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Field Notes

Selected Programs for Hand Calculators in Civil Engineering

Abandoned Strip Mine Reclamation

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EDITOR'S NOTE

This issue introduces some format changes to Field Notes. First, we are now using the Courier type style; this larger, more open type will make this and following issues easier to read. We also are using larger paper; Government agencies now have the option of using the commercial 8½ x 11-inch paper size for their publications.

Gordon L. Rome
Editor

SELECTED PROGRAMS FOR HAND CALCULATORS IN CIVIL ENGINEERING

Bernhold Rankenberg
Region 5

There are times when it is not practical to use the Regional Computer Center or mini-computers in Civil Engineering, although the recurring nature of some problems (those consisting of a series of arithmetic calculations) makes them amenable to a programmed solution. Use of hand-held programmable calculators, such as those found in most National Forest Engineering Offices, provides the necessary alternative method.

The programs presented here are written for calculators that use algebraic notation, such as Texas Instruments' Model SR-52. Programs usually can be stored on magnetic cards to eliminate the necessity of keying-in the program each time it is used. Without magnetic cards, the keying-in process would be necessary. This not only is tedious for the longer programs, but the keying-in process is -- in itself -- a prime source for introducing errors.

PROGRAM EXAMPLES

Program A: Three-Axle Truck on Simple Beam. This program will calculate maximum moments and shear at any point in a simple beam loaded with a 3-axle truck having axles 14 feet (4.27m) apart. The truck loads are AASHTO HS loads.

The usual procedure is to select a maximum moment from AASHTO's *Standard Specifications for Highway Bridges* for a given span; then the moment curve is calculated, using the assumption that it is parabolic. That assumption is erroneous, however. The moment for a 40-ft. (12.19m) span, for example, is approximately 6 percent low at the 1/4 point, using the parabolic assumption. The error increases for longer spans; an 80-ft. (24.38m) span has a 20 percent error. This program will not work for off-highway loads or for spans of less than 14 ft. (4.27m).

The moments are based on the shear diagram for the area under the rear axle of the truck. The center moment however, is calculated by placing the center of the span equidistant from the resultant of all axle loads and the nearest axle. It is likely that the area calculation procedure used in this program could be used as well on a moment diagram to calculate deflection by the conjugate beam method.

The shears given produce a shear envelope of maximum and minimum shears for a moving load; they are given until x in Program A is 14 ft. (4.27m) from *Ra*.

Program B: Moment Distribution. This program will calculate moments in the structure shown. The user must provide fixed-end moments and distribution factors for each joint. The carry-over factor is assumed to be 0.5; therefore, the sections must be uniform. The end joints can be assumed to be completely fixed, or pin-connected, or nonexistent, i.e., a structure with cantilever ends.

This program probably could be adapted to problems in sidesway and temperature expansion. It can be applied to haunched members by going into the program and substituting an appropriate carry-over factor other than 0.5.

Although the operations involved are simple and repetitious, they must be made in a specific sequence and the results must go to a specific location. With eight moments to manipulate, the program is a long one that requires 218 steps.

Program C: Moment of Inertia. This program will calculate the moment of inertia of an "I" section; one or more of the flanges can be eliminated and the program will still work.

This program is especially useful in calculating the moment of inertia of composite sections. To do so, use the given thickness of flange and slab, but calculate an equivalent width for the composite slab and flange using an appropriate N value. The program also is helpful in the conjugate beam method for calculating deflections. As shown in the exhibits, the program produces other data, including the distance of the center of gravity from the bottom flange.

Program D: Mannings Equation. This program solves the Equation 7-36 shown in *King's Handbook (5th. Edition)*, pages 7-13. The solution is by trial and error, but converges rapidly; generally, two or three trials are adequate, depending on the accuracy desired. After the proper depth is calculated to produce a given Q, pressing the RUN button will calculate velocity in fee per second.

