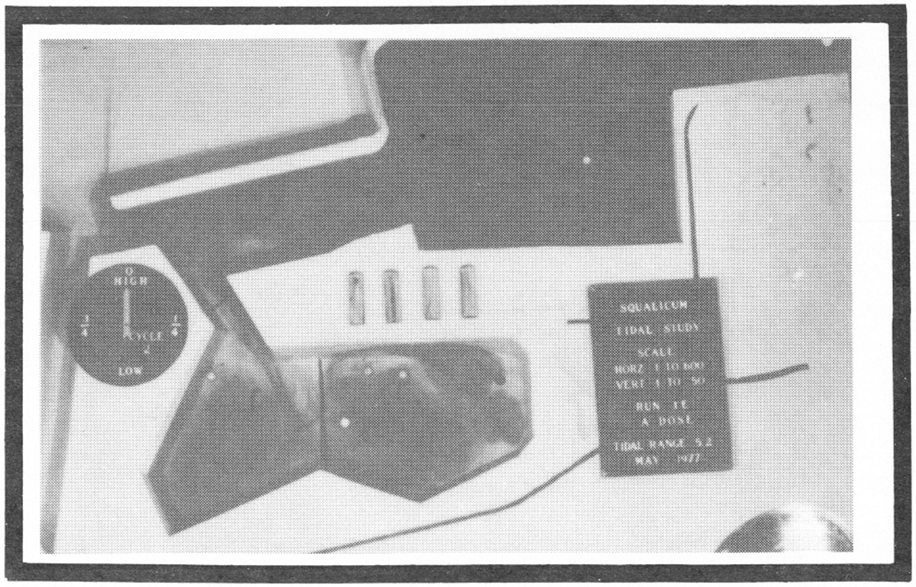

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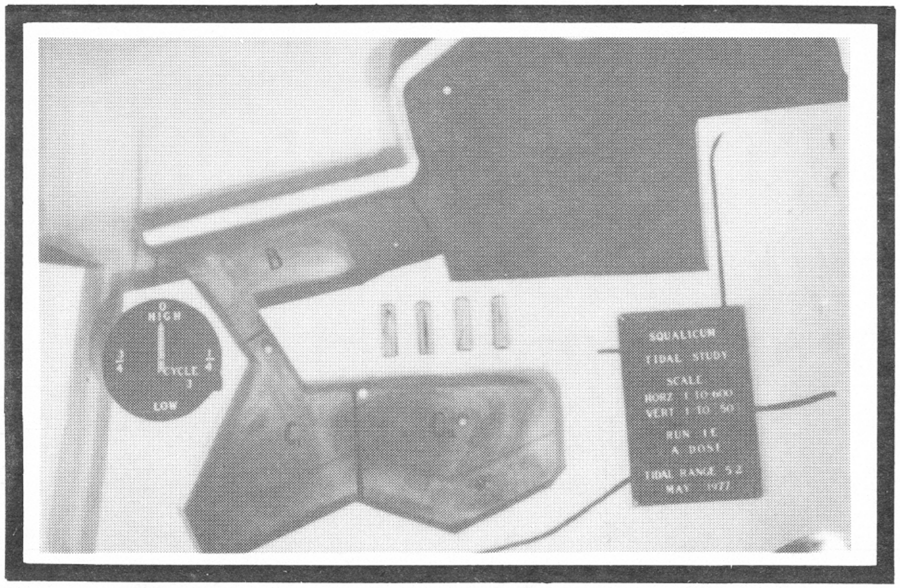

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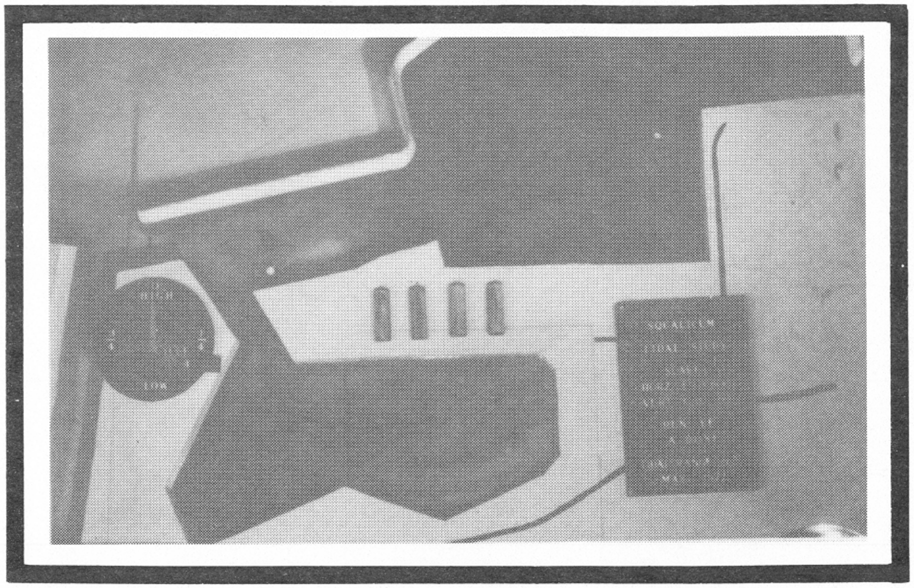

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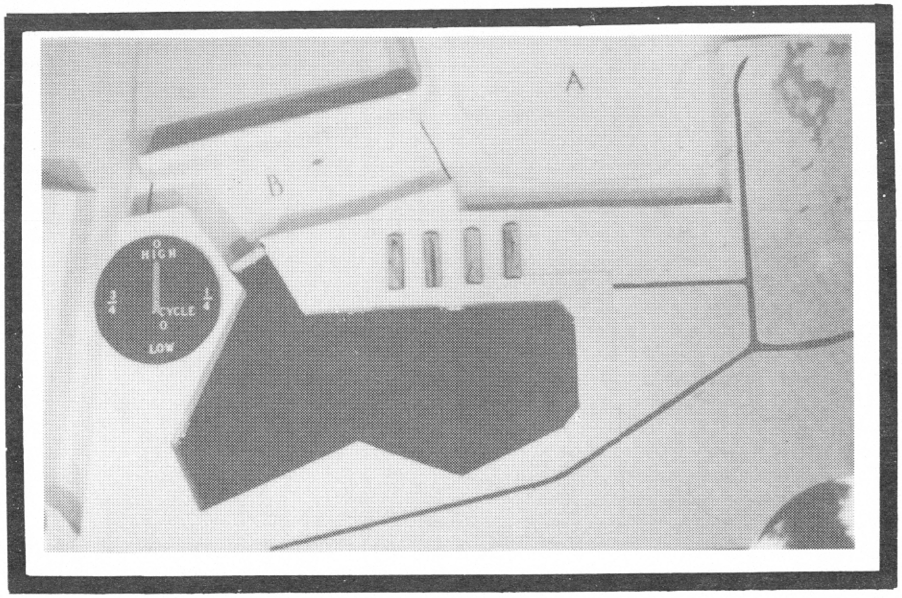

