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HAND-HELD CALCULATOR ALGORITHMS FOR COASTAL ENGINEERING
(SECOND SERIES)(U) COASTAL ENGINEERING RESEARCH CENTER
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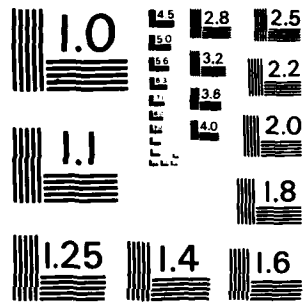
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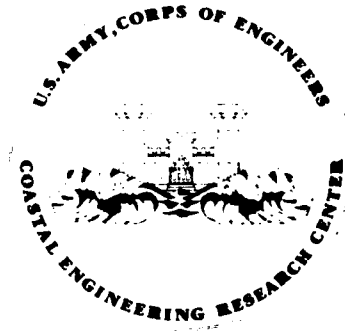
Hand-Held Calculator Algorithms for Coastal Engineering (Second Series)

by

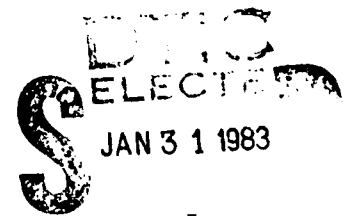
Todd L. Walton, Jr.

COASTAL ENGINEERING TECHNICAL AID NO. 82-4

NOVEMBER 1982



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report provides algorithms for a number of calculator programs useful in performing coastal engineering calculations, primarily in the area of wave transformations and wave generation. Six programs are included for use with HP41CV hand-held calculators which employ the Reverse Polish Notation (RPN). These programs can be used to compute linear wave parameters, orbital velocities, breaking wave height and direction, shallow-water wave forecasts, depth-limited breaking wave height, and wave transmission past a vertical barrier.		

PREFACE

This report provides coastal engineers a second series of algorithms for a number of hand-held calculator programs for coastal engineering, primarily in the area of wave transformations and wave generation. These algorithms were developed under the U.S. Army Coastal Engineering Research Center's (CERC) Littoral Data Collection Methods and Their Engineering Application work unit, Shore Protection and Restoration Program, Coastal Engineering Area of Civil Works Research and Development.

The report was prepared by Dr. Todd L. Walton, Jr., Hydraulic Engineer, under the general supervision of Dr. J.R. Weggel, Chief, Evaluation Branch, and Mr. N. Parker, Chief, Engineering Development Division.

The author acknowledges the assistance of J. Dean in preparing the manuscript. The review by Dr. J.R. Weggel is appreciated.

Technical Director of CERC was Dr. Robert W. Whalin, P.E., upon publication of this report.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.



TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director



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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins ¹

¹To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9) (F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9) (F - 32) + 273.15$.

HAND-HELD CALCULATOR ALGORITHMS FOR COASTAL
ENGINEERING (Second Series)

by
Todd L. Walton, Jr.

I. INTRODUCTION

The advent of the hand-held programable calculator has led to the development of numerous programs in various fields of engineering and science. Coastal engineering is no exception. This report provides algorithms for a number of calculator programs useful in performing coastal engineering calculations, primarily in the area of wave transformations and wave generation.

There are basically two types of hand-held programable calculators: those that use algebraic logic, such as Texas Instruments, Algebraic Operating System (AOS) notation, and those that use Reverse Polish Notation (RPN), such as Hewlett-Packard. The six programs presented herein are versions of RPN logic suitable for use on HP41CV programable calculators with or without accessory printer. Each program is documented, the assumptions are briefly described, and references to more detailed presentations of the theory are given. This same set of algorithms was programed for the TI-59 (AOS logic) and HP67 (RPN logic) calculators in an earlier report with the same title (Walton, Birkemeier, and Weggel, 1982)¹.

Each of the RPN programs incorporates HP41 compatible print routines which print and label all input and output parameters. The user only has to enter the input parameters and the results are automatically computed and printed. Since the printing routines increase program length by as much as 25 percent, use of a magnetic card for permanent program storage is recommended. All print steps are marked with asterisks and need not be entered if printing is not desired.

II. PROGRAMS

Six programs (100, 101, 102, 103, 104, and 105) are presented in this report. Program 100, a simple program that computes linear wave theory wavelength for a given depth, is designed to be used as the basis for any program that requires wavelength; in fact, it has been incorporated into programs 101, 102, and 105.

Program 101 is another basic program which computes not only wavelength but also a number of other linear wave theory parameters. This program forms the basis for program 102 and can be adapted to other programs as well.

¹WALTON, T.L., BIRKEMEIER, W.A., and WEGGEL, J.R., "Hand-Held Calculator Algorithms for Coastal Engineering," CETA 82-1, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Jan. 1982.

Program 102 computes linear wave parameters and breaking wave height and direction based on nearshore or deepwater wave information. Program 103 can be used to forecast wave height and period in shallow water. Program 104 and 105 address wave conditions at structures--program 104 predicts the depth-limited design breaking wave height at a structure; 105 uses Fuchs' equation to predict wave transmission over a thin barrier.

Each program allows either English or metric input and output. Program listings are annotated, making it possible to follow the logic of the algorithm and to make modifications if desired.

There are undoubtedly many calculator programs not included here that have been developed on coastal engineering subjects. Practicing engineers who would like to disseminate such programs (in either AOS or RPN) to other users are encouraged to submit them to the Coastal Engineering Research Center (CERC). If the response is great enough, additional reports presenting the programs will be prepared. Comments, programs, or suggestions for programs should be sent to:

Commander and Director
US Army Coastal Engineering Research Center
ATTN: Evaluation Branch
Kingman Building
Fort Belvoir, VA 22060

These programs and future programs will generally correspond to the following numbering scheme:

Miscellaneous	0-99
Waves and currents	100-299
Inlets	300-499
Beaches	500-699
Geology	700-899
Structures	900-1099

In general, the documentation of programs submitted should be in a format paralleling that of the programs presented in this report. A blank set of forms which can be reproduced is included in the Appendix.