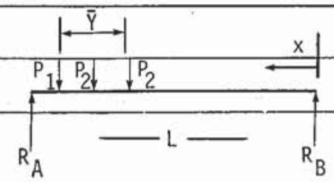
This program might be improved by manipulating the equation to derive D as a function of Q, thereby calculating D directly, rather than using a trial-and-error method. However, since X and Y are defined in terms of D, the small increase in convenience does not seem to justify the effort.

EXHIBIT A

TITLE Truck (3 Axle) on Simple Span PAGE 1 OF 3

◀A◀				

◀B◀				



STEP	PROCEDURE	ENTER	PRESS			DISPLAY
		P_1	STO	02		
		P_2	STO	03		
		L	STO	06		
		X	A			Mx
			RCL			$V_{MAX} = R_B = V_X$
	ASSUMPTIONS:		RCL	05		RA
	1. ∠ ≥14' (4.27m)		RCL	04		$M_{(MAX)}$
	2. $\bar{Y}$ = 18.67' (5.69m)		B			

TITLE Truck (3 Axle) on Simple Span PAGE 2 OF 3
PROGRAMMER DATE

LOC	CODE	KEY	COMMENTS
000 112		*LBL	
		A	
		STO	
		0	
		1	
005 117		RCL	
		0	
		6	
		-	
		RCL	
010 122		0	
		1	
		-	
		2	
		8	
015 127		=	
		INV	
		if Pos	
		D	
		RCL	
020 132		0	
		2	
		X	
		)	
		RCL	
025 137		0	
		1	
		+	
		2	
		8	
030 142		)	
		+	
		RCL	
		0	
		3	
035 147		X	
		(	
		2	

LOC	CODE	KEY	COMMENTS
		X	
		RCL	
040 152		0	
		1	
		+	
		1	
		4	
045 157		)	
		)	
		÷	
		RCL	
		0	
050 162		6	
		=	
		STO	
		0	R_A
		4	
055 167		C	
		RCL	
		0	
		5	
		X	
060 172		RCL	
		0	
		1	
		=	
		HLT	
065 177		LBL	
		B	
		RCL	
		0	
		3	
070 182		X	
		(	
		RCL	
		0	
		6	
075 187		-	

LOC	CODE	KEY	COMMENTS
		9	
		.	
		3	
		4	
080 192		)	
		+	
		RCL	
		0	
		2	
085 197		X	
		(	
		RCL	
		0	
		6	
090 202		÷	
		2	
		+	
		1	
		6	
095 207			
		3	
		3	
		)	
		)	
100 212		÷	
		RCL	
		0	
		6	
		=	
105 217		STO	
		0	R_A
		4	
		C	
		RCL	
110 222		0	
		5	

LABELS	
A	Main Program
B	M_{MAX}
C	$R_B = 2P_2 + P_1 - RA$
D	if $P_1 = 0$
E	
A'	
B'	
C'	
D'	
E'	

REGISTERS	
00	
01	X
02	P_1
03	P_2
04	R_A
05	R_B (VMAX)
06	L
07	
08	
09	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	

FLAGS	
0	
1	
2	
3	
4	

TITLE Truck (3 Axle) on Simple Span PAGE 3 OF 3
PROGRAMMER DATE

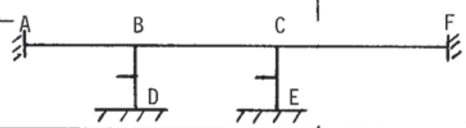
LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112		X				=				1		A
		(				STO				=		B
		RCL		040 152		0				HLT		C
		0				5						D
		6				*RTN		080 192				E
005 117		÷				LBL						A'
		2				D						B'
		+		045 157		RCL						C'
		2				0						D'
		.				3		085 197				E'
010 122		3				X						REGISTERS
		3				2						00
		)		050 162		X						01
		-				(						02
		RCL				RCL		090 202				03
015 127		0				0						04
		3				6						05
		X		055 167		-						06
		1				RCL						07
		4				0		095 207				08
020 132		=	M_{MAX}			1						09
		HLT				-						10
		LBL		060 172		7						11
		C				)						12
		RCL				÷		100 212				13
025 137		0				RCL						14
		4				0						15
		(-)		065 177		6						16
		+				=						17
		2				STO		105 217				18
030 142		X				0						19
		RCL				5						FLAGS
		0		070 182		RCL						0
		3				0						1
		+				5		110 222				2
035 147		RCL				X						3
		0				RCL						4
		2		075 187		0						