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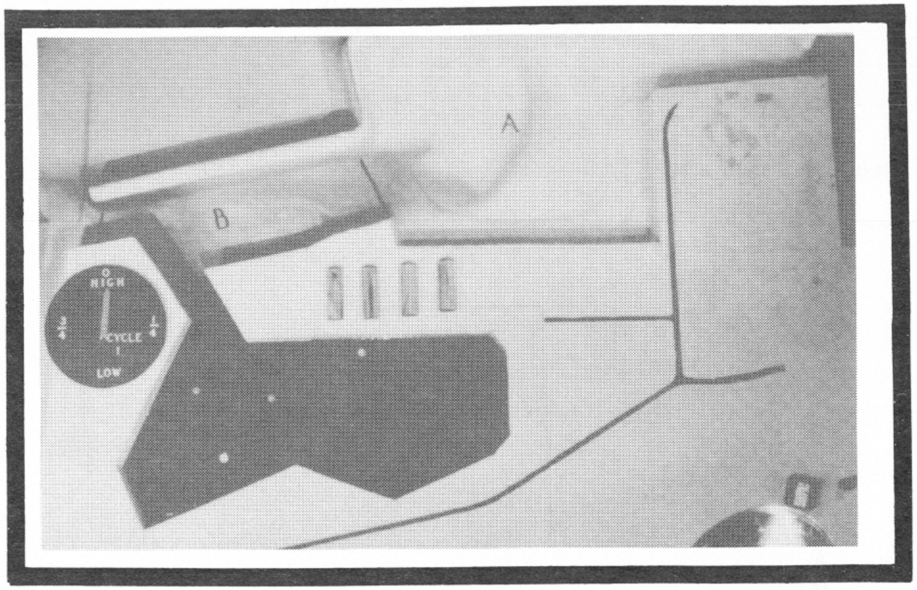

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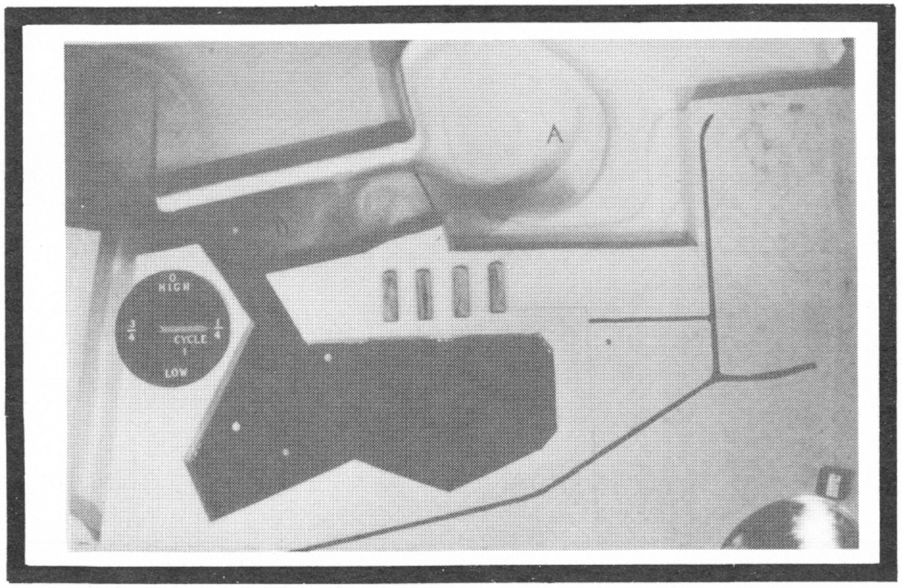

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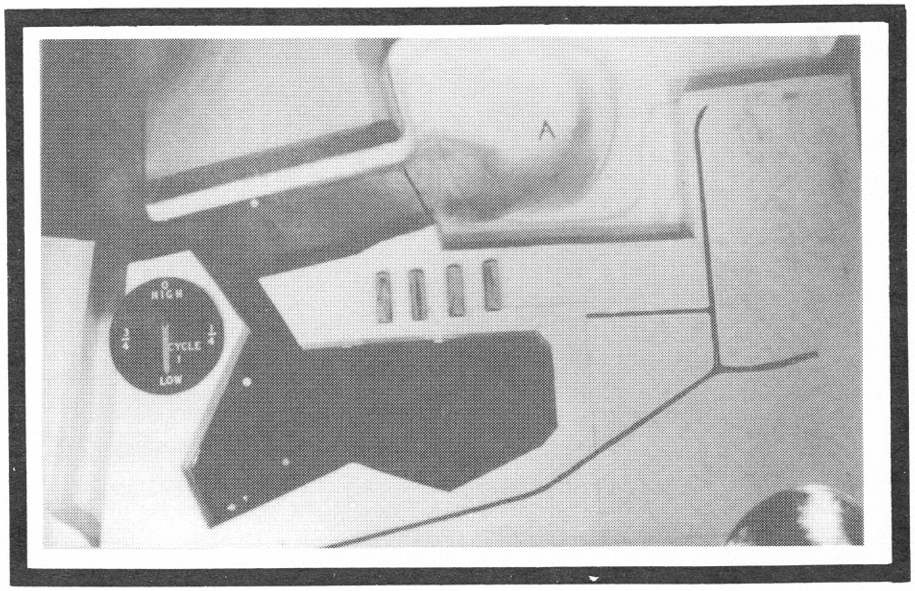

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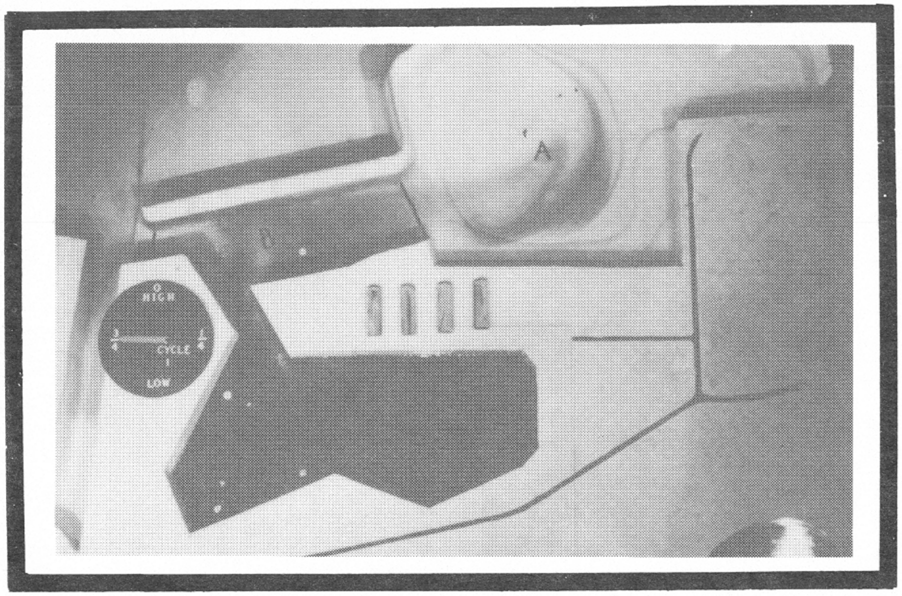

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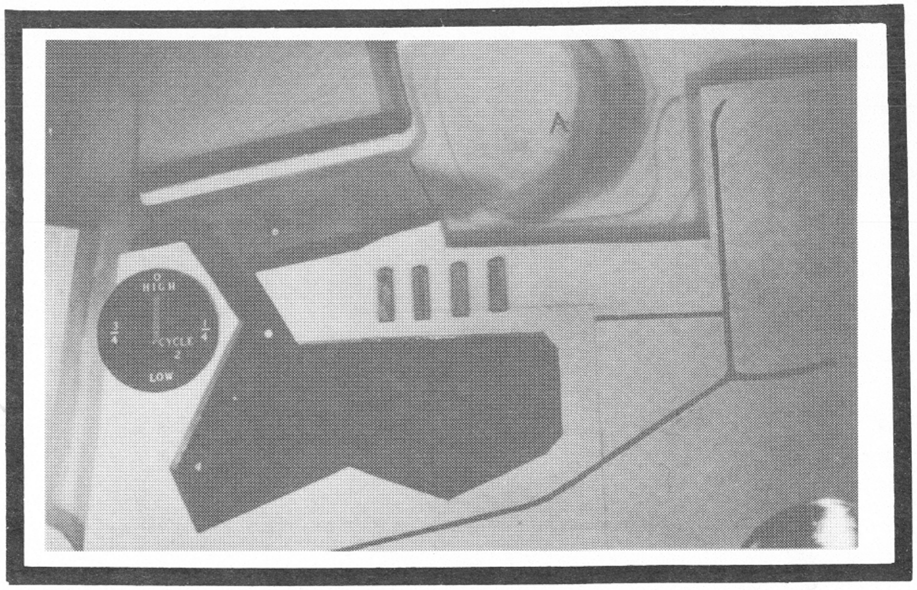