Program Description

Program Title	100R-41CV Linear Wave Theory Wavelength (RPN Logic)		
Name	T.L. Walton, Jr.	Date	1/82
Address	Coastal Engineering Research Center		
City	Kingman Building	State	Virginia
	Fort Belvoir,	Zip Code	22060

Program Description, Equations, Variables, etc.

This algorithm takes deepwater wavelength as input and using the depth at a given site iterates to obtain wavelength by linear wave theory. Algorithm uses English or metric system of units.

REFERENCE

U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER,
Shore Protection Manual, 3d ed., Vol. I, Eq. (2-4), Stock No. 008-022-00113-1, U.S. Government Printing Office, Washington, D.C., 1977.

Operating Limits and Warnings

100R-41CV-1

User Instructions

100R-41CV LINEAR THEORY WAVELENGTH (RPN LOGIC)

SIZE: 011

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	LOAD PROGRAM (WAVEL)		[XEQ] "WAVEL"	E OR M?
	TO CALCULATE L IN ENGLISH UNITS:			
2	PRESS GTO "E"		GTO "E"	
3	PRESS R/S		[R/S]	PERIOD?
4	ENTER PERIOD T, PRESS R/S	T(sec)	[R/S]	DEPTH?
5	ENTER DEPTH D, PRESS R/S	d(ft)	[R/S]	L(ft)
	TO CALCULATE L IN METRIC UNITS:			
2a	PRESS GTO "M"		GTO "M"	
3a	PRESS R/S		[R/S]	PERIOD?
4a	ENTER PERIOD T, PRESS R/S	T(sec)	[R/S]	DEPTH?
5a	ENTER DEPTH D, PRESS R/S	d(meters)	[R/S]	L(meters)
	Example 1 and 1a			
	T = 10sec, d = 10ft (3.05m)			
	ENGLISH AND METRIC PRINTOUTS			
	ENGLISH			
	PERIOD=	10.0000 ***		
	DEPTH=	10.0000 ***		
	LENGTH=	175.7738 ***		
	METRIC			
	PERIOD=	10.0000 ***		
	DEPTH=	3.0500 ***		
	LENGTH=	53.6663 ***		
			note: " = [ALPHA]	

100R-41CV-2

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
01	LBL "WAVEL"			57	ETX		
02	"E OR M ?"			58	+		
03	PROMPT			59	/		$\tanh \frac{2\pi d}{L_{old}}$
04	LBL E			60	RCL 01		
05	32.2			61	*		$L' = L_0 \tanh \left(\frac{2\pi d}{L_{old}} \right)$
06	STO 06		$g(\text{English}) \rightarrow R_{06}$	62	RCL 03		
07	"ENGLISH"			63	+		
08	PRA			64	2		
09	GTO 01			65	/		$\frac{L' + L_{old}}{2} \quad z_2$
10	LBL "M"			66	STO 02		
11	"METRIC"			67	RCL 03		
12	PRA			68	-		
13	9.81			69	ABS		ϵ (error
14	STO 06		$g(\text{metric}) \rightarrow R_{06}$	70	I		1ft or
15	LBL 01			71	X?Y?		"ance"
16	"PERIOD="			72	GTO 05		
17	PRA			73	RCL 02		
18	"PERIOD?"			74	GTO "ITERAT"		
19	PROMPT			75	LBL 05		
20	PRX			76	RCL 02		L in display
21	STO 07		$T \rightarrow R_{07}$	77	"LENGTH="		
22	X^2			78	PRA		
23	RCL 06			79	PRX		
24	*			80	STOP		
25	2			81	.END.		
26	/						
27	PI						
28	/						
29	STO 01		$L_0 \rightarrow R_{01}$				
30	"DEPTH="						
31	PRA						
32	"DEPTH?"						
33	PROMPT						
34	PRX						
35	ENTER						
36	2						
37	*						
38	PI						
39	*						
40	STO 05		$2\pi d \rightarrow R_{05}$				
41	RCL 01						
42	LBL "ITERAT"						
43	STO 03		$L_{old} \rightarrow R_{03}$				
44	1/X						
45	PCL 05						
46	*						
47	STO 04						
48	ETX						
49	PCL 04						
50	CHS						
51	ETX						
52	-						
53	PCL 04						
54	ETX						
55	PCL 04						
56	CHS						

100R-41CV-3

* THESE STEPS MUST BE DELETED IF NO PRINTER IS AVAILABLE

Program Description

Program Title	101R-41CV Calculation of Wave Parameters from Linear Theory (RPN Logic)		
Name	T.L. Walton, Jr.		1/82
Address	Coastal Engineering Research Center		
City	Kingman Building	State	Zip Code
	Fort Belvoir,	Virginia	22060

Program Description, Equations, Variables, etc.

This program calculates the product of the wave number and depth, kd , the ratio of group wave speed to wave celerity, $n = 0.5 (1+2kd/\sinh 2kd)$, the group wave speed, C_g , the shoaling coefficient, K_s , the refraction coefficient, K_r , horizontal orbital velocity, u , and vertical orbital velocity, w .

Program input includes wave period, T , deepwater wave angle, α_0 , deepwater wave height, H_0 , wave phase angle, θ , depth of water, d , at which results are desired, and depth from surface, z , at which velocities are calculated. This program assumes straight and parallel offshore bottom contours for assumption of Snell's law of refraction. Algorithm uses English or metric system of units.

REFERENCE

U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, *Shore Protection Manual*, 3d ed., Vol. I, Ch. 2, Stock No. 008-022-00113-1, U.S. Government Printing Office, Washington, D.C., 1977.

Operating Limits and Warnings

If printer is not used, R/S must be inserted where output values are desired (i.e., where printer output steps are deleted).