EXHIBIT B

TITLE Moment Distribution PAGE 1 OF 4

A				

B				



STEP	PROCEDURE	ENTER	PRESS			DISPLAY
	ASSUMPTIONS:					
	1. Constant Section.					
	2. JTs "A" & "F" can be any degree of fixity.					
	3. All distr. factors are entered with minus signs.					
1.		F.E.M CF	STO	02		
2.		F.E.M. CE	STO	03		
3.		F.E.M. BD	STO	04		
4.		F.E.M. FC	STO	05		
5.		F.E.M. CB	STO	08		
6.		F.E.M. BC	STO	09		
7.		F.E.M. BA	STO	10		
8.		F.E.M. AB	STO	11		
9.		Distr. factor CE	-	STO	12	
10.		Distr. factor CB	-	STO	13	
11.		Distr. factor BD	-	STO	14	
12.		Distr. factor BC	-	STO	15	
13.		Distr. factor BA	-	STO	16	
14.		Distr. factor AB	-	STO	17	
15.		Distr. factor FC	-	STO	18	

TITLE Moment Distribution PAGE 2 OF 4

◄A◄				

◄B◄				

STEP	PROCEDURE	ENTER	PRESS			DISPLAY
16.		Distr. factor CF	-	STO	19	
			A			M @ JT B
			RCL	02		MOM. CF
			RCL	03		MOM. CE
			RCL	04		MOM. BD
			RCL	05		MOM. FC
			RCL	08		MOM. CB
			RCL	09		MOM. BC
			RCL	10		MOM. BA
			RCL	11		MOM. AB
	M_{DB}=½ MBD if "D" is fixed.					
	MDB = 0 if "D" is pin-					
	connected.					

TITLE Moment Distribution PAGE 3 OF 4
PROGRAMMER DATE

LOC	CODE	KEY	COMMENTS
000 112		#LBL	
		A	
		B	
		X	
		D	D.F.BA
005 117		÷	
		2	
		=	
		SUM	
		1	FEM AB
010 122		1	
		B	
		x	
		E	DF BC
		÷	
015 127		2	
		=	
		SUM	
		0	FEM CB
		8	
020 132		B	
		X	
		D	DF BA
		=	
		STO	
025 137		0	
		6	
		B	
		X	
		E	DF BC
030 142		=	
		STO	
		0	
		7	
		B	
035 147		X	
		C'	DF BD
		=	
		SUM	
		0	FEM BD
040 152		4	
		RCL	
		0	
		6	
		=	
045 157		SUM	
		1	FEM BA
		0	
		RCL	
		0	
050 162		7	
		=	
		SUM	
		0	FEM BC
		9	
055 167		C	
		X	
		A'	DF CB
		÷	
		2	
060 172		=	
		SUM	
		0	FEM BC
		9	
		C	
065 177		X	
		SBR	
		1'	DF CF
		÷	
		2	
070 182		=	
		SUM	
		0	FEM FC
		5	
		C	
075 187		X	
		A'	D.F.CB
		=	
		STO	
		0	
080 192		6	
		C	
		X	
		SBR	
		1'	DF. CF
085 197		=	
		STO	
		0	
		7	
		C	
090 202		X	
		D'	DF CE
		=	
		SUM	
		)	FEM CE
095 207		3	
		RCL	
		Q·	
		6	
		=	
100 212		SUM	
		0	FEM CB
		8	
		RCL	
		0	
105 217		7·	
		=	
		SUM	
		0	FEM CF
		2	
110 222		RCL	
		0	

