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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER



Bethesda, Md. 20084

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OVERLAND DYNAMICS OF THE AMPHIBIOUS ASSAULT
LANDING CRAFT JEFF (B) ONE-SIXTH SCALE MODEL

by

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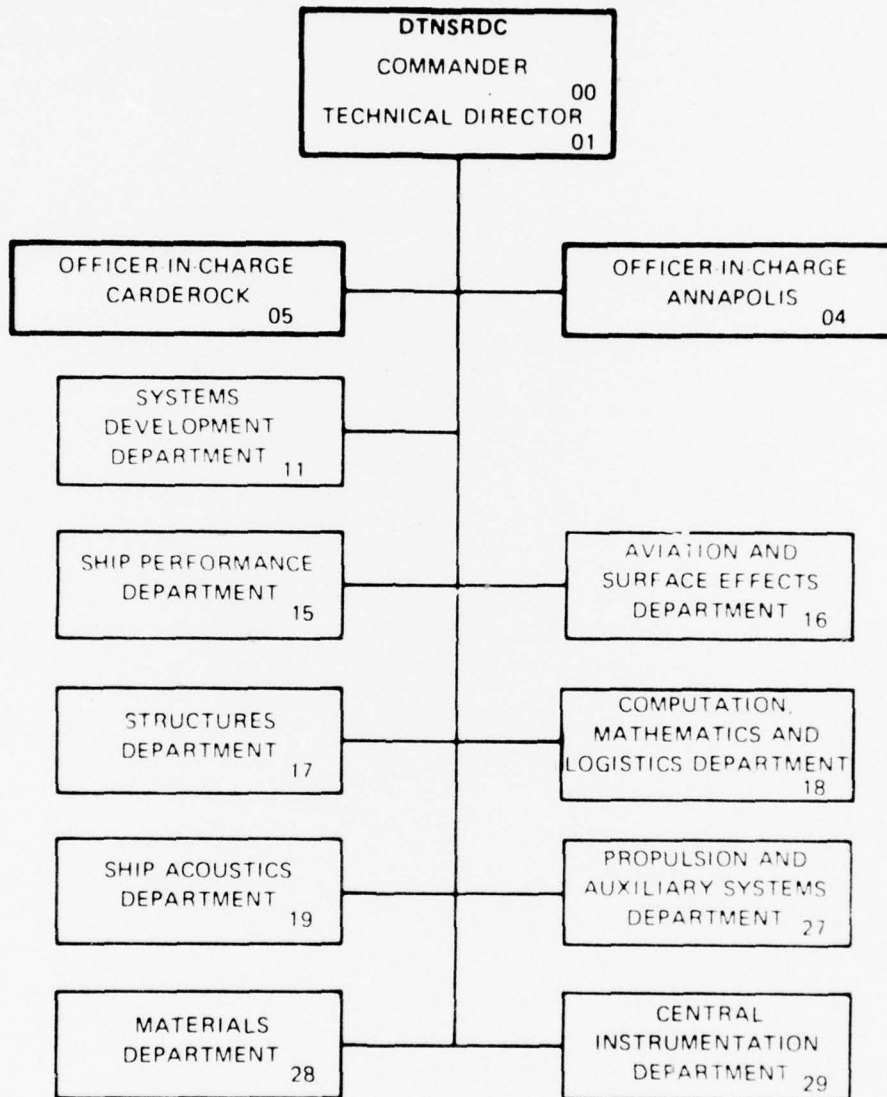
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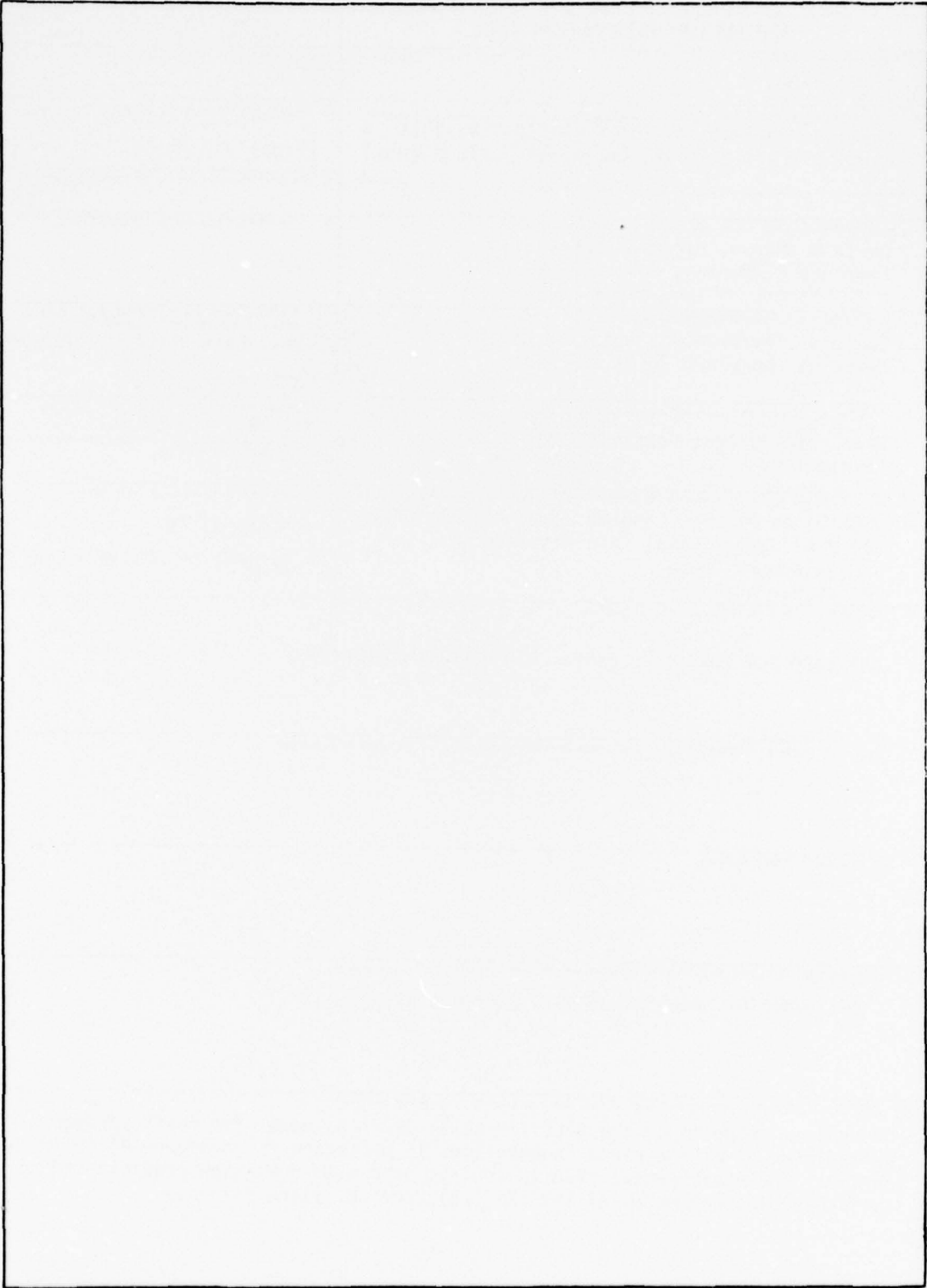
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NOTATION