101R-41CV-1

User Instructions

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
	TO COMPUTE IN METRIC UNITS:			
2a	PRESS GTO "M"		GTO "M"	
	STEPS 3a-17a ARE THE SAME AS			
	STEPS 3-17 EXCEPT			
	INPUT H_0, z IN METERS			
	OUTPUT H (meters)			
	C_g, U, W IN METERS/SEC			
	EXAMPLES 1 and 1a:			
	$T=8$ SEC, $d=50$ ft (15.244m), $\alpha_0=30^\circ$			
	$H_0=18$ ft (5.4878m), $z=-15$ ft (-4.5732m), $\theta=60^\circ$			
	PRINTOUTS:			
	ENGLISH		METRIC	
	PERIOD=	_____	PERIOD=	_____
	8.0000 ***		8.0000 ***	
	DEPTH=	_____	DEPTH=	_____
	50.0000 ***		15.2440 ***	
	$W_0=$	_____	$W_0=$	_____
	30.0000 ***		30.0000 ***	
	$H_0=$	_____	$H_0=$	_____
	18.0000 ***		5.4878 ***	
	$z=$	_____	$z=$	_____
	-15.0000 ***		-4.5732 ***	
	PHASE=	_____	PHASE=	_____
	60.0000 ***		60.0000 ***	
	$KD=$	_____	$KD=$	_____
	1.1631 ***		1.1600 ***	
	$N=$	_____	$N=$	_____
	0.7294 ***		0.7302 ***	
	$CG=$	_____	$CG=$	_____
	24.6248 ***		7.5367 ***	
	$KS=$	_____	$KS=$	_____
	0.9124 ***		0.9103 ***	
	$VP=$	_____	$KR=$	_____
	0.9748 ***		0.9752 ***	
	$H=$	_____	$H=$	_____
	16.0095 ***		4.8716 ***	
	$U=$	_____	$U=$	_____
	2.9437 ***		0.5000 ***	
	$W=$	_____	$W=$	_____
	2.4258 ***		1.0465 ***	

101R-41CV-3

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
01	LBL "LINEAR"			56	STO 15		$\theta \rightarrow R_{15}$
02	"E OR M?"			57	LBL "MAIN"		
03	PROMPT			58	XEQ 00		
04	LBL E			59	2		
05	32.2			60	*		
06	STO 14		$g(\text{English}) \rightarrow R_M$	61	STO 11		$g\theta/L \rightarrow R_{11}$
07	"ENGLISH"			62	XEQ 01		
08	PRA			63	1/X		
09	GTO 03			64	RCL 11		
10	LBL "M"			65	*		
11	"METRIC"			66	1		
12	PRA			67	+		
13	9.81			68	2		
14	STO 14		$g(\text{Metric}) \rightarrow R_M$	69	/		
15	LBL 03			70	"M="		$n \rightarrow R_x$
16	"PERIOD?"			71	PRA		
17	PROMPT			72	PRX		
18	"PERIOD="			73	STO 11		$n \rightarrow R_{11}$
19	PRA			74	RCL 04		
20	PRX			75	*		
21	STO 02		$T \rightarrow R_{02}$	76	RCL 02		
22	"DEPTH?"			77	/		
23	PROMPT			78	"CG="		$C_g \rightarrow R_x$
24	"DEPTH="			79	PRA		
25	PRA			80	PRX		
26	PRX			81	1/X		
27	PI			82	RCL 02		
28	*			83	*		
29	2			84	RCL 14		
30	*			85	*		
31	STO 01		$2\theta d \rightarrow R_{01}$	86	4		
32	"AD?"			87	/		
33	PROMPT			88	PI		
34	"AD="			89	/		
35	PRA			90	SQRT		$K_s = \sqrt{C_g/c_g} \rightarrow R_x$
36	PRX			91	"KS="		
37	SIN			92	PRA		
38	STO 00		$\sin \alpha_0 \rightarrow R_{00}$	93	PRX		$K_s \rightarrow R_{11}$
39	"HO?"			94	STO 11		
40	PROMPT			95	RCL 00		
41	"HO="			96	RCL 01		
42	PRA			97	*		
43	PRX			98	RCL 03		$K_0 \sin \alpha_0$
44	STO 08		$H_0 \rightarrow R_{08}$	99	/		$\sin \alpha$
45	"Z?"			100	PCL 09		
46	PROMPT			101	/		
47	"Z="			102	X12		
48	PRA			103	1		
49	PRX			104	-		
50	STO 12		$z \rightarrow R_{12}$	105	CHS		$\cos^2 \alpha$
51	"PHASE?"			106	1/X		
52	PROMPT			107	1		
53	"PHASE="			108	ENTER↑		
54	PRA			109	RCL 00		
55	PRX			110	X12		
				111	-		

*DELETE THESE LINES IF A PRINTER IS NOT AVAILABLE. 101R-41CV-4
 ALSO SEE 'OPERATING LIMITS AND WARNINGS' ON PAGE 101R-41CV-1.