LABELS	
A	Main Prog.
B	ΣM @ JTB
C	ΣM @ JTC
D	RCL 16
E	RCL 15
A'	RCL 13
B'	RCL 18
C'	RCL 14
D'	RCL 12
E'	RCL 17
SBR 1'	RCL 19
00	*dsz
01	-
02	FEM CF
03	FEM CE
04	FEM BD
05	FEM FC
06	Storage
07	Storage
08	FEM CB
09	FEM BC
10	FEM BA
11	FEM AB
12	DF CE
13	DF CB
14	DF BD
15	CF BC
16	DF BA
17	DF AB
18	DF FC
19	DF CF

FLAGS	
0	
1	
2	
3	
4	

TITLE Moment Distribution PAGE 4 OF 4

PROGRAMMER ______ DATE ______

LOC	CODE	KEY	COMMENTS
000 112		5	
		X	
		B'	D.F. BC
		÷	
		2	
005 117		=	
		SUM	
		0	FEM CF
		2	
		RCL	
010 122		1	
		1	
		X	
		E'	D.F.AB
		÷	
015 127		2	
		=	
		SUM	
		1	
		0	
020 132		B	
		=	
		STO	
		0	
		0	
025 137		*dsz	
		A	
		HLT	
		#LBL	
		B	
030 142		(	
		RCL	
		0	
		9	
		+	
035 147		RCL	
		1	
		0	

LOC	CODE	KEY	COMMENTS
		+	
		RCL	
040 152		0	
		4	
		)	
		*RTN	
		*LBL	
045 157		C	
		(	
		RCL	
		0	
		2	
050 162		+	
		RCL	
		0	
		3	
		+	
055 167		RCL	
		0	
		8	
		)	
		*RTN	
060 172		*LBL	
		D	
		RCL	
		1	
		6	
065 177		*RTN	
		*LBL	
		E	
		RCL	
		1	
070 182		5	
		*RTN	
		*LBL	
		A'	
		RCL	
075 187		1	

LOC	CODE	KEY	COMMENTS
		3	
		*RTN	
		*LBL	
		B'	
080 192		RCL	
		1	
		8	
		*RTN	
		*LBL	
085 197		C'	
		RCL	
		1	
		4	
		*RTN	
090 202		*LBL	
		D'	
		RCL	
		1	
		2	
095 207		*RTN	
		*LBL	
		E'	
		RCL	
		1	
100 212		7	
		*RTN	
		*LBL	
		1'	
		RCL	
105 217		1	
		9	
		*RTN	
110 222			

LABELS
A
B
C
D
E
A'
B'
C'
D'
E'
REGISTERS
00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
FLAGS
0
1
2
3
4

EXHIBIT C

TITLE Moment of Inertia of "I" Section PAGE 1 OF 3

◄A◄				

◄B◄				

STEP	PROCEDURE	ENTER	PRESS			DISPLAY
1	Enter height of					
	bottom flange		STO	01		
2	Enter width of bottom flange		STO	02		
3	Enter height of web		STO	04		
4	Enter width of web		STO	05		
5	Enter height of top flange		STO	07		
6	Enter width of top flange		STO	08		
7				A		$Ad^2 + I_o$
			RCL	03		Area Bot. Flg.
			RCL	06		Area Web
			RCL	09		Area Top Flg.
			RCL	11		$\bar{Y}$ (from Bot.)
			RCL	12		Ad^2

TITLE Moment of Inertia of "I" Section PAGE 2 OF 3

PROGRAMMER ______ DATE ______

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
000 112		#LBL				X				1	
		A				RCL				+	
		RCL		040 152		0				RCL	
		0				3				0	
		1				÷		080 192		4	
005 117		X				2				)	
		RCL				=				X	
		0		045 157		SUM				RCL	
		2				1	A.Y.			0	
		=				0		085 197		9	
010 122		SUM				(				=	
		0	A_1			RCL				SUM	
		3		050 162		0				1	ΣAY
		RCL				4				0	
		0				÷		090 202		RCL	
015 127		4				2				1	
		X				+				0	
		RCL		055 167		RCL				÷	
		0				0				(	
		5				1		095 207		RCL	
020 132		=				)				0	
		SUM				X				3	
		0	A_2	060 172		RCL				+	
		6				0				RCL	
		RCL				6		100 212		0	
025 137		0				=				6	
		7				SUM				+	
		X		065 177		1	$(A_2+A_1)Y$			RCL	
		RCL				0				0	
		0				(		105 217		9	
030 142		8				RCL				=	
		=				0				STO	
		SUM		070 182		7				1	$\bar{Y}$
		0	A_3			÷				1	
		9				2		110 222		(	
035 147		RCL				+				RCL	
		0				RCL					
		1		075 187		0					