A	Discharge area
B	Cushion beam
C_G	Discharge coefficient for the gully
C_S	Discharge coefficient under the skirt
h	Gully height
L	Gully length
L_C	Cushion length
x	Distance from the vertical face of the gully to the leading edge of the bow fingers
z	Heave
α	Angle between downstream face of the gully and the horizontal plane

ABSTRACT

The dynamic response of the AALC 1/6 scale JEFF (B) model for craft passage over gullies or ground plane indentations is presented for a series of gully lengths. The experimental results are compared with responses predicted by a static mathematical model of the JEFF (B) vertical plane response.

ADMINISTRATIVE INFORMATION

This study was sponsored by the Naval Sea Systems Command under Task Area S1417, Task 14174; and administered by the Amphibious Assault Landing Craft Program Office, Systems Development Department, David W. Taylor Naval Ship Research and Development Center under Work Unit Number 1-1180-740.

INTRODUCTION

The overland dynamics of the Amphibious Assault Landing Craft (AALC) air cushion vehicles (ACV) have been examined both analytically¹ and experimentally^{2,3} as part of the technological development effort of the AALC program. The motivations for these studies include general analytic model development and validation, preparation for continued AALC design efforts and preparation for full-scale AALC Navy trials. All of these goals require the examination of model-scale data generated by realistic operation over various ground terrains. This is especially important in the preparation for full-scale overland trials where it is necessary to provide a priori assurance that the ACV's will be neither damaged nor severely impeded by any ground terrain encountered during the trials. This goal can be completely satisfied by operating a model over a test site which is geometrically and dynamically equivalent to that which the full-scale craft will encounter. The expense of such an experimental program makes it impossible to implement. It is therefore necessary to test the vehicle over generalized obstacles which are representative of actual full-scale terrain elements, but which may be easily classified by a small number of parameters. The gullies chosen for examination in this experimental program adequately satisfy these requirements.

Indentations are common in overland terrain suitable for ACV operations. These indentations which are here referred to as gullies correspond to stream beds, roadside drainage ditches, agricultural drainage ditches, natural surface discontinuities such as low elevation bluffs in beach areas, trenches, variations in elevation of dense vegetation, and finally natural sand dune formations in coastal areas. The generalized

gully chosen to represent this variety of natural terrains is a trapezoidal indentation represented by three parameters in an otherwise horizontal plane. The three parameters are the depth of the gully, h , the length of the gully at the level of the lower plane, L , and the angle that the downstream face of the gully makes with the horizontal, α . These parameters are shown in Figure 1 where the longitudinal coordinate, x , is defined as the distance between the upstream vertical face of the gully and the leading bottom edge of the bow fingers of the JEFF (B) ACV.

The gully geometry represented allows a wide variety of operational conditions to be tested. In addition to gullies of discrete length, the geometry includes vertical face down-steps and walls or up-steps with sloping leading edges for a specified condition of infinite gully length. It is also possible to represent additional skirt leakage with this geometry through the consideration of very deep (large h) but short (small L) gullies.

EXPERIMENTAL INVESTIGATION

The experimental program consisted of forward speed passages of the 1/6 JEFF (B) model over various discrete gullies. The gullies are two-dimensional, rectangular in longitudinal cross-section and ranged in length from 12 to 48 inches (.30 to 1.22 meters) and in depth from 4 to 7.5 inches (.10 to .19 meters). Figure 1 shows schematically the model crossing a typical gully.

The instrumentation for this series of experiments consisted of a timer and a color video camera. Measurements of craft attitude as a function of time and position were obtained from the video screen of a stop-action recorder-player.