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
112 *				* 168 "H="			$w \rightarrow R_x$
113 SORT				* 169 PRA			
114 SORT				* 170 PRX			
115 STO 10			$K_f \rightarrow R_{10}$	171 RTN			
* 116 "KR="				172*LBL 00			"kd" subroutine
* 117 PRA			$K_f \rightarrow R_x$	173 RCL 02			lines 172-218
* 118 PRX				174 *P2			
119 RCL 08				175 RCL 14			
120 RCL 10				176 *			
121 *				177 2			
122 RCL 11				178 /			
123 *				179 P1			
* 124 "H="			$H \rightarrow R_x$	180 /			
* 125 PRA				181 STO 03			$L_0 \rightarrow R_{03}$
* 126 PRX				182*LBL "ITERAT"			
127 RCL 14				183 STO 11			$L_{old} \rightarrow R_{11}$
128 *				184 1/X			
129 PCL 02				185 PCL 01			
130 *				186 *			
131 2				187 STO 13			$\frac{2\pi d}{L} \rightarrow R_{13}$
132 /				188 XEQ 02			L_{old}
133 RCL 04				189 STO 06			$\cosh(R_{13}) \rightarrow R_{06}$
134 /				190 RCL 13			
135 PCL 06				191 XEQ 01			$\sinh(R_{13}) \rightarrow R_{05}$
136 /				192 STO 05			
137 STO 08			$\frac{H \pi}{L} \frac{1}{\cosh(\frac{2\pi d}{L})} \rightarrow R_{08}$	193 RCL 06			
138 PCL 01				194 /			
139 2				195 PCL 03			
140 /				196 *			
141 P1				197 PCL 11			
142 /				198 +			
143 RCL 12				199 2			
144 +				200 /			$L' \rightarrow R_{04}$
145 2				201 STO 04			
146 *				202 RCL 11			
147 P1				203 -			
148 *				204 ABS			
149 RCL 04				205 1			
150 /				206 XYY?			
151 STO 05			$\frac{2\pi(z+d)}{L} \rightarrow R_{05}$	207 GTO 25			
152 XEQ 02				208 RCL 04			
153 RCL 08				209 GTO "ITERAT"			
154 *				210*LBL 25			
155 PCL 15				211 RCL 01			
156 COS				212 RCL 04			
157 *				213 /			
* 158 "U="				214 STO 09			$kd \rightarrow R_{09}$
* 159 PRA				* 215 "KR="			$kd \rightarrow R_x$
* 160 PRX				* 216 PRA			
161 PCL 05				* 217 PRX			
162 XEQ 01				218 RTN			
163 RCL 09				219*LBL 01			subroutine
164 *				220 STO 07			$\sinh(\)$ lines
165 PCL 15				221 EYX			219-228
166 SIN				222 RCL 07			
167 *				223 CHS			

* DELETE THESE LINES IF A PRINTER IS NOT AVAILABLE. 101R-41CV-5
 ALSO SEE 'OPERATING LIMITS AND WARNINGS' ON PAGE 101R-41CV-1.

Program Description

Program Title	102R-41CV Linear Wave Approximation to Breaking Wave Height and Breaking Wave Angle (RPN Logic)		
Name	T.L. Walton, Jr.	Date	1/82
Address	Coastal Engineering Research Center		
City	Kingman Building	State	Virginia
	Fort Belvoir,	Zip Code	22060
Program Description, Equations, Variables, etc.			
<p>This program calculates breaking wave height, H_b, and breaking wave angle, α_b, using linear wave theory approximations combined with the shallow-water breaking assumption. Input parameters are wave height, H, wave period, T, wave angle, α, and the water depth, d, where the preceding three variables are measured. An additional input parameter is nearshore beach slope, m. The ratio of the breaking wave height to the water depth at breaking is predicted using the equation</p>			
$\kappa = H_b/d_b = 1.16 \left(\frac{m}{\sqrt{H'_0/L_0}} \right)^{0.22}$			
<p>from Singamsetti and Wind (1980), where d_b is the water depth at breaking, H'_0 the deepwater wave height, and L_0 the deepwater wavelength. This solution requires the assumption of straight and parallel offshore bottom contours for the application of Snell's law of refraction. Input wave parameters H, T, and α can be in any depth of water, d. Algorithm uses English or metric system of units. The development of the equation is derived on the attached solution sheet.</p>			
REFERENCES			
<p>SINGAMSETTI, S.R., and WIND, H.G., "Characteristics of Shoaling and Breaking Periodic Waves Normally Incident to Plane Beaches of Constant Slope," Report No. M1371, Toegepast Onberzoek Waterstaat, July 1980.</p>			
<p>U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, <i>Shore Protection Manual</i>, 3d ed., Vol. I, Ch. 2, Stock No. 008-022-00113-1, U.S. Government Printing Office, Washington, D.C., 1977.</p>			
Operating Limits and Warnings			

102R-41CV-1

SOLUTION SHEET FOR PROGRAM 102R-41CV

Development of the equation:

From conservations of energy

$$\frac{\gamma H^2}{8} C_g \cos \alpha = \frac{\gamma H_i^2}{8} C_{gi} \cos \alpha_i \quad (1)$$

where the subscript i indicates incident wave parameters.

If left-hand side of above equation represents conditions at breaking then

$$C_g = C = C_b \approx \sqrt{gd_b} = \sqrt{gH_b/\kappa} \quad (2)$$

where

$$\kappa = \frac{H_b}{d_b} \quad (3)$$

Now assume

$$\kappa = 1.16 \left(\frac{m}{\sqrt{H'_0}/L_0} \right)^{0.22} \quad (4)$$

where H'_0 is unrefracted deepwater wave height.

Using (1), (2), (3), and (4) it can be found

$$H_b = \left\{ \left(\frac{\kappa}{g} \right)^{1/2} H_i^2 C_{gi} \cos \alpha_i \right\}^{2/5} \quad (5)$$

From Snell's law of refraction

$$\frac{\sin \alpha_b}{C_b} = \frac{\sin \alpha_i}{C_i} \quad (6)$$

therefore,

$$\sin \alpha_b = \left(\frac{\sin \alpha_i}{C_i} \right) \left\{ \left(\frac{g}{\kappa} H_b \right)^{1/2} \right\} \quad (7)$$