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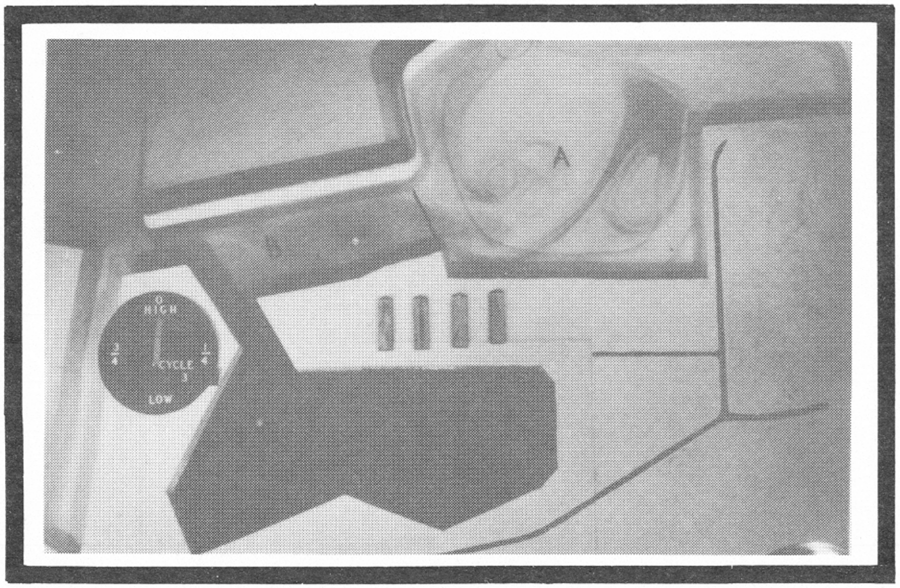

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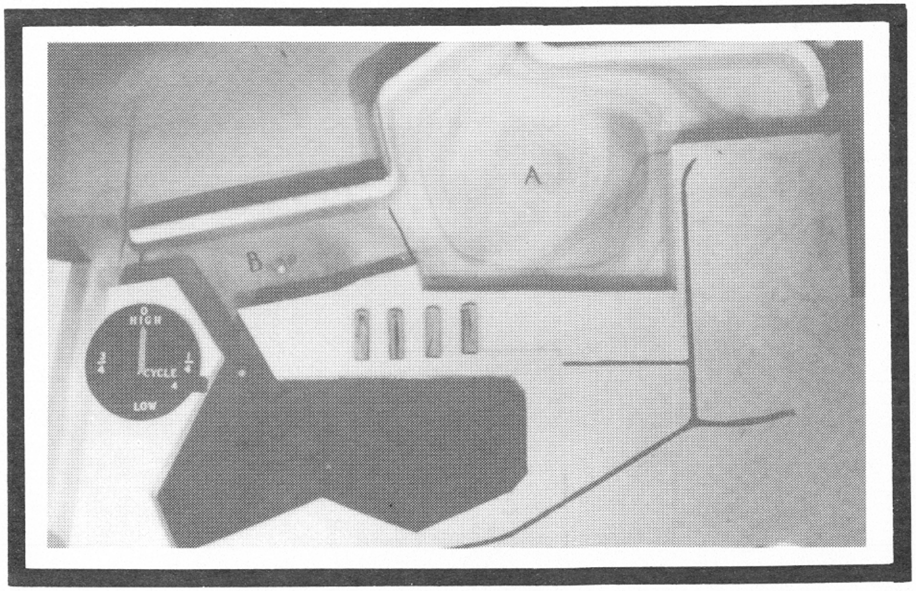

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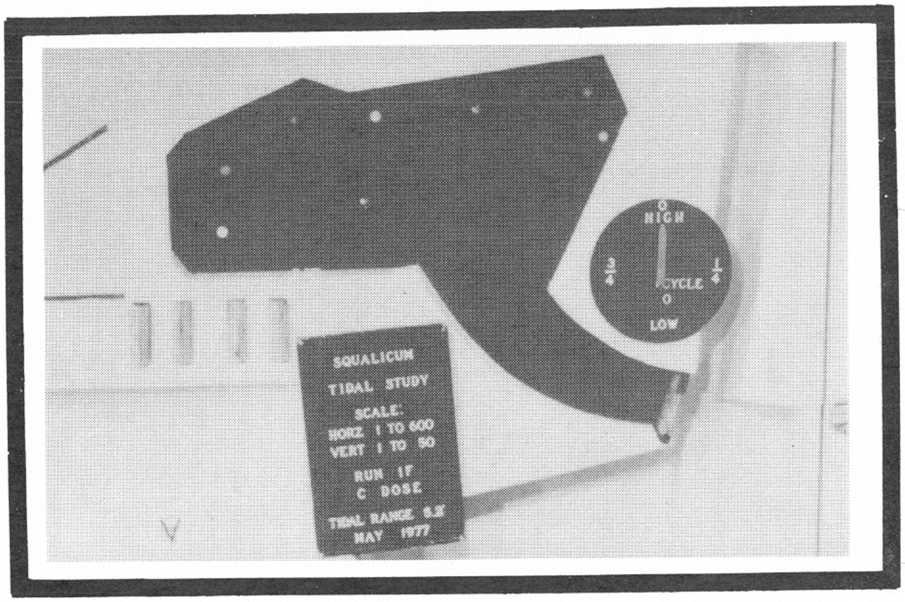

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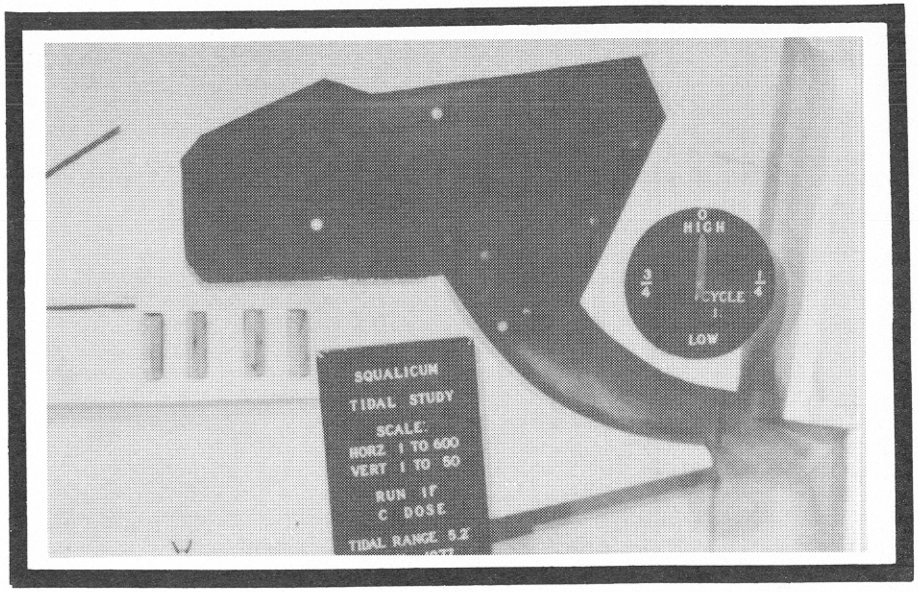