The 1/6 scale JEFF (B) model is shown schematically in Figure 1. The physical characteristics of the model are listed in Table 1. The JEFF (B) model has been completely described by the Bell Aerospace Company.⁴ The model has a radio controlled propulsion system and for the high speed runs, the model was self-propelled using the bow thrusters and the propellers. During the low speed runs, the model was towed across the gully by hand. Model speed was measured by timing the passage over the gully using the video-tape record of the model motion and a continuously running clock recorded on the video tape.

Prior to the performance of the overland experiments, the model was balanced to design displacement and trim. The lift system was adjusted to provide design values of cushion and bag pressures and the lift/thrust system discharge was adjusted to the recommended full-scale ratio. The measured pressures are presented in Table 2. The locations of the pressure taps noted in Table 2 are shown on Figure 2. Table 3 shows the various bag to cushion pressure ratios.

EXPERIMENTAL RESULTS

Seven gully passages are presented in Figures 3 through 8 of this report. Each case consists of heave position and pitch attitude as a function of craft position relative to the leading edge of the gully. Six significant events are shown on each figure. These are $x=0$, where the bottom leading edge of the bow fingers encounters the first edge; A, the bow fingers encounter the second edge; B, the stability keel crosses the first edge; C, the stability keel crosses the second edge; D, the stern fingers cross the first edge; and E, where the stern fingers cross the second edge.

The two runs presented in Figures 3 and 4 are for the model passing over a 4-inch by 12-inch (10cm by 30 cm) gully. These figures show that the model sinks and pitches sharply bow down as the bow crosses the gully. The inertial effects in the response are evident in the time delay (shown here as a spatial lag) in both heave and pitch at the higher speed when compared to the lower. In fact, at the higher speed the model does not show significant response in heave until one-third of the model has crossed the gully. Passage of the stability keel across the gully produces no discernible response. When the stern nears the gully, the model pitches bow up and the heave position becomes sharply positive. Throughout the major (central) portion of the passage, the craft simply sinks by approximately 0.6 inches and slides across the gully at level pitch trim.

Figures 5 and 6 present the results for the model passing over a 4-inch by 18-inch (10cm by 45 cm) gully at two different speeds. The model response becomes clearly more complicated for this longer gully. At the lower speed, the model heaves as the bow enters the gully, but shows

no pitch response until the bow crosses the second edge. At that point, the model suddenly raises up and then settles at a point midway between the maximum and minimum heave positions. When the stability keel passes the gully, the model pitches bow-up and sinks. Data were not obtained for stern crossings of the gully because the reference points could not be clearly seen on the video screen for this series of runs. The higher speed shows more gentle motion than at the lower speed but with basically similar response.

The final three runs presented in Figures 7 and 8 pertain to passage over a gully 4 inches deep and 24 inches long (10 cm by 60 cm). At all three speeds, the model pitches bow down when the bow crosses the gully. At the highest speed, the model pitches so much that the model rises in heave before falling. When the stability keel crosses the gully, the pitch attitude becomes positive and the model rises.

STATIC MODEL

The static heave displacement of an ACV standing over a gully may be estimated by a procedure which employs a simple discharge model. If it is assumed that the transverse stability keel of the JEFF (B) has no effect on the static heave position, then for level pitch trim, the sum of the cushion fluid discharges under the skirt and through the gully cross-sectional area is equal to the lift system discharge over level ground. Three cases must be considered: (1) the heave displacement is less than the cushion gap height and cushion discharge occurs at the gully and around the craft perimeter, (2) the heave displacement is greater than the gap height and the cushion discharge occurs completely at the gully with no discharge on the craft perimeter, (3) the gully length is greater

than the craft length and the vertical displacement of the craft is equal to the gully height. Writing the discharge equalities for the three cases leads to the static heave displacement, z , as

$$z = \begin{cases} \frac{Lh}{B + L_c} \cdot \frac{C_g}{C_s} & \text{for } z < h_c, L < L_c \\ h + h_c - \frac{A}{2L} \cdot \frac{C_s}{C_g} & \text{for } h_c < z < h, L < L_c \\ h & \text{for } L > L_c \end{cases} \quad (1)$$

where h_c is the gap height, A is the discharge area, L_c and B are the cushion length and beam and C_G and C_s are the discharge coefficients for the gully and under skirt flow area respectively. The resultant expression is static since it involves no inertial effects and is therefore independent of craft speed. Further, the static model does not include the effect of skirt deformation over the horizontal plane.

Figures 3 to 8 show that the heave displacement is greater than the cushion gap height and less than the gully height; thus, the second expression for heave is appropriate. Since the model fingers were ragged and worn and ripped in several places from previous overland experiments, the gap height, h_c , is approximately zero. Assuming a discharge area of 120 in^2 (750 cm^2), $C_s = 0.6$ and $C_G = 0.9$, then the heave displacement expression (in inches) is

$$z = h - \frac{40}{L} \quad (2)$$

The accuracy of the static model represented by the previous equation is shown in Table 4 through a comparison of predicted and measured heave positions for the gully lengths and transit speeds examined experimentally. The equation over-predicts the measured displacement as expected, but the magnitude of the error is not great enough to discourage the use of this simple equation for rapid engineering estimates of the expected heave

displacement of an ACV operating at low speed over a gully.

Comparison between the experimental results and the static model shows that the dynamic effects must be considered in order to accurately predict heave. One of the main trends shown in Table 4 is that the heave displacement is greater for higher speeds. This can possibly be explained by the fact that the engine speed was set for a propeller pitch of 10 degrees. This propeller pitch was used for the higher speed runs, but for the low speed runs, the propeller pitch was set to zero without readjusting the engine speed. The engines consequently speeded up and the lift fans produced a higher flow and a stiffer cushion.