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
01	LBL	"ANGLE"		57	/		
02	"E OR M?"			58	STO 03		$L_0 \rightarrow R_{03}$
03	PROMPT			59	LBL "ITERAT"		
04	LBL	E		60	STO 11		$L_{old} \rightarrow R_{11}$
05	32.2			61	1/X		
06	STO 14			62	RCL 12		
07	"ENGLISH"		$g(\text{English}) \rightarrow R_{14}$	63	*		
08	PRA			64	STO 13		$\frac{2\pi d}{L_{old}} \rightarrow R_{13}$
09	GTO 01			65	XEQ 02		$\cosh(R_{13}) \rightarrow R_{06}$
10	LBL	"M"		66	STO 06		
11	"METRIC"			67	RCL 13		
12	PPA			68	XEQ 03		$\sinh(R_{13}) \rightarrow R_{05}$
13	3.21			69	STO 05		
14	STO 14		$g(\text{metric}) \rightarrow R_{14}$	70	RCL 06		
15	LBL	01		71	/		
16	"SLOPE="			72	RCL 03		
17	PRA			73	*		
18	"SLOPE?"			74	RCL 11		
19	PROMPT			75	+		
20	PRX		$m \rightarrow R_{15}$	76	2		
21	STO 15			77	/		
22	"DEPTH="			78	STO 04		
23	PRA			79	RCL 11		
24	"DEPTH?"			80	-		
25	PROMPT			81	ABS		
26	PRX		$d \rightarrow R_{01}$	82	!		
27	STO 01			83	X/Y?		
28	P1			84	GTO 13		
29	*			85	RCL 04		
30	2			86	GTO "ITERAT"		
31	*			87	LBL 13		
32	STO 12		$2\pi d \rightarrow R_{12}$	88	RCL 12		
33	"ANGLE="			89	RCL 04		
34	PPA			90	/		
35	"ANGLE?"			91	STO 09		$k_d \rightarrow R_{09}$
36	PROMPT			92	"KD="		$\rightarrow \text{display}$
37	PRX			93	PRA		
38	STO 00			94	PRX		
39	"M="			95	STOP		
40	PRA			96	2		
41	"M?"			97	*		
42	PROMPT			98	STO 11		$2k_d \rightarrow R_{11}$
43	PRX			99	XEQ 03		
44	STO 08		$H \rightarrow R_{08}$	100	1/X		
45	"PERIOD="			101	RCL 11		
46	PPA			102	*		
47	"PERIOD?"			103	!		
48	PROMPT			104	+		
49	PRX		$T \rightarrow R_{02}$	105	2		
50	STO 02			106	/		
51	Y1			107	STO 01		$n \rightarrow R_{01}$
52	RCL 14			108	"N="		$\rightarrow \text{display}$
53	*			109	PRA		
54	2			110	PRX		
55	/			111	STOP		
56	01			112	RCL 04		

* DELETE THESE STEPS IF A PRINTER IS NOT AVAILABLE. 102R-41CV-5

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	*			*169	"HB="		H_b in display
114	RCL 02			*170	PRA		
115	/			*171	PRX		
116	STO 04		$C_g \rightarrow R_{0g}$ \rightarrow display	172	STOP		
*117	"CG="			173	RCL 06		
*118	PRA			174	1/X		
*119	PRX			175	*		
120	STOP			176	SQRT		
121	1/X			177	RCL 00		
122	PCL 02			178	SIN		
123	*			179	*		
124	RCL 14			180	RCL 04		
125	*			181	/		
126	4			182	RCL 01		
127	/			183	*		
128	PI			184	ASIN		α_b in display
129	/			*185	"AB="		
130	SQRT			*186	PRA		
131	STO 11		$K_s \rightarrow R_{11}$ \rightarrow display	*187	PRX		
*132	"KS="			188	STOP		
*133	PRA			189	RTN		sinh () subroutine
*134	PRX			190	*LBL 03		
135	STOP			191	STO 07		
136	RCL 08			192	E+X		
137	RCL 11		H_o' in display	193	RCL 07		
138	/			194	CHS		
*139	"HOKR="			195	E+X		
*140	PRA			196	-		
*141	PRX			197	2		
142	STOP			198	/		
143	RCL 03			199	RTN		cosh () subroutine
144	/			200	*LBL 02		
145	SQRT			201	STO 07		
146	PCL 15			202	E+X		
147	/			203	RCL 07		
148	1/X			204	CHS		
149	.22			205	E+X		
150	Y+X			206	+		
151	1.16			207	2		
152	*			208	/		
153	RCL 14			209	.END.		
154	/						
155	STO 06						
156	RCL 08						
157	X+2						
158	RCL 04						
159	*						
160	RCL 00						
161	COS						
162	*						
163	.4						
164	Y+X						
165	RCL 06						
166	.2						
167	Y+X						
168	*						

* DELETE THESE STEPS IF A PRINTER IS NOT AVAILABLE.

102R-41CV-6

Program Description

Program Title	103R-41C Shallow-Water Wave Forecasting Equations (RPN Logic)		
Name	T.L. Walton, Jr.	Date	1/82
Address	Coastal Engineering Research Center		
	Kingman Building		
City	Fort Belvoir,	State	Virginia
		Zip Code	22060
Program Description, Equations, Variables, etc.			
<p>This algorithm computes the wave height, H, wave period, T, and minimum duration, t, from input values of the water depth, d, fetch length, F, and adjusted windspeed, U_A, using equations (1), (2), and (3) of CETN-I-6. Equations (1) and (2) are for constant water depth and unlimited wind duration and have been revised from equations (3-25) and (3-26) of the Shore Protection Manual. Wave height and period in this algorithm are significant wave height and period. Algorithm uses English or metric system of units.</p>			
REFERENCES			
U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, <i>Shore Protection Manual</i> , 3d ed., Vols. I, II, and III, Stock No. 008-022-00113-1, U.S. Government Printing Office, Washington, D.C., 1977, 1,262 pp.			
U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, "Method for Determining Adjusted Windspeed, U_A , for Wave Forecasting," CETN-I-5, Fort Belvoir, Va., 1981.			
U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, "Revised Method for Wave Forecasting in Shallow Water," CETN-I-6, Fort Belvoir, Va., 1981.			
U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, "Revised Method for Wave Forecasting in Deep Water," CETN-I-7, Fort Belvoir, Va., 1981.			
Operating Limits and Warnings			
If a printer is not used, R/S must be inserted where output values are desired (i.e., where printer output steps are deleted).			