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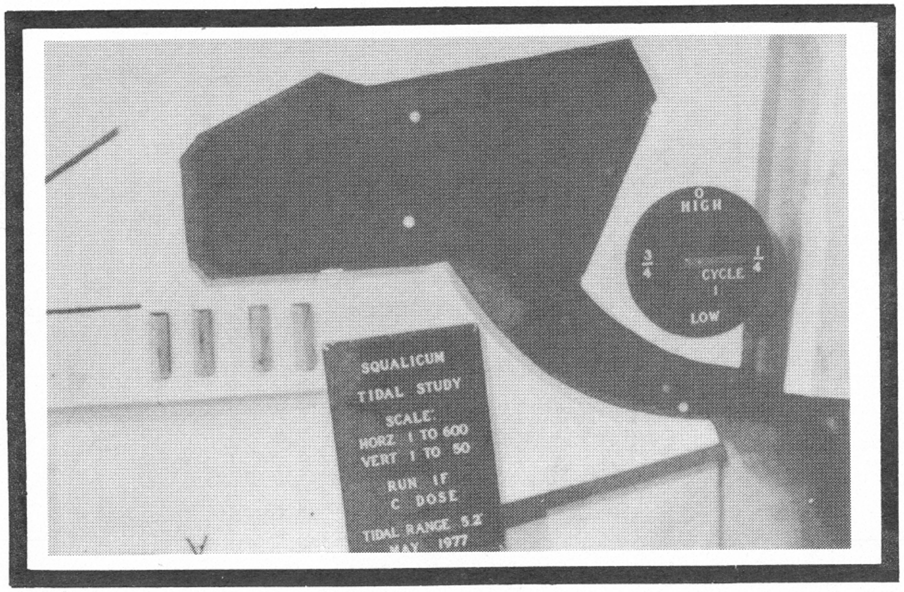

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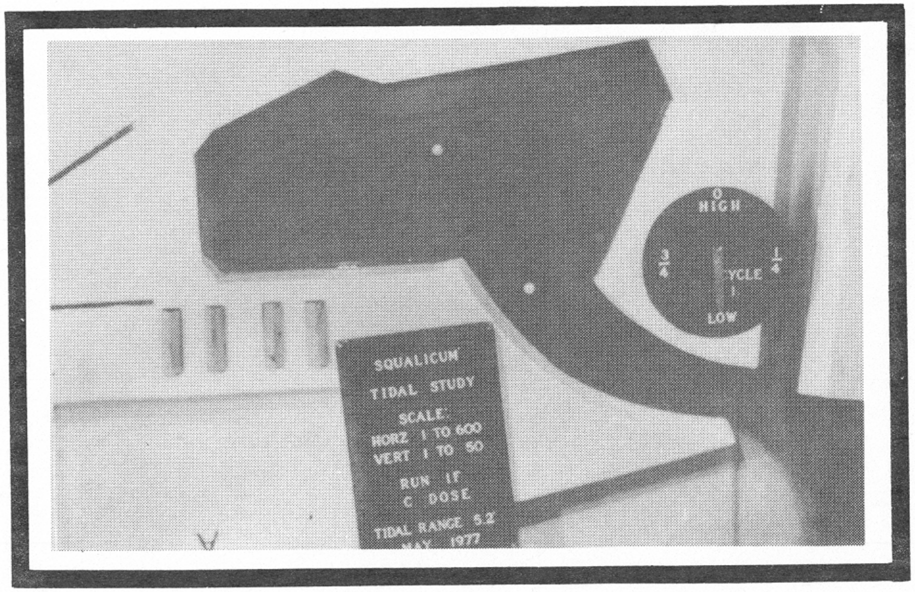

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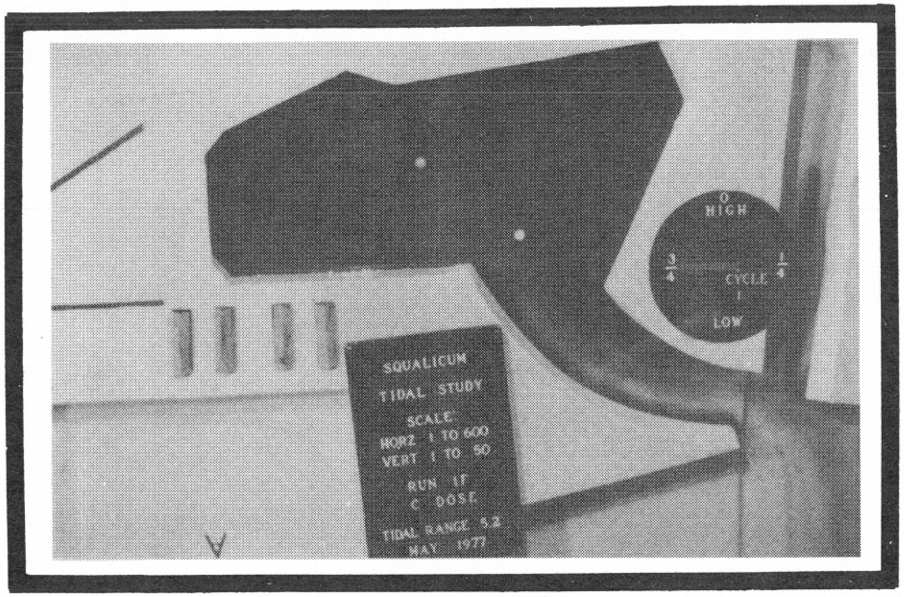

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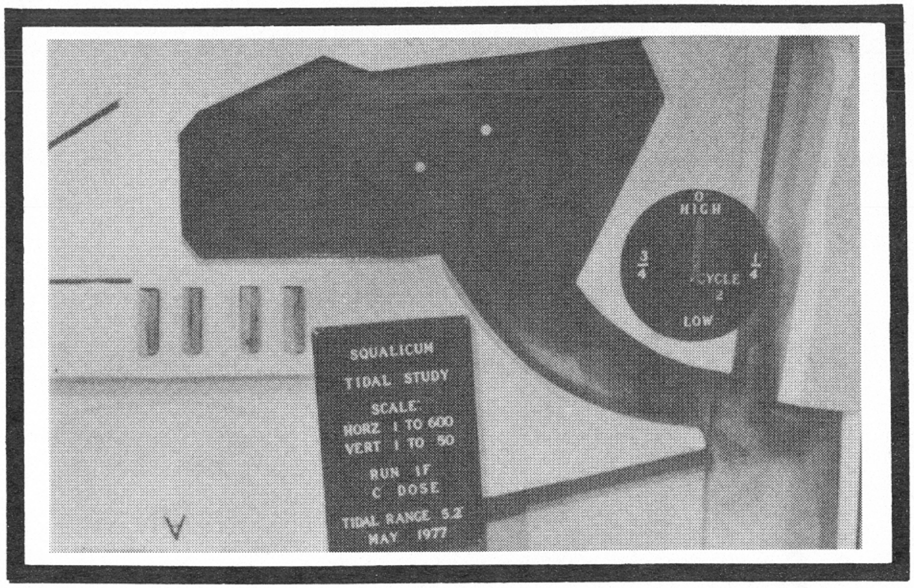

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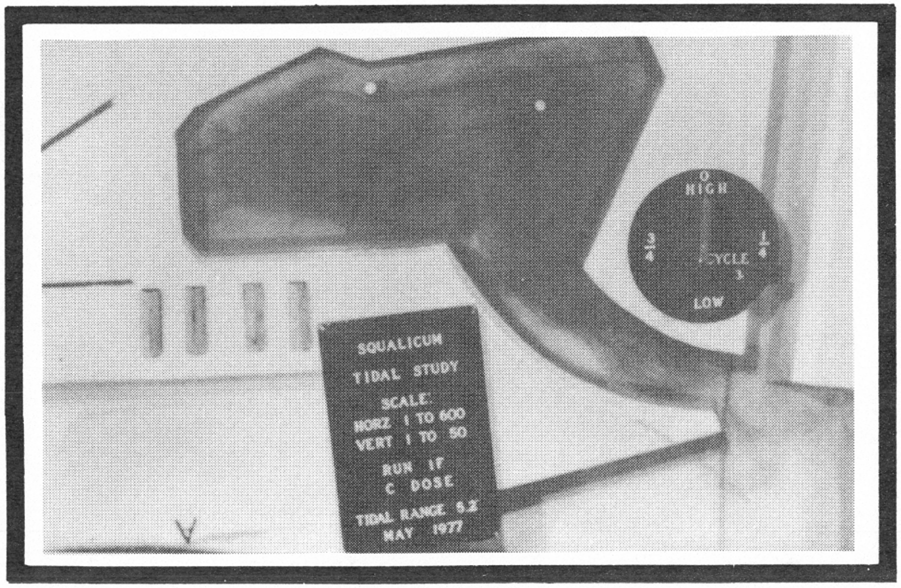