LABELS	
A	
B	
C	
D	
E	
A'	
B'	
C'	
D'	
E'	

REGISTERS	
00	
01	Ht. of Bot. Flg.
02	Width of Bot. Flg.
03	Area of Bot. Flg.
04	Ht. of Web
05	Width of Web
06	Area of Web (A_2)
07	Ht. of Top Flg.
08	Width of Top Flg.
09	Area of Top Flg. (A_3)
10	ΣAY
11	$\bar{Y}$
12	ΣAd^2
13	
14	
15	
16	
17	
18	
19	

FLAGS	
0	
1	
2	
3	
4	

TITLE Moment of Inertia of "I" Section PAGE 3 OF 3
PROGRAMMER DATE

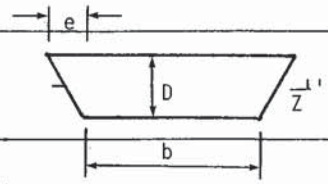
LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112		0				=				X		A
		1				SUM				RCL		B
		÷		040 152		1	$(A_1+A_2)d^2$			0		C
		2				2				2		D
		-				(		080 192		+		E
005 117		RCL				RCL				RCL		A'
		1				0				0		B'
		1		045 157		7				4		C'
		)				÷				Y^X		D'
		$*X^2$				2		085 197		3		E'
010 122		X				+				X		REGISTERS
		RCL				RCL				RCL		00
		0		050 162		0				0		01
		3				1				5		02
		=				+		090 202		+		03
015 127		SUM				RCL				RCL		04
		1	A_1d^2			0				0		05
		2		055 167		4				7		06
		(				-				Y^X		07
		RCL				RCL		095 207		3		08
020 132		0				1				X		09
		4				1				RCL		10
		÷		060 172		)				0		11
		2				$*X^2$				8		12
		+				X		100 212		)		13
025 137		RCL				RCL				÷		14
		0				0				1		15
		1		065 177		9				2		16
		-				=				+		17
		RCL				SUM		105 217		RCL		18
030 142		1				1	ΣAd^2			1	ΣAd^2	19
		1				2				2		FLAGS
		)		070 182		(				=	ΣAd^2+I_D	0
		$*X^2$				RCL				HLT		1
		X				0		110 222				2
035 147		RCL				1						3
		0				Y^X						4
		6		075 187		3						

EXHIBIT D

TITLE Manning's Equation for Trapezoidal Channel PAGE 1 OF 4

A				

B				



This is a trial and error solution of the following equation:

$$Q = \frac{1.486(Z + 1/x)^{5/3} D^{8/3} S^{1/2}}{n[1/x + 2(Z^2+1)^{1/2}]^{2/3}}$$

Where Z = e ÷ D

X = D ÷ b

S = Slope of stream (FT/FT)

N = Mannings "N"

D = Depth

Q = CFS (Known)

STEP	PROCEDURE	ENTER	PRESS			DISPLAY
1.	Enter average side slope as ratio of horizontal to vertical Example: 2:1 = 2	Z	STO	01		
2.	Enter width of bottom	b (Ft)	STO	02		
3.	Enter Slope	S (Ft)	STO	03		
4.	Enter Manning's "N"	"N"	STO	04		
5.	Enter Assumed Depth	D (Ft)	STO	06		
6.				A		Q (CFS)
7.	If "Q" is incorrect, enter another "D"		STO	06		

TITLE Manning's Equation for Trapezoidal Channel PAGE 2 OF 4

STEP	PROCEDURE	ENTER	PRESS			DISPLAY
8.				A		Q
9.	If "Q" is correct:			RUN		V (FPS)