103R-41CV-1

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
01	*LBL "FOCAST"			57	RCL 05		
02	*E OF M ?			58	*		
03	PROMPT			59	STO 01		$gF/U_A^2 \rightarrow R_{01}$
04	*LBL E			60	RCL 00		
05	32.2			61	.75		
06	STO 09		$g(\text{English}) \rightarrow R_{09}$	62	YXX		
07	1.47		English Conversion	63	.53		
08	STO 07		$\rightarrow R_{07}$	64	*		
09	5200		English Conversion	65	XEQ 03		$\tanh\left[.53\left(\frac{gd}{U_A^2}\right)^{0.75}\right]$
10	STO 01		$\rightarrow R_{01}$	66	STO 04		
11	*"ENGLISH"			67	RCL 01		$\rightarrow R_{01}$
12	PRX			68	SQRT		
13	STO 01			69	.00565		
14	*LBL "M"			70	*		
15	*"METRIC"			71	RCL 04		
16	PRX			72	/		
17	9.81			73	XEQ 03		$\tanh\left[\frac{.00565(gF)}{R_{01}}\left(\frac{gF}{U_A^2}\right)^{0.5}\right]$
18	STO 09		$g(\text{Metric}) \rightarrow R_{09}$	74	RCL 04		
19	.2772		metric conversion	75	*		
20	STO 07		$\rightarrow R_{01}$	76	.283		
21	1000		Metric Conversion	77	*		
22	STO 01		$\rightarrow R_{01}$	78	RCL 08		
23	*LBL 01			79	/		
24	"UA"			80	"H"		
25	PROMPT			81	PRX		
26	"UA"			82	PRX		
27	PRX			83	RCL 00		
28	PRX			84	.375		
29	STO 03		$U_A \rightarrow R_{03}$	85	YXX		
30	"FETCH"			86	.833		
31	PROMPT			87	*		
32	"FETCH"			88	XEQ 03		$\tanh\left[0.833\left(\frac{gd}{U_A^2}\right)^{0.75}\right]$
33	PRX			89	STO 04		
34	PRX			90	RCL 01		$\rightarrow R_{01}$
35	STO 05		$F \rightarrow R_{05}$	91	.333		
36	"DEPTH"			92	YXX		
37	PROMPT			93	.0379		
38	"DEPTH"			94	*		
39	PRX			95	RCL 04		
40	PRX			96	/		
41	STO 06		$d \rightarrow R_{06}$	97	XEQ 03		$\tanh\left[\frac{0.0379(gF)}{R_{01}}\left(\frac{gF}{U_A^2}\right)^{0.333}\right]$
42	RCL 03			98	RCL 04		
43	RCL 07			99	*		
44	*			100	7.54		
45	STO 07		converted $U_A \rightarrow R_{01}$	101	*		
46	RCL 09			102	RCL 08		
47	RCL 07			103	/		
48	X*2			104	RCL 07		
49	/			105	/		
50	STO 02		$g/U_A^2 \rightarrow R_{02}$	106	"T"		
51	RCL 06			107	PRX		
52	*			108	PRX		
53	STO 00		$gd/U_A^2 \rightarrow R_{00}$	109	RCL 09		
54	RCL 08			110	*		
55	RCL 01			111	RCL 07		
56	*			112	*		

*DELETE IF PRINTER IS NOT AVAILABLE
 ALSO SEE 'operating Limits and Warnings' on p. 103R-41CV-1

103R-41CV-4

Program Description

Program Title	104R-41CV Depth-Limited Design Breaking Wave Height at Structure (RPN Logic)		
Name	T.L. Walton, Jr.	Date	1/82
Address	Coastal Engineering Research Center		
City	Kingman Building	State	Virginia
	Fort Belvoir,	Zip Code	22060

Program Description, Equations, Variables, etc.

This algorithm computes the depth-limited breaking wave height at a structure for design purposes. It can be used in lieu of Figure 7-4 of the Shore Protection Manual. The equation for the curves in Figure 7-4 is not given in the SPM but can be found by simultaneous solution of SPM equations (2-91), (2-92), (2-93), (7-3), and (7-4). Input is wave period, T , and water depth at the structure toe, d_s . The development of the equation is derived on the attached solution sheet. Algorithm uses English or metric system of units.

REFERENCE

U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, *Shore Protection Manual*, 3d ed., Vols. I and II, Chs. 2 and 7, Stock No. 008-022-00113-1, U.S. Government Printing Office, Washington, D.C., 1977.

Operating Limits and Warnings

104R-41CV-1

SOLUTION SHEET FOR PROGRAM 104R-41CV

The following equations are given in the Shore Protection Manual:

$$\frac{d_b}{H_b} = \frac{1}{b - (aH_b/gT^2)} \quad (2-91)$$

$$a = 43.75(1 - e^{-1.9m}) \quad (2-92)$$

$$b = \frac{1.56}{(1 + e^{-19.5m})} \quad (2-93)$$

$$x_p = \tau_p H_b = (4.0 - 9.25 m) H_b \quad (7-3)$$

$$H_b = \frac{d_s}{\beta - m\tau_p} \quad (7-4)$$

Equation (7-4) can be rewritten in dimensionless form as:

$$\hat{H}_b = \frac{\hat{d}_s}{[(b - a\hat{H}_b)^{-1} - m\tau_p]}$$

where

$$\hat{H}_b = H_b/gT^2 \text{ and } \hat{d}_s = d_s/gT^2$$

The above equation can then be solved via the quadratic formula for \hat{H}_b in terms of \hat{d}_s , τ_p , m , a , and b where the positive root provides useful results.

$$\hat{H}_b = \left\{ (m\tau_p b - a\hat{d}_s - 1) + \left[(m\tau_p b - a\hat{d}_s - 1)^2 + 4am\tau_p b\hat{d}_s \right]^{1/2} \right\} (2am\tau_p)^{-1}$$

This is the equation used in the program for design breaking wave height.