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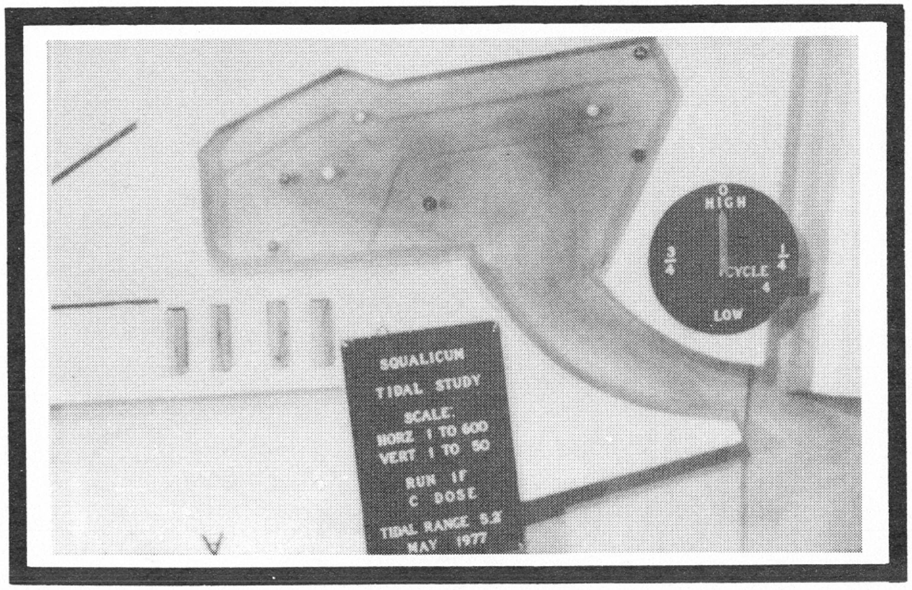

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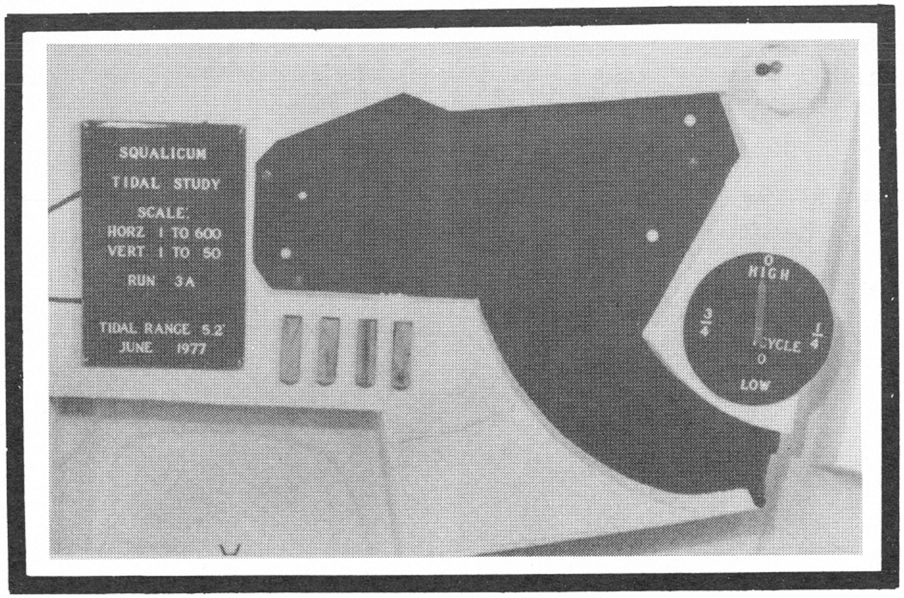

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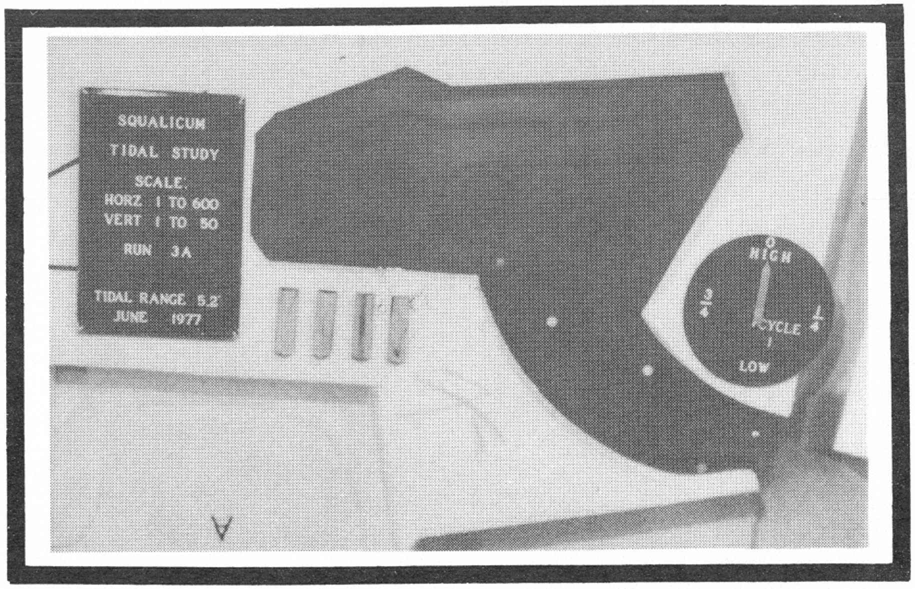

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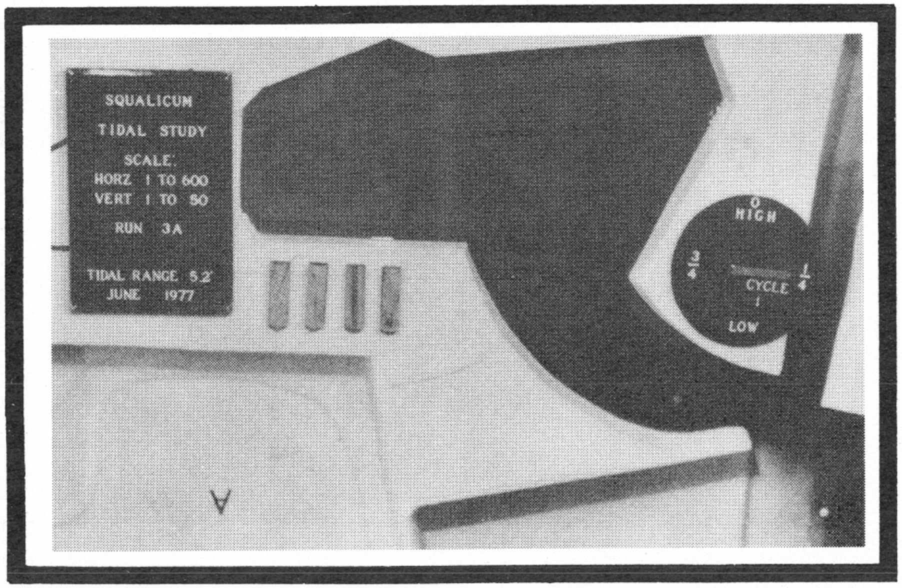