The experimental pitching motion must also be considered in connection with the pitching moments induced by the propulsors and thrusters used during the high speed runs. Additionally, the changes in lift fan flow rate and cushion stiffness for the lower speeds must be considered. Finally, since the model was pushed across the gullies, some additional damping could have been artificially produced through the test procedure.

CONCLUSIONS

The one-sixth scale model JEFF (B) was tested over three gully widths at several speeds. The following conclusions can be drawn from the results of this limited number of cases and conditions.

1. The pitch motion in all cases is lessened by an increase in speed.
2. The bow pitches down into the gully until it reaches the far side, then level trim is restored and finally the bow pitches up when the stern crosses the gully.
3. The effect of the stability keel increases by reducing pitching as the gully length increases.
4. The heave displacement is not affected by the stability keel.
5. The heave displacement is affected by the gully length and lift fan flow rate.

The figures provided are only examples of data obtained from this experimental program. The primary product of the experiment is the recorded observation of craft response, which, although it is not quantitative in nature, is invaluable for an understanding of the dynamic behavior of the craft.

RECOMMENDATIONS

For any further tests of this type, the following recommendations are made:

1. Ultrasonic wave height sensors should be used to obtain the pitch and heave motion.
2. Static measurements on the gully should be made.
3. The lift system flow rate should be adjusted so that it is the same for all speeds.

ACKNOWLEDGMENT

The authors extend their sincere appreciation to the entire crew of the DTNSRDC Amphibious Assault Landing Craft Office Experimental Trials Unit (ETU) located at the Naval Coastal Systems Laboratory at Panama City, Florida, and under the command of Cdr. W.G. Wilder. The members of the ETU have individually and collectively produced a model-scale program which would have been otherwise impossible to perform.

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4. Bell Aerospace Company, "Preliminary Design Summary Report, AALC C150-50", Report No. 7385-950007 (Oct. 1970).

TABLE 1

PHYSICAL CHARACTERISTICS OF THE 1/6 SCALE JEFF (B) MODEL

LOA	Length, overall	14.6 ft	4.45 m
L	Length, cushion, effective	13.33 ft	4.06 m
BOA	Beam, overall	7.84 ft	2.39 m
B	Beam, cushion, maximum	6.64 ft	2.02 m
M	Mass, tested	38.84 slugs	567 kg
RPM	Fan speed, rpm	3300-3400	
α	Angle of bow figures	$45^{\circ} \pm 1^{\circ}$	
h_F	Height of bow figures	3.9<4.8 in	9.9<12.1 cm
X_K	Bow fingers to stability keel	6.42 ft	1.96 m

TABLE 2

BAG AND CUSHION PRESSURES FOR JEFF (B) MODEL

Tap No.	Tap Location	Pressure	
		lb/ft ²	Pascals
1	Bow bag	19.1	914.5
2	Starboard forward cushion	13.8	660.7
3	Starboard forward bag	18.4	881.0
4	Starboard forward cushion	14.5	694.3
5	Starboard stern bag	18.4	881.0
6	Starboard stern cushion	12.7	608.1
7	Stern bag	17.7	847.5
8	Port stern cushion	13.1	627.2
9	Port stern bag	18.4	881.0
10	Port forward cushion	13.8	660.7
11	Port forward bag	17.7	847.5
12	Port forward cushion	13.8	660.7

TABLE 3

BAG TO CUSHION PRESSURE RATIOS FOR JEFF (B) MODEL

Bag to Cushion Location	Pressure Ratio
Starboard forward	1.30
Port forward	1.28
Starboard aft	1.44
Port aft	1.41
Bow	1.37
Stern	1.37
Average	1.34

TABLE 4
PREDICTED STATIC HEAVE OVER GULLY

Height		Length		Speed		Heave Responses			
in	h	in	L	kts	U	Z measured		Z predicted	
	cm		cm		m/sec	in	cm	in	cm
4	10	12	30.5	.77	.40	0.6	1.5	.65	1.6
4	10	12	30.5	6.07	3.12	0.6	1.5	.65	1.6
4	10	18	46	1.39	.72	0.6	1.5	1.8	4.6
4	10	18	46	3.38	1.74	1.1	2.8	1.8	4.6
4	10	24	61	1.78	.92	1.5	3.8	2.33	5.9
4	10	24	61	2.84	1.46	1.05	2.7	2.33	5.9
4	10	24	61	3.79	1.95	1.8	4.6	2.33	5.9