TITLE Moment Distribution PAGE 3 OF 4
PROGRAMMER ____________ DATE ____________

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112		#LBL				SUM				A'	D.F.CB	A Main Prog.
		A				0	FEM BD			=		B ΣM @ JTB
		B		040 152		4				STO		C ΣM @ JTC
		X				RCL				0		D RCL 16
		D	D.F.BA			0		080 192		6		E RCL 15
005 117		÷				6				C		A' RCL 13
		2				=				X		B' RCL 18
		=		045 157		SUM				SBR		C' RCL 14
		SUM				1	FEM BA			1'	DF. CF	D' RCL 12
		1	FEM AB			0		085 197		=		E' RCL 17
010 122		1				RCL				STO		SBR 1' RCL 19
		B				0				0		00 *dsz
		x		050 162		7				7		01 -
		E	DF BC			=				C		02 FEM CF
		÷				SUM		090 202		X		03 FEM CE
015 127		2				0	FEM BC			D'	DF CE	04 FEM BD
		=				9				=		05 FEM FC
		SUM		055 167		C				SUM		06 Storage
		0	FEM CB			X				)	FEM CE	07 Storage
		8				A'	DF CB	095 207		3		08 FEM CB
020 132		B				÷				RCL		09 FEM BC
		X				2				0		10 FEM BA
		D	DF BA	060 172		=				6		11 FEM AB
		=				SUM				=		12 DF CE
		STO				0	FEM BC	100 212		SUM		13 DF CB
025 137		0				9				0	FEM CB	14 DF BD
		6				C				8		15 CF BC
		B		065 177		X				RCL		16 DF BA
		X				SBR				0		17 DF AB
		E	DF BC			1'	DF CF	105 217		7		18 DF FC
030 142		=				÷				=		19 DF CF
		STO				2				SUM		FLAGS
		0		070 182		=				0	FEM CF	0
		7				SUM				2		1
		B				0	FEM FC	110 222		RCL		2
035 147		X				5				0		3
		C'	DF BD			C						4
		=		075 187		X						

TITLE Manning's Equation for Trapezoidal Channel PAGE 4 OF 4
PROGRAMMER ______ DATE ______

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112		5										A
		÷										B
		RCL		040 152								C
		1										D
		1						080 192				E
005 117		=										A'
		STO										B'
		1		045 157								C'
		2										D'
		=						085 197				E'
010 122		HLT										REGISTERS
												00
				050 162								01
												02
								090 202				03
015 127												04
												05
				055 167								06
												07
								095 207				08
020 132												09
												10
				060 172								11
												12
								100 212				13
025 137												14
												15
				065 177								16
												17
								105 217				18
030 142												19
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				070 182								0
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								110 222				2
035 147												3
												4
				075 187								

ABANDONED STRIP MINE RECLAMATION

Al Vanderpoel
Engineer
Wayne-Hosier National Forest

Almost 10,000 acres (4,047 hectares) of the Wayne National Forest in southern Ohio are scarred by abandoned strip mines. In 1978, as a result of a grant from the Appalachian Regional Commission, the Forrest Service undertook its first large-scale reclamation of such lands on 40 acres (16.19 hectares) that had been mined soon after World War II.

Known as the *Yost Tract*, this area was characterized by 50-ft. (15.24m) vertical walls, strip pits filled with acid water, and mounds of overburden material (Fig. 1). Because of the exposed coal residues, there was almost no vegetation, and surface water runoff was very acidic; the pH level in the soils ranged from less than 3.5 to 5.5.

Figure 1.--Conditions before reclamation work showing highwall, strip pit, and spoil bank

A Forest Service team of specialists developed guidelines that were used in preparing a contract package to reclaim the site, and in developing a Land Use Plan for the area. The plan consisted of:

1. Draining the acid water ponds;

2. Burying as much acid material as possible, and covering the site with a minimum of 24 inches (60.96cm) of nontoxic material;

3. Restoring the land to its original contour (to the top of the vertical walls);

4. Covering the area with 12 inches (30.48cm) of top-soil;

5. Cleaning and opening drainage-ways;

6. Liming, fertilizing, and revegetating the site with grasses immediately; and

7. Planting a variety of tree species that seemed appropriate to the site.

A public works contract was awarded for this project in April 1978; the earthwork was subcontracted to a coal mining firm experienced with this type of reclamation work. Using D-9 dozers for clearing, grubbing, and earthwork, the area was leveled initially and the acid ponds drained, after which the site was shaped to final grade (Fig. 2). Scrapers were used to haul borrow material for covering 10 (4.047 hectares) of the 40 acres (16.19 hectares) with 12 inches (30.48cm) of cover soil; the 10 acres chosen were the worst soils on the site.