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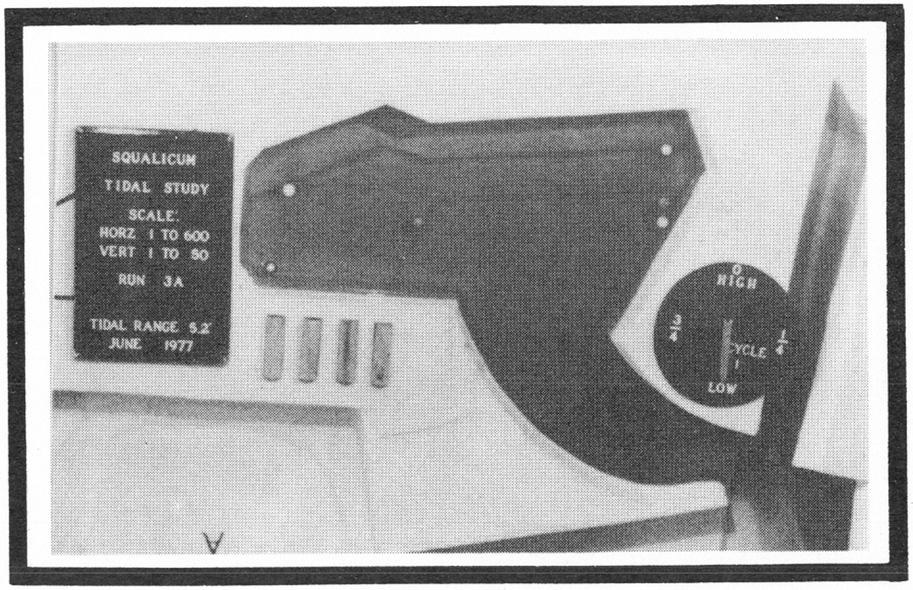

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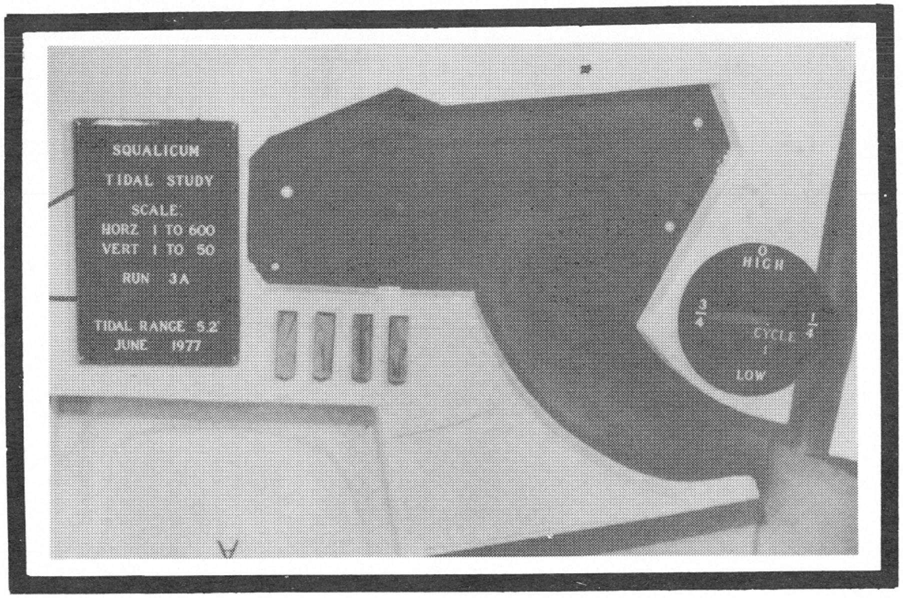

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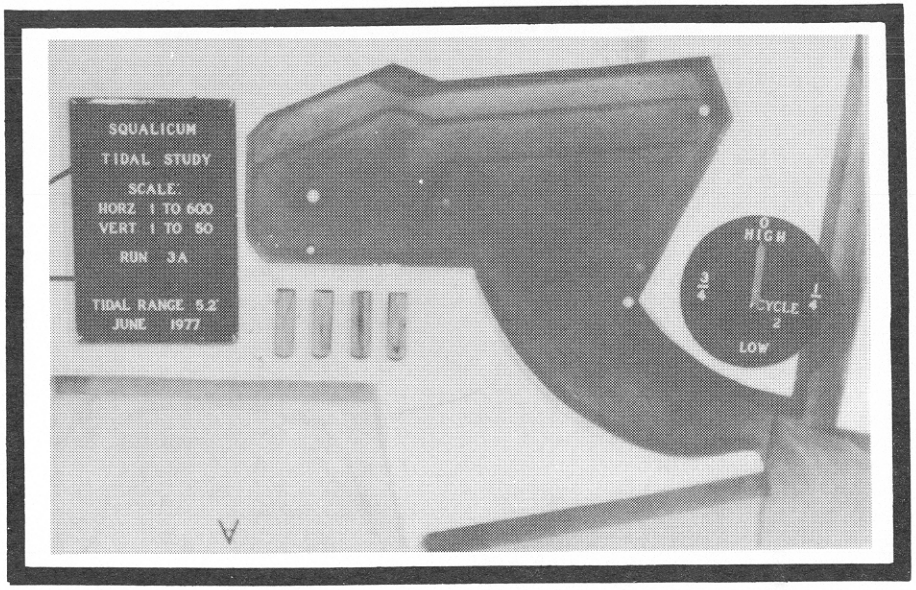

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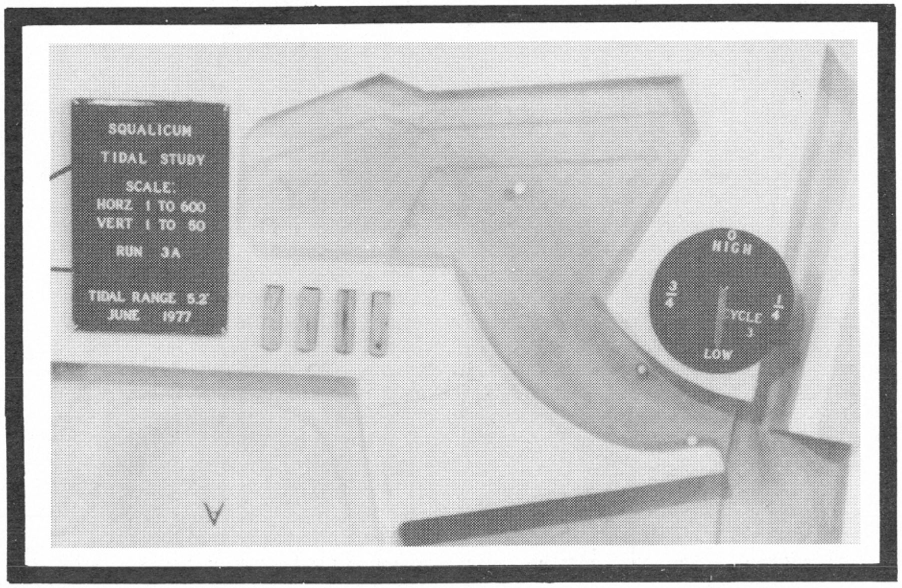