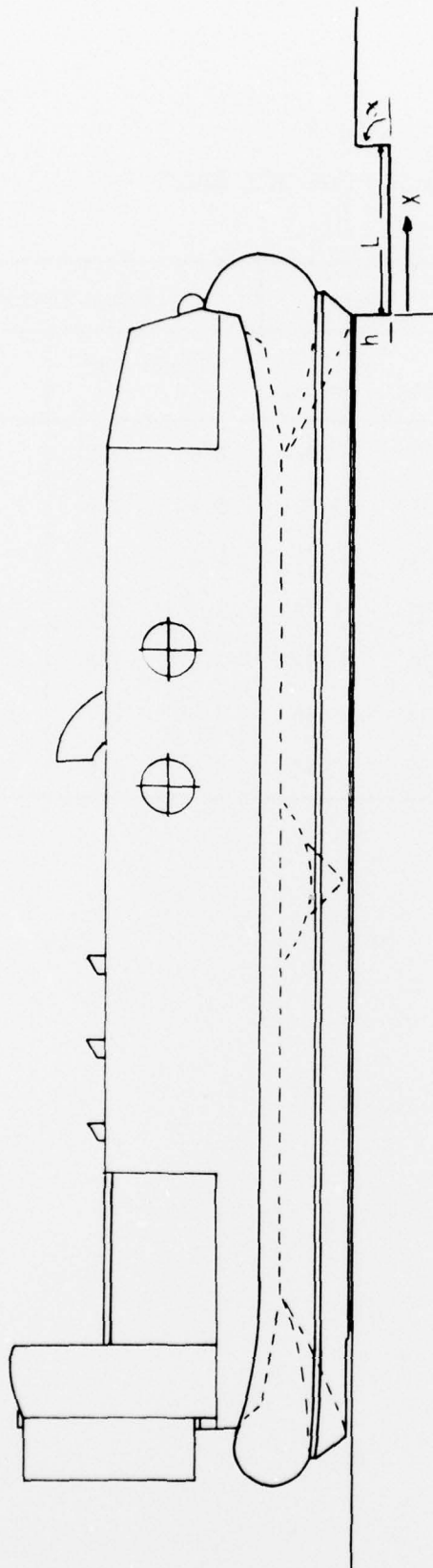


Figure 1 - Sketch of the 1/6 Scale JEFF (B) Model Traversing a Gully at $X = 0$.