New waterways were constructed to replace the existing drainages on the site, using stone riprap (Fig. 3). Also, diversion ditches were cut halfway down the finished slope to intercept runoff. The contractor's work was completed when the entire area was lined heavily and then fertilized, seeded, and covered with hay as mulch; an anti-erosion disk was used to crimp the hay into the soil. Figure 4, the completed project, is the same location as shown in Figure 1.

Three D-9 dozers, two scrapers, and a front-end loader were used in the project, which was completed in 122 days at a cost of $4,950 per acre (.4047 hectare). The time and cost compare favorably with the State and Soil Conservation Service projects in the area. Downtime was essentially zero, but the work was delayed 4 weeks because of wet weather.

Figure 2.--Dozers push material to final grade

Figure 3.--New waterways established on site

Figure 4.--Completed project at same location as Figure 1

Based on this work, some recommendations that could be applied to similar projects in the future are:

1. Reduce construction and overhead costs by using a service contract. Calculate earthwork quantities from photogrammetry, rather than by field work, or by use of design quantities.

2. Cut the amount of earthwork required by restoring the land to other than its original contour.

3. Accomodate the difficulty in sorting excavation material to obtain topsoil in the planning stage; thus, borrow material is needed.

4. Note, in planning, that the material excavated in this particular type of site may expand about 30 percent.

WASHINGTON OFFICE NEWS

CONSULTATION & STANDARDS

Walter E. Furen
Assistant Director

COST-EFFECTIVENESS ANALYSIS IN ENGINEERING MANAGEMENT

Originally developed by civilian economists in 1936, "benefit-cost analysis" evolved naturally into "cost-effectiveness analysis" -- a familiar tool for economic evaluation of complex national defense and space exploration systems. That tool can be applied efficiently to routine engineering management problems, particularly for situations in which personnel, equipment, or dollar resources are restricted.

Simple cost-effectiveness analysis of a functional specialty (such as geotechnical engineering) can be used:

1. to obtain maximum benefits available from a limited program effort;

2. to determine investigation intensity levels required for the program;

3. to provide assurance that work levels are commensurate with project opportunities, risks, and values; and

4. to develop an awareness of operating costs, as well as unit costs, for meaningful work segments.

SITUATION EXAMPLES

Evaluating Alternative Methods to Accomplish a Specific Work Element.
Suppose that laboratory work is being accomplished by force account methods, and that commercial laboratory facilities are available to do that work under contract. The cost elements in this situation then can be compared directly on a unit cost basis.

To provide a comparison base, determine the relative importance of other pertinent elements, such as responsiveness (turnaround time), accuracy, availability of equipment, and other factors. Then, independently evaluate each element (including cost) for each alternative, and compute a weighted rating for those factors. The weighted ratings are a means for comparing the alternatives.

Determine Priorities for Projects and Programs.

1. For each unit of work, compute the "fixed cost" to be expended for the estimated time to be dedicated to the work, including the cost of personnel, equipment, and supplies.

2. Identify the project/program objectives and make a comparative rating for each. Evaluate the predicted accomplishments in terms of each objective.

3. The weighted ratings computed for each project/program can be used to determine the greatest potential benefit to be derived in return for expenditures of limited resources (personnel, equipment, supplies, and dollar equivalents).

Although the techniques for cost-effectiveness analysis were developed to solve highly-complex problems in economics, the methods -- coupled with rational decision analysis -- become extremely meaningful tools for an engineering manager in making decisions on a day-to-day basis.