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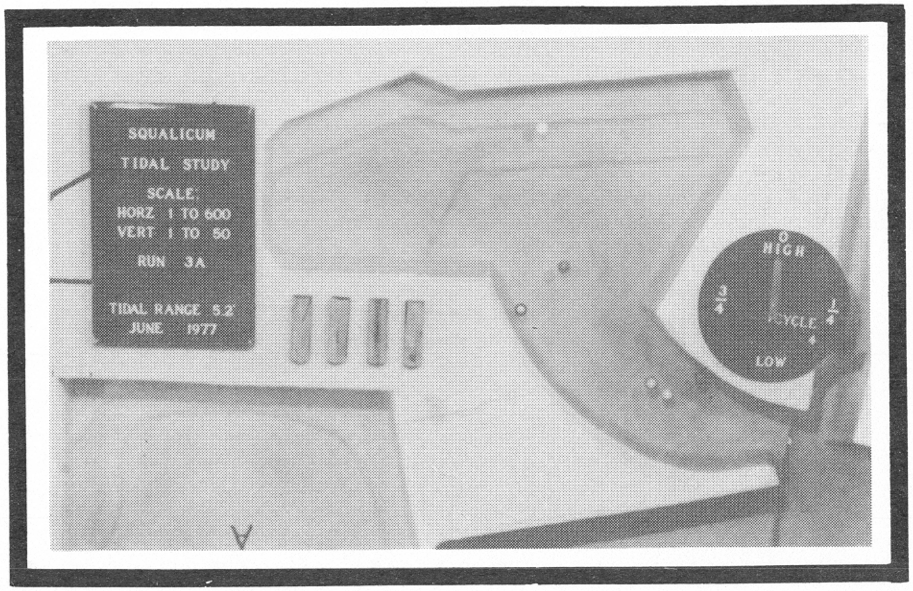

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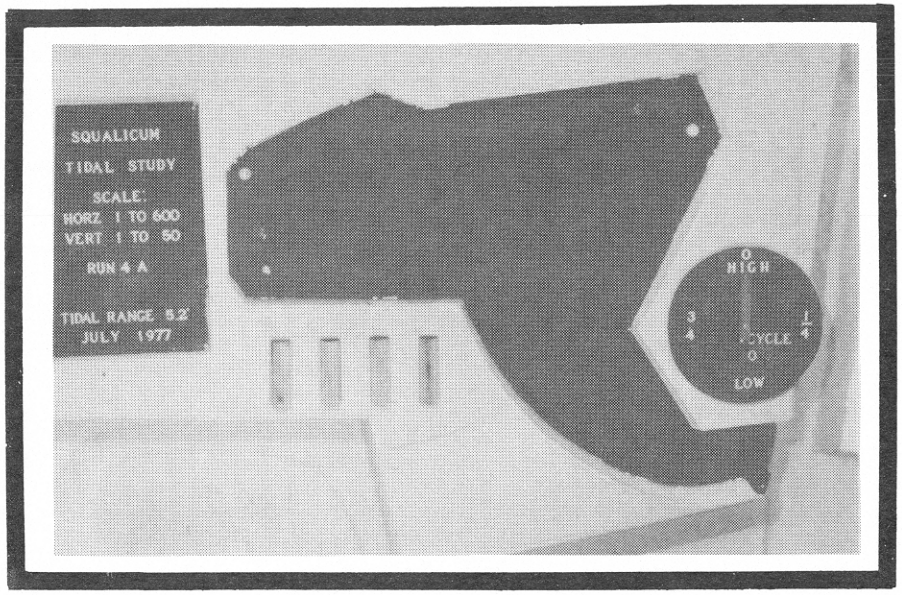

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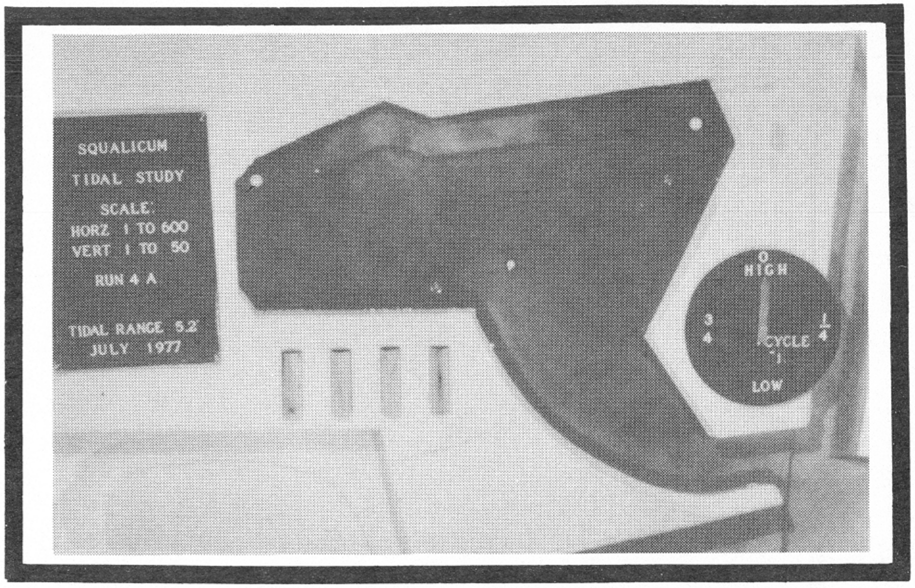

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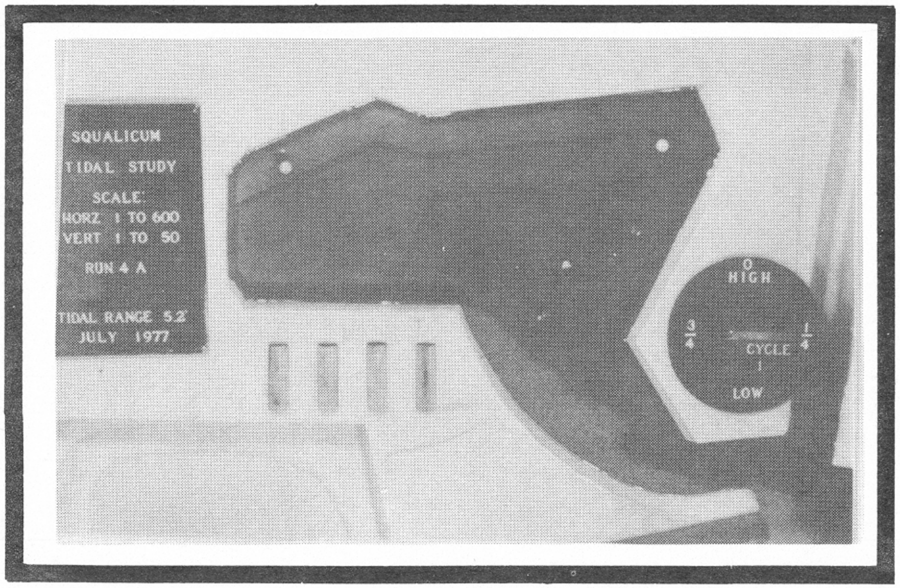

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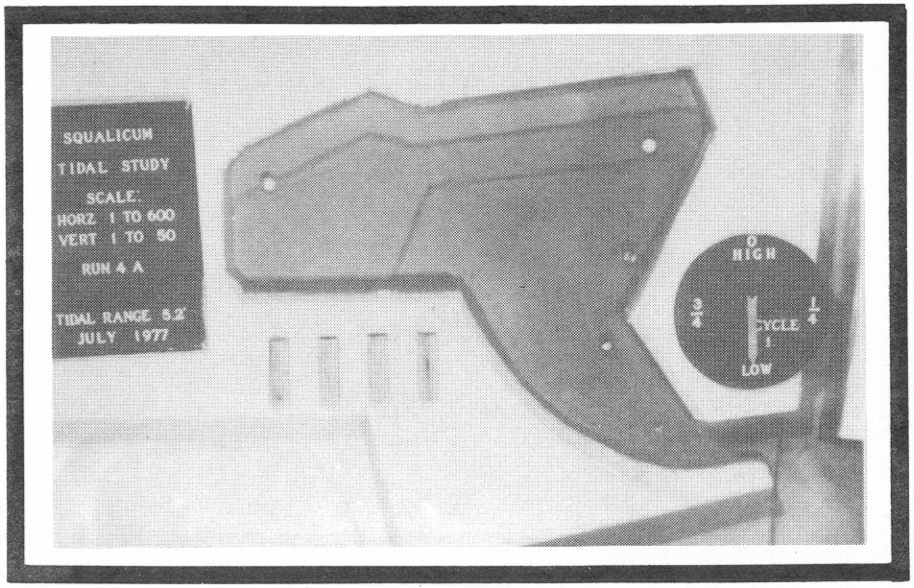