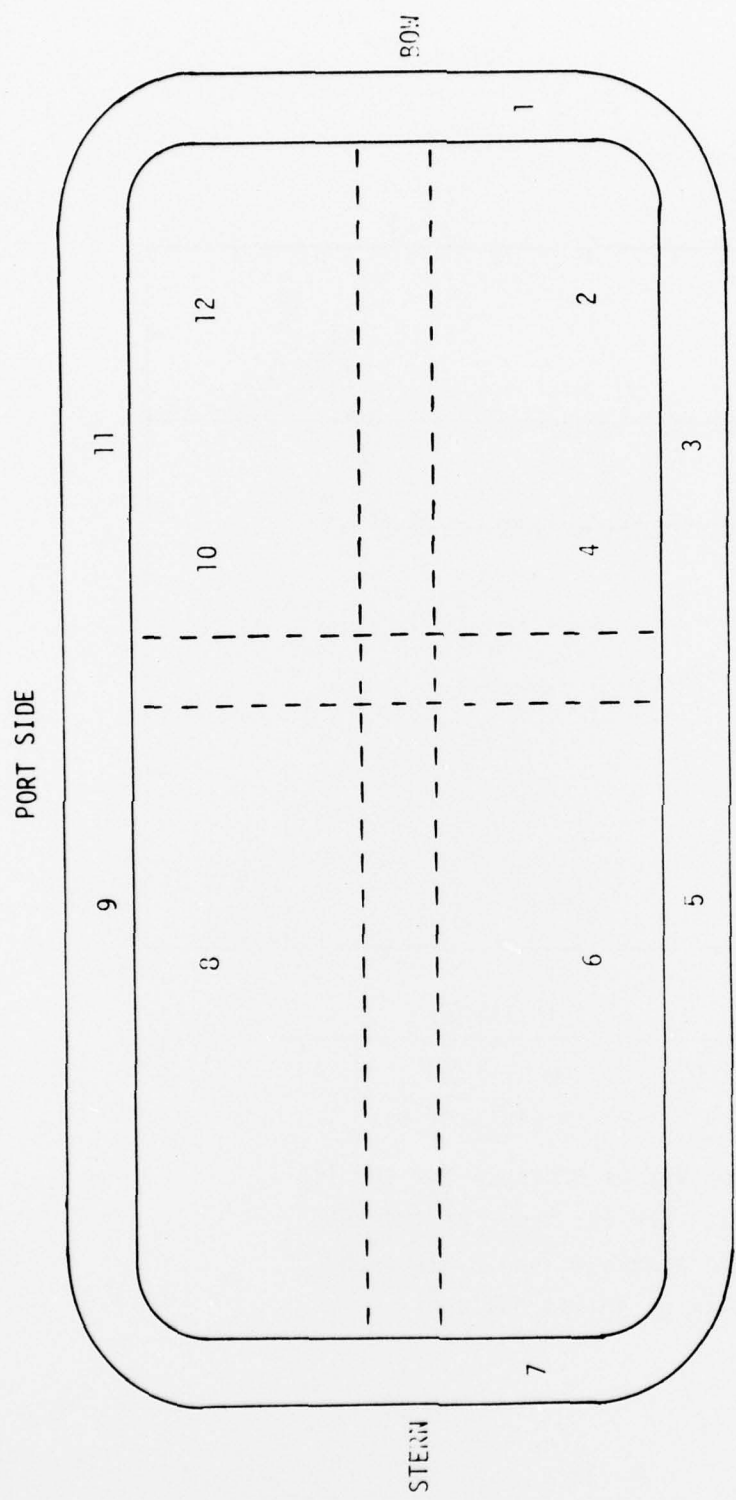


Figure 2 - JEFF B 1/6 Scale Model Pressure Tap Locations

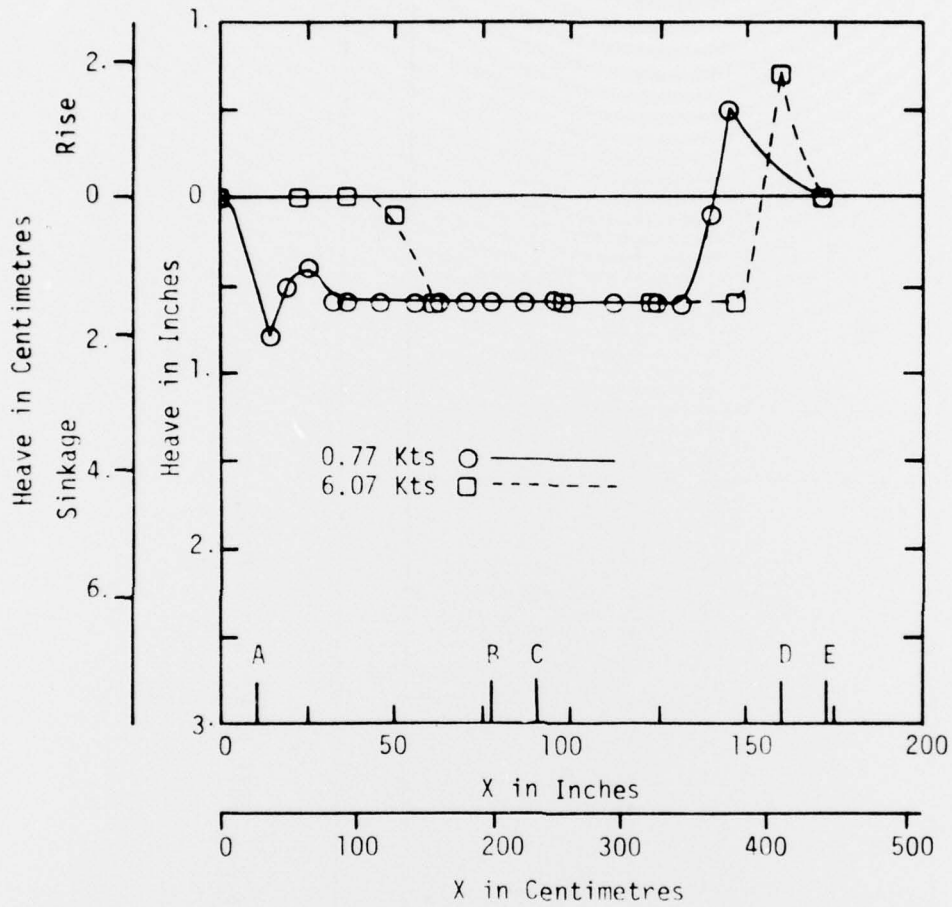


Figure 3 - Heave Versus Distance for the 1/6 Scale JEFF (B) Model of the AALC Traversing a 4 Inch by 12 Inch (10 cm by 30 cm) Gully

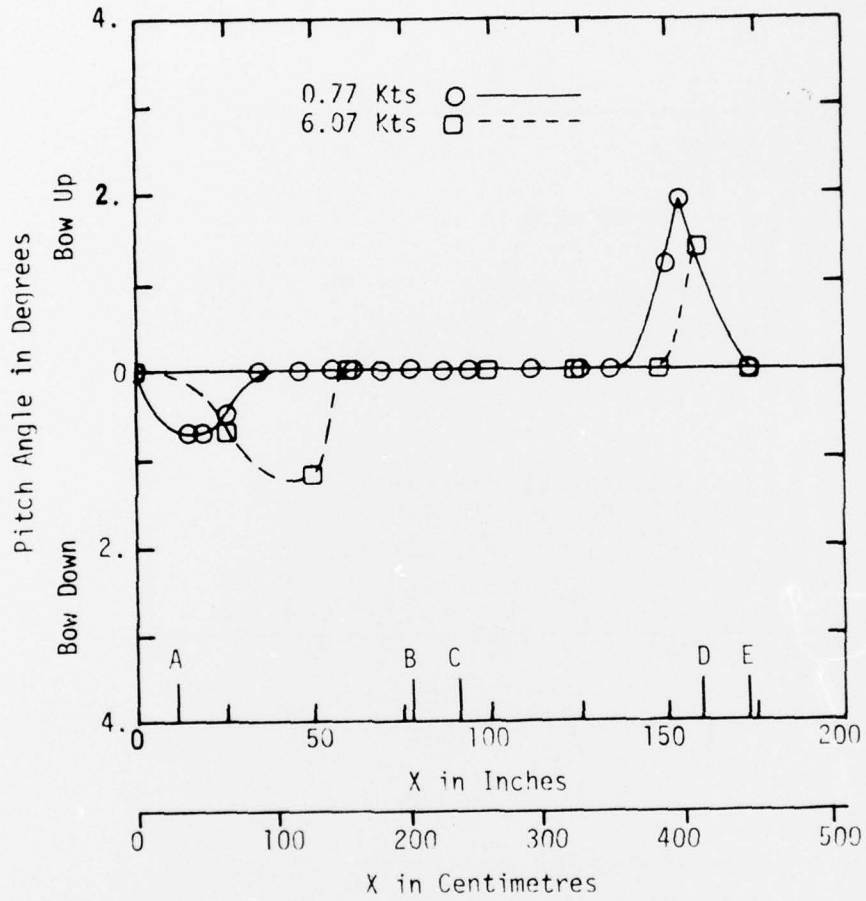


Figure 4 - Pitch Angle Versus Distance for the 1/6 Scale JEFF (B) Model of the AALC Traversing a 4 Inch by 12 Inch (10 cm by 30 cm) Gully