104R-41CV-2

User Instructions

104R-41CV DEPTH-LIMITED DESIGN BREAKING
WAVE HEIGHT AT STRUCTURE (RPN LOGIC)

SIZE: 021

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	LOAD PROGRAM (HB)		[XEQ] "HB"	E OR M?
	TO CALCULATE H_b IN ENGLISH UNITS:			
2	PRESS GTO "E"		GTO "E"	
3	PRESS R/S		[R/S]	SLOPE?
4	ENTER SLOPE m , PRESS R/S	m	[R/S]	DEPTH?
5	ENTER DEPTH D , PRESS R/S	$d(ft)$	[R/S]	PERIOD?
6	ENTER PERIOD T , PRESS R/S	$T(sec)$	[R/S]	
7	READ H_b IN FEET			$H_b(ft)$
	TO CALCULATE H_b IN METRIC UNITS:			
2a	PRESS GTO "M"		GTO "M"	
3a	PRESS R/S		[R/S]	SLOPE?
4a	ENTER SLOPE m , PRESS R/S	m	[R/S]	DEPTH?
5a	ENTER DEPTH D , PRESS R/S	$d(meters)$	[R/S]	PERIOD?
6a	ENTER PERIOD T , PRESS R/S	$T(sec)$	[R/S]	
7a	READ H_b IN METERS			$H_b(meters)$
	Example 1 and 1a			
	$m = 0.10$, $d = 10ft (3.05m)$, $T = 10sec$			
	ENGLISH PRINTOUT:		METRIC PRINTOUT:	
	ENGLISH		METRIC	
	SLOPE=		SLOPE=	
	0.1000 ***		0.1000 ***	
	DEPTH=		DEPTH=	
	10.0000 ***		3.0500 ***	
	PERIOD=		PERIOD=	
	10.0000 ***		10.0000 ***	
	H_b =		H_b =	
	17.9818 ***		5.4631 ***	
				note: " = [ALPHA]

104R-41CV-3

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
01	LBL "H"			57	1		
02	"E OR M ?"			58	+		
03	PROMPT			59	1.56		
04	LBL E			60	/		
05	32.2		$g(\text{English}) \rightarrow R_{08}$	61	1/X		
06	STO 08			62	STO 04		
07	"ENGLISH"			63	RCL 00		
08	PRA			64	ENTER↑		
09	GTO 01			65	9.25		
10	LBL "M"			66	*		
11	"METRIC"			67	4		
12	PRA			68	-		
13	9.81		$g(\text{Metric}) \rightarrow R_{08}$	69	CMS		
14	STO 08			70	RCL 00		
15	LBL 01			71	*		
16	"SLOPE="			72	STO 05		$m_j p = m(4 - 9.25m)$
17	PRA			73	RCL 04		$\rightarrow R_{05}$
18	"SLOPE?"			74	*		
19	PROMPT			75	!		
20	PRX			76	-		
21	STO 00		$m \rightarrow R_{00}$	77	RCL 01		
22	"DEPTH="			78	RCL 03		
23	PRA			79	*		
24	"DEPTH?"			80	-		
25	PROMPT			81	STO 06		$m_j p b - a \hat{d}_s - 1$
26	PRX			82	X↑2		$\rightarrow R_{06}$
27	STO 07		$d_s \rightarrow R_{07}$	83	4		
28	"PERIOD="			84	RCL 03		
29	PRA			85	*		
30	"PERIOD?"			86	RCL 04		
31	PROMPT			87	*		
32	PRX			88	RCL 05		
33	STO 09		$T \rightarrow R_{09}$	89	*		
34	"?"			90	RCL 01		
35	RCL 08			91	*		
36	*			92	+		
37	1/X			93	SQRT		
38	RCL 07			94	RCL 06		
39	*			95	+		
40	STO 01		$\frac{d_s}{gT^2} \rightarrow R_{01}$	96	2		
41	RCL 00			97	/		
42	19			98	RCL 03		
43	*			99	/		
44	CMS			100	RCL 05		
45	E↑X			101	/		
46	CMS			102	RCL 01		
47	1			103	/		
48	+			104	RCL 07		
49	43.75			105	*		
50	*			106	"H="		H_b in display
51	STO 07		$43.75(1 - e^{-19m}) \rightarrow R_{03}$	107	PRA		
52	RCL 00			108	PRX		
53	19.5			109	STOP		
54	*			110	.END.		
55	CMS						
56	E↑X						

* THESE STEPS MUST BE DELETED IF NO PRINTER IS AVAILABLE 101R-41CV-4

Program Description

Program Title	105R-41CV Wave Transmission - Fuchs' Equation (RPN Logic)	
Name	T.L. Walton, Jr.	Date 1/82
Address	Coastal Engineering Research Center	
City	Kingman Building	State Virginia
	Fort Belvoir,	Zip Code 22060
Program Description, Equations, Variables, etc.		
This algorithm computes wavelength, L, in water depth, d, given the wave period, T. The program then computes wave transmission over a thin vertical barrier in water depth, d, using Fuchs' equation:		
$\frac{H_t}{H_i} = \sqrt{1 - \frac{\frac{4\pi h}{L} + \sinh \frac{4\pi h}{L}}{\frac{4\pi d}{L} + \sinh \frac{4\pi d}{L}}}$		
where H_t is the transmitted wave height, H_i the incident wave height, and h the height of barrier. Note that this equation <i>cannot</i> be used when wave transmission is by overtopping of a structure. Algorithm uses English or metric system of units.		
REFERENCE		
U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, <i>Shore Protection Manual</i> , 3d ed., Vol. II, Ch. 7, Stock No. 008-022-00113-1, U.S. Government Printing Office, Washington, D.C., 1977, p. 7-62.		
Operating Limits and Warnings		