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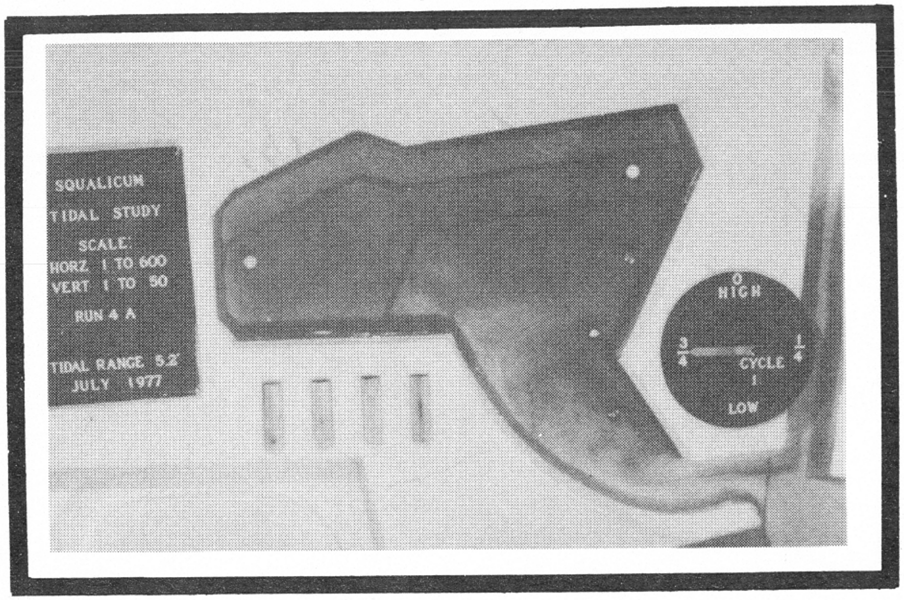

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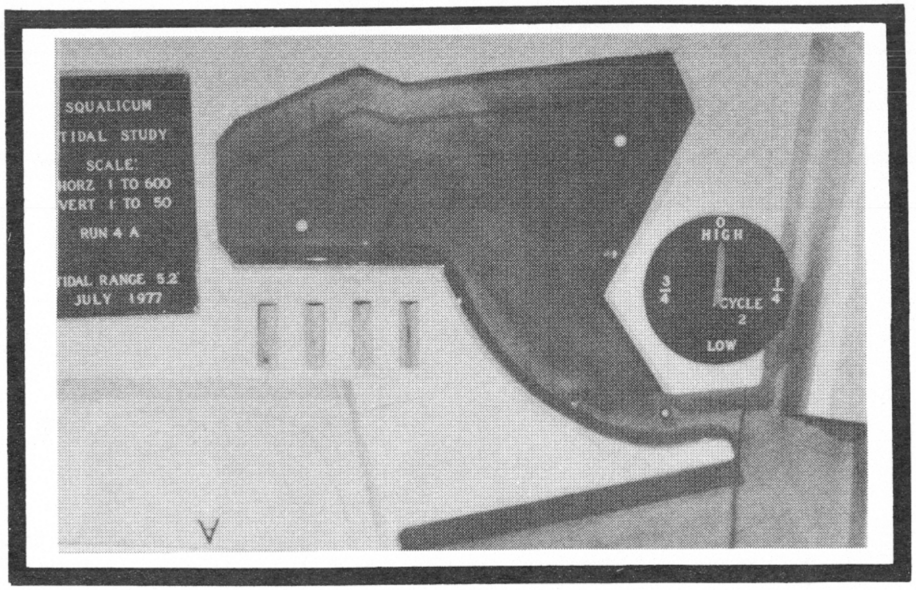

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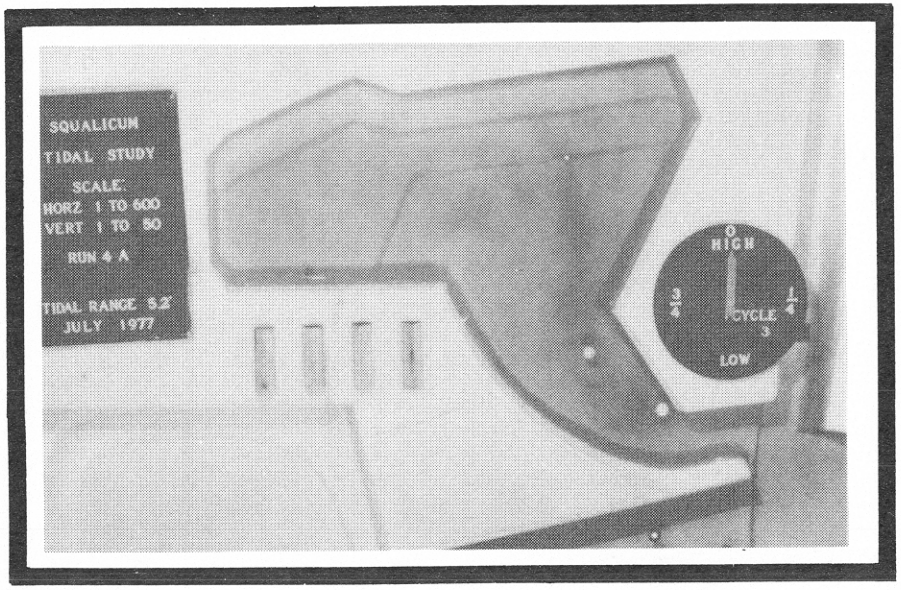

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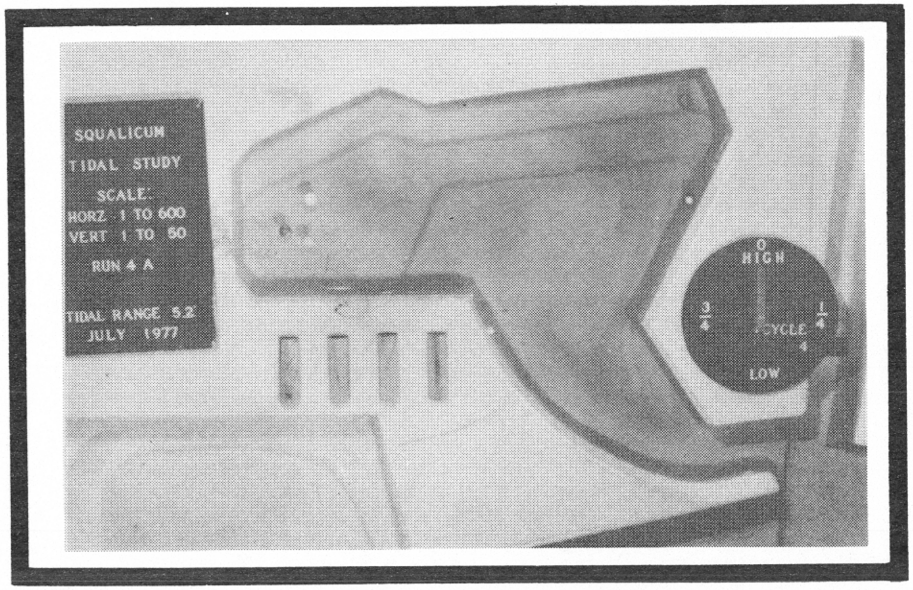

G-8 4/0

G5-G8 FINAL PLAN, INNER CURVE OF CHANNEL LINEARIZED