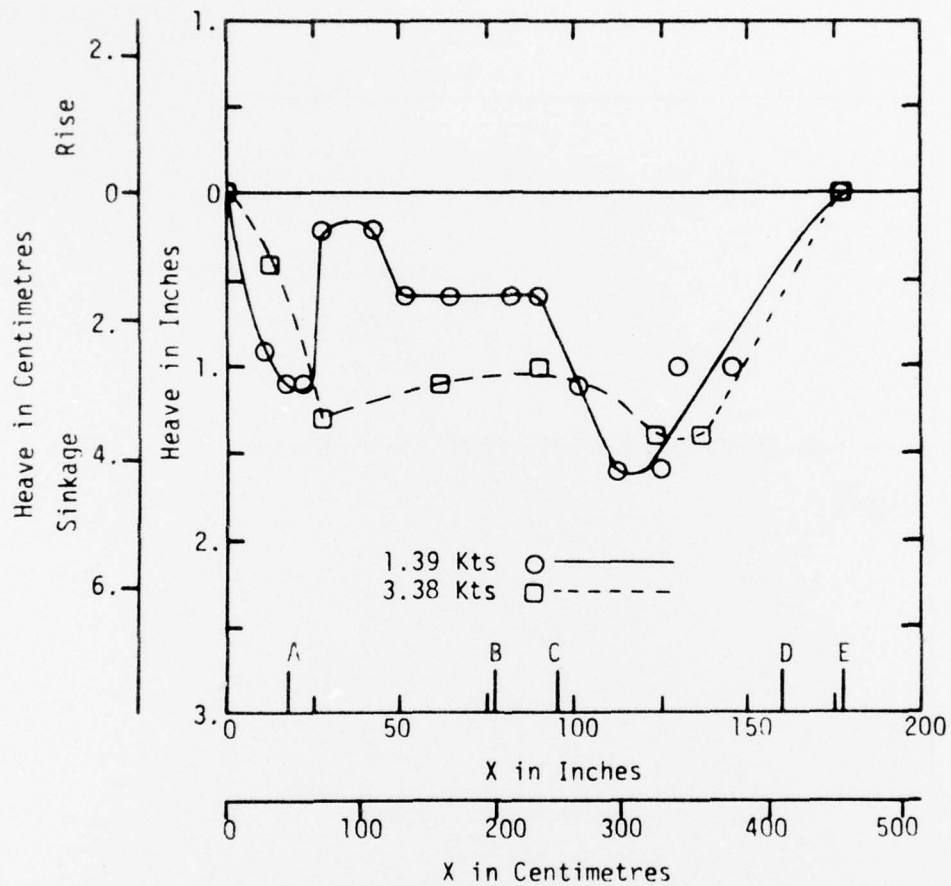


Figure 5 - Heave Versus Distance for the 1/6 Scale
 JEFF (B) Model of the AALC Traversing
 a 4 Inch by 18 Inch (10 cm by 30 cm) Gully

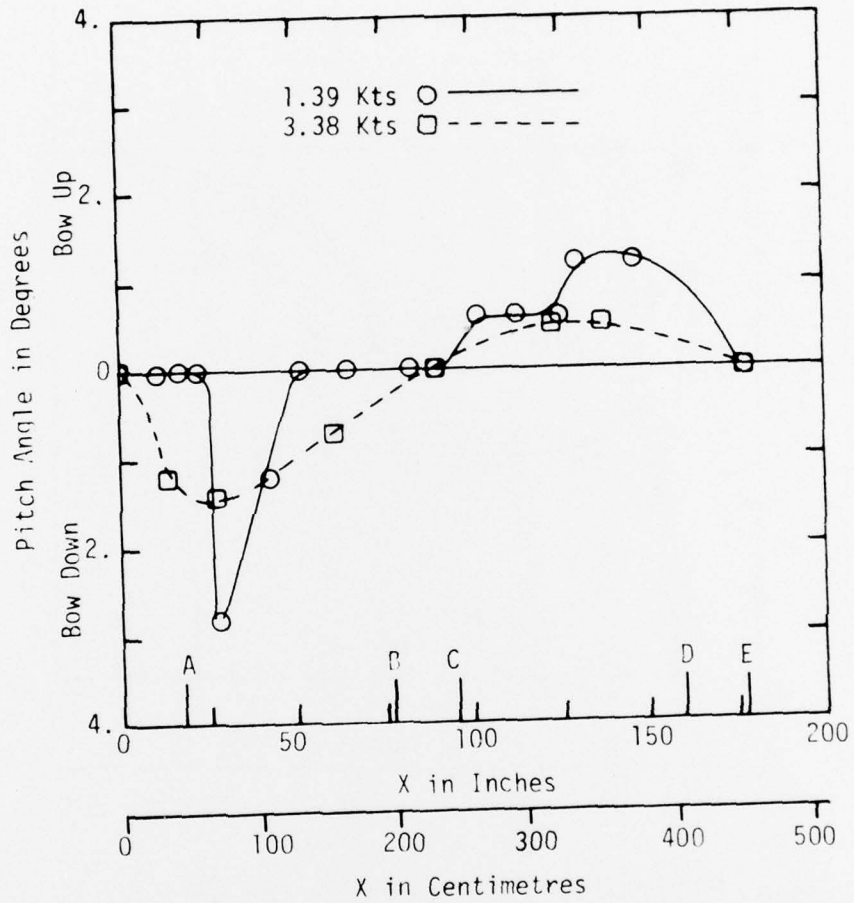


Figure 6 - Pitch Angle Versus Distance for the
 1/6 Scale JEFF (B) Model of the AALC
 Traversing a 4 Inch by 18 Inch
 (10 cm by 30 cm) Gully