105R-41CV-1

User Instructions

105R-41CV WAVE TRANSMISSION - FUCHS' EQUATION (RPN logic)

SIZE: 021

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	LOAD PROGRAM (FUCH)		[XEQ] "FUCH"	
	TO CALCULATE IN ENGLISH UNITS:			
2	PRESS GTO "E"		GTO "E"	
3	PRESS R/S		[R/S]	DEPTH?
4	ENTER DEPTH D, PRESS R/S	d (ft.)	[R/S]	SIL HT?
5	ENTER SILL HEIGHT H, PRESS R/S	h (ft)	[R/S]	PERIOD?
6	ENTER PERIOD T, PRESS R/S	T (sec)	[R/S]	
7	READ $K_t = H_t/H_i$ (TRANSMISSION COEFFICIENT)			K_t
	TO CALCULATE IN METRIC UNITS:			
2a	PRESS GTO "M"		GTO "M"	
	STEPS 3a-7a ARE THE SAME AS STEPS 3-7 ABOVE EXCEPT			
	INPUT d, h, IN METERS			
	OUTPUT L (PRINTER ONLY) METERS			
	Example 1 and 1a:			
	Values used: d=15ft (4.5732m), h=10ft (3.0480m), T=10sec			
	PRINTOUTS:			
	ENGLISH DEPTH=		METRIC DEPTH=	
	15.0000 ***		4.5732 ***	
	SIL HT=		SIL HT=	
	10.0000 ***		3.0480 ***	
	PERIOD=		PERIOD=	
	10.0000 ***		10.0000 ***	
	L=		L=	
	213.0230 ***		64.9450 ***	
	K_t =		K_t =	
	0.5977 ***		0.5977 ***	
	note: " = [ALPHA]			

105R-41CV-2

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
01	LBL "FUCH"			57	E*Y		
02	"E GP M ?"			58	PCL 04		
03	PROMPT			59	CHS		
04	LBL E			60	E*Y		
05	32.2			61	+		
06	STO 06		$g(\text{English}) \rightarrow R_{06}$	62	/		$\tanh\left(\frac{2\pi d}{L_{old}}\right)$
07	"ENGLISH"			63	RCL 01		
08	PRA			64	*		
09	GTO 01			65	RCL 03		
10	LBL "M"			66	+		
11	"METRIC"			67	2		
12	PRA			68	/		$L' \rightarrow R_{02}$
13	9.81			69	STO 02		
14	STO 06		$g(\text{Metric}) \rightarrow R_{06}$	70	PCL 03		
15	LBL 01			71	-		
16	"DEPTH?"			72	ABS		
17	PROMPT			73	1		
18	"DEPTH="			74	X*Y?		
19	PRA			75	GTO 13		
20	PRX			76	PCL 02		
21	2			77	GTO "ITERAT"		
22	*			78	LBL 13		
23	PI			79	RCL 02		
24	*			80	"L="		
25	STO 00		$2\pi d \rightarrow R_{00}$	81	PRA		
26	"SIL HT?"			82	PRX		
27	PROMPT			83	1/X		
28	"SIL HT="			84	RCL 00		
29	PRA			85	*		
30	PRX			86	2		
31	STO 08		$h \rightarrow R_{08}$	87	*		
32	"PERIOD?"			88	STO 06		$4\pi d/L \rightarrow R_{06}$
33	PROMPT			89	XEQ 03		
34	"PERIOD="			90	RCL 06		
35	PRA			91	+		
36	PRX			92	STO 07		$R_{06} + \sinh(R_{06}) \rightarrow R_{07}$
37	X*2			93	4		
38	RCL 06			94	ENTER		
39	*			95	PI		
40	2			96	*		
41	/			97	RCL 08		
42	PI			98	*		
43	/			99	RCL 02		
44	STO 01		$L_0 \rightarrow R_{01}$	100	/		
45	LBL "ITERAT"			101	STO 09		$\frac{4\pi h}{L} \rightarrow R_{09}$
46	STO 03		$L_{old} \rightarrow R_{03}$	102	XEQ 03		
47	1/X			103	RCL 09		
48	PCL 00			104	+		
49	*			105	RCL 07		
50	STO 04		$\frac{2\pi d}{L_{old}} \rightarrow R_{04}$	106	/		
51	E*Y			107	CHS		
52	PCL 04			108	1		
53	CHS			109	+		
54	E*Y			110	SQRT		$H_t/H_c = K_t$ in display
55	-			111	"KT="		
56	PCL 04			112	PRA		
				113	PRX		

* THESE LINES MUST BE DELETED IF A PRINTER IS NOT AVAILABLE. 10SR-41CV-3

APPENDIX
BLANK PROGRAM FORMS

Program Description

Program Title		
Name		Date
Address		
City	State	Zip Code
Program Description, Equations, Variables, etc.		
Operating Limits and Warnings		

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001							
				060			
010							
				070			
020							
				080			
030							
				090			
040							
				100			
050							
				110			

Walton, Todd L.
Hand-held calculator algorithms for coastal engineering (second series) / by Todd L. Walton, Jr.--Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center ; Springfield, Va. : available from NTIS, 1982.
[41] p. : 27 cm.--(Coastal engineering technical aid ; no. 82-4)
Cover title.

"November 1982."
This report provides algorithms for a number of calculator programs useful in performing coastal engineering calculations, primarily in the area of wave transformations and wave generation. Six programs are included for use with HP41CV hand-held calculators which employ the Reverse Polish Notation (RPN). These programs can be used to compute linear wave parameters, orbital velocities, breaking wave height and direction, shallow-water wave forecasts, depth-limited breaking wave height, and wave transmission past a vertical barrier.
1. Calculator algorithms. 2. Coastal engineering. 3. Wave generation. 4. Wave transformation. 1. Title. II. Series.
.U581ta
no. 82-4
627
TC203

Walton, Todd L.
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