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TECHNOLOGICAL IMPROVEMENTS

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SOLAR POWERED VAULT TOILET VENTING SYSTEM

There are some 27,000 vault toilets located in the National Forests. The natural odors associated with those installations are disagreeable to the people using and maintaining those structures; consequently, there is a tendency to avoid using them, as well as to postpone or avoid servicing the units.

Other problems are related to the disagreeable conditions; the incidence of vandalism is greater, and people use the area around the building instead of the facilities provided. Increased vandalism results in increased maintenance costs, and the human wastes on the ground can become health hazards that are transmitted by insects, rodents, and water.

The *San Dimas Equipment Development Center (SDEDC)* has been testing systems to provide ventilation and to reduce the objectionable odors in the buildings. Several general patterns and constraints were identified during the preliminary work:

1. The buildings are used more frequently during daytime than at night;

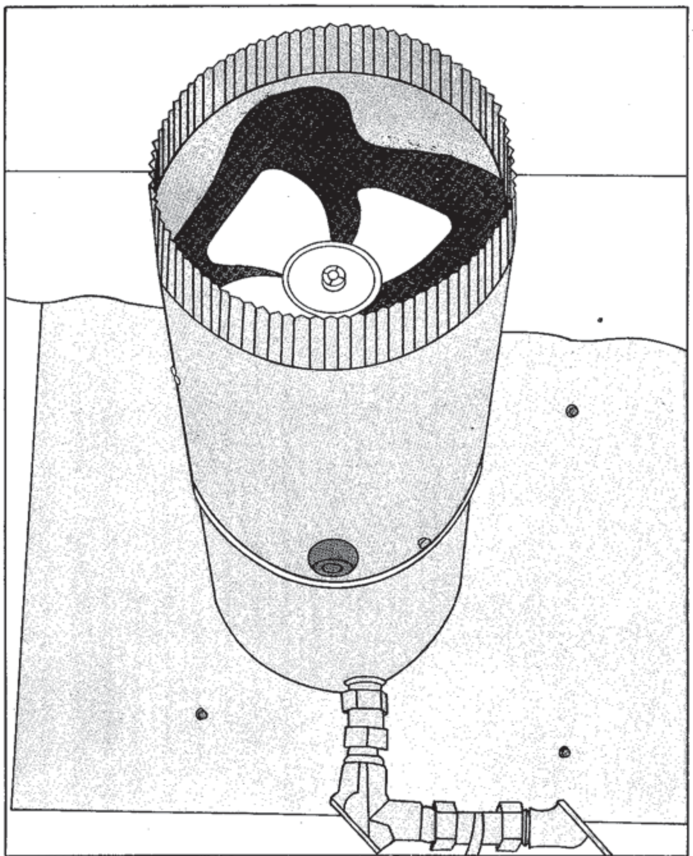
2. They are used more frequently during clear weather than during inclement conditions;

3. Because the units are isolated, access to power sources is severely limited;

4. Servicing of ventilating equipment must be simple; and

5. Costs for installation must be low.

The SDEDC prototype for the ventilation system consisted of a 20-watt solar array supplying electrical energy to a small fan motor in a 6-inch (15.2cm) diameter stack for the roof of the building (See Figure). The installation requires only small modification to existing structures.



Solar-powered ventilating unit, designed by SDEDC for use in vault toilets. The photo shows a completely installed unit.

The units were tested in Regions 4 and 5, and they proved satisfactory. The solar array provides sufficient energy on clear, sunny days to aspirate the structures at a maximum of .750 cf/minute (229cm/minute); this results in an exchange of all the air in the vault every few minutes. Since the most frequent use occurs during the daytime, no backup electrical system was required, and the usual regulator, batteries, and diodes were unneccessary.

The Department of Energy has funds available for other Federal agencies to purchase solar arrays for use in the development of solar energy systems. The Forest Service plans to install about 500 SDEDC ventilation systems at selected sites throughout the United States (about 2 percent of the existing vault toilet installations). The cost will run about $235 per unit.

The results of this project will be shared with other Federal, State, and local agencies.

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