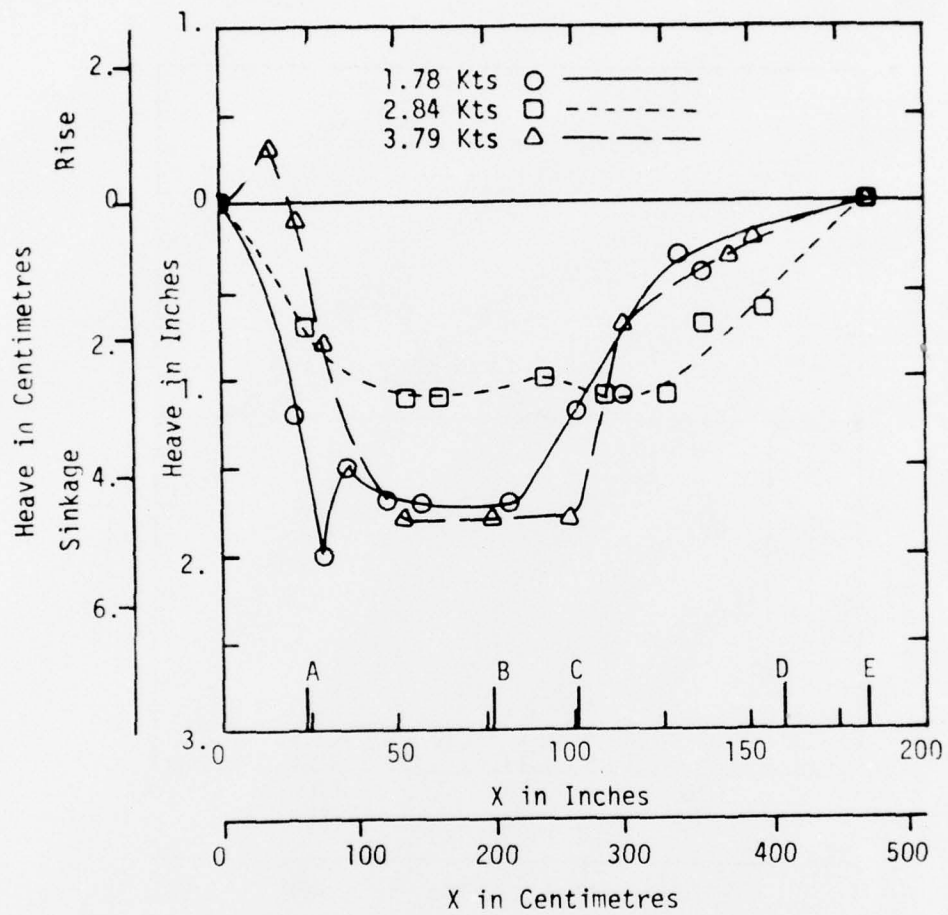


Figure 7 - Heave Versus Distance for the 1/6
 Scale JEFF (B) Model of the AALC
 Traversing a 4 Inch by 24 Inch
 (10 cm by 60 cm) Gully

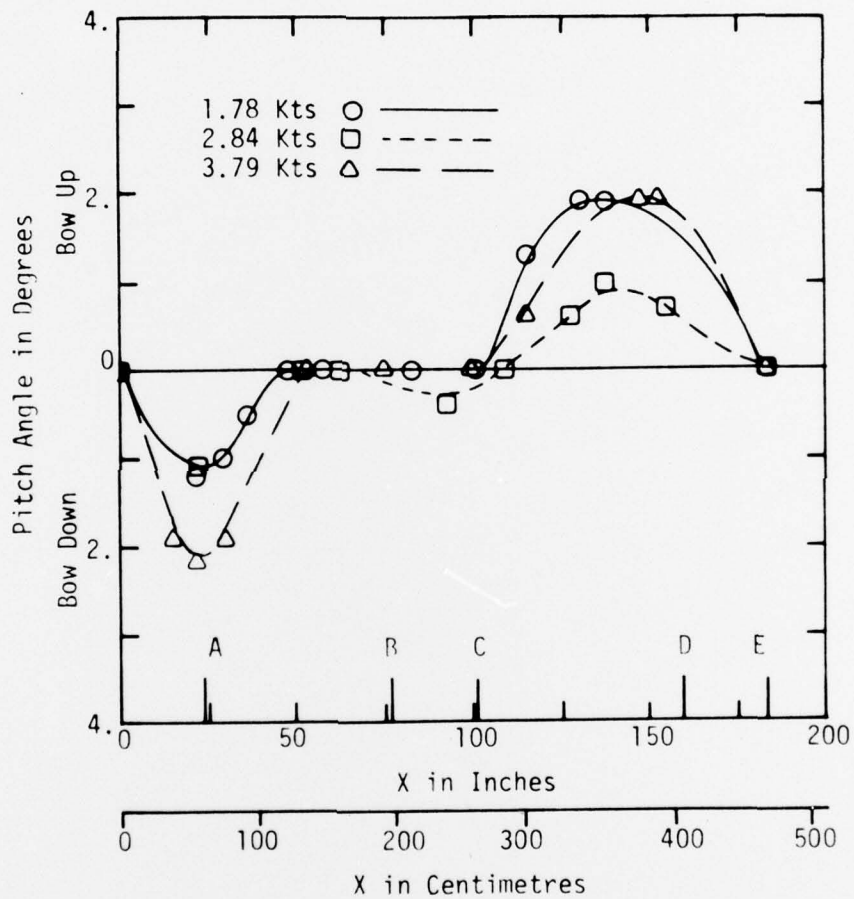


Figure 8 - Pitch Angle Versus Distance for the 1/6 Scale JEFF (B) Model of the AALC Traversing a 4 Inch by 24 Inch (10 cm by 60 cm) Gully

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