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THE CITANDUY RIVER BASIN DEVELOPMENT PROJECT

CITANDUY UPPER WATERSHED MANAGEMENT PROJECT

FEASIBILITY REPORT

APPENDICES

SUBMITTED BY

PRC ENGINEERING CONSULTANTS, INC.
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JANUARY 1980

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BACKGROUND TABLES FOR RESOURCE BASE

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TABLE A-1

DISTRIBUTION OF ECONOMIC LAND USE AREAS BY DISTRICT AND SUBDISTRICT

FOR CITANDUY SUBBASINS

(Hectares)

District/Subdistrict	Total Area	Out of Basin	Upper Citanduy	Cimuntur	Cijolang	Cikawung	Ciseel-Lower Citanduy	Total Citanduy	Critical Areas Total	Critical Areas Citanduy
Tasikmalaya District										
Pager Ageung			8,159					8,159		844
Ciawi			7,439					7,439		469
Rajapolah			3,041					3,041		
Cisayong			7,186					7,186		
Indihiang			6,929					6,929		
Tasikmalaya			1,922					1,922		
Cibeureum			6,368					6,368		75
Manonjaya			5,804				536	6,340		369
Cineam			682				9,541	10,223		732
Total			47,530				10,077	57,607		2,489
Ciamis District										
Ciamis			2,543	10,171				12,714		1,319
Cikoneng			5,764					5,764		2,631
Cijeunjing			1,963	5,888				7,851		1,457
Panumbangan			4,360					4,360		1,806
Panjalu			5,370	5,369				10,739		1.085
Cihaurbeuti			5,480					5,480		712
Kawali				7,196				7,196		1,364
Panawangan				1,745	6,982			8,727		1,560
Buniseuri				7,467				7,467		679
Rancah				6,418	6,418			12,836		2,367
Cisaga				8,173	4,087			12,260		1,075
Rajadesa				6,779	2,260			9,039		712
Banjar							10,827	10,827		843
Banjarsari							17,857	17,857		5,615

TABLE A-1

DISTRIBUTION OF ECONOMIC LAND USE AREAS BY DISTRICT AND SUBDISTRICT FOR CITANDUY SUBBASINS (CONT'D)

(Hectares)

District/Subdistrict	Total Area	Out of Basin	Upper Citanduy	Cimuntur	Cijolang	Cikawung	Ciseel-Lower Citanduy	Total Citanduy	Critical Areas Total	Critical Areas Citanduy
Ciamis District										
Lakbok							8,289	8,289		
Cimaragas							9,731	9.731		5,639
Pamarican							17,592	17,592		8,492
Padaherang							14,157	14,157		3,638
Kalipucang							7,352	7,352		1,831
Total			25,480	59,206	19,747		85,855	190,288		42,825
Kuningan District										
Selajambe					3,050			3,050		2,180
Subang					8,015			8,015		1,809
Total					11,065			11,065		3,989
Cilacap District										
Gandrungmangu	10,728	10,134				594		594	55	55
Sidareja	13,282	8,855				4,427		4,427	1,100	367
Karangpucung	17,380	6,130				11,250		11,250	2,691	1,742
Majenang	13,842					13,842		13,842	1,152	1,152
Wanareja	16,496					16,496		16,496	1,511	1,511
Dayeuhluhur	16,835				16,835			16,835	1,739	1,739
Cimanggu	19,119					19,119		19,119	3,645	3,645
Cilacap	13,268	13,268								
Jerukleqi	11,580	11,580								
Kawunganten	15,375	15,375							1,617	
Kedungreja	11,487	7,658							2,300	
						3,829		3,829		
Total Cilacap	159,392	73,000			16,835	69,557		86,392	15,810	10,211

TABLE A-1

DISTRIBUTION OF ECONOMIC LAND USE AREAS BY DISTRICT AND SUBDISTRICT FOR CITANDUY SUBBASINS (CONT'D)

(Hectares)

District/Subdistrict	Total Area	Out of Basin	Upper Citanduy	Cimuntur	Cijolang	Cikawung	Ciseel-Lower Citanduy	Total Citanduy	Critical Areas	
									Total	Citanduy
Total Land Use			73,010	59,206	47,647	69,557	95,932	345,352		59,514
Other Areas			990	1,794	353	443	1,068	4,648		
Total Watershed			74,000	61,000	48,000	70,000	92,000	350,000		
% Other Areas			1.3	2.9	0.7	0.6	1.1	1.3		

TABLE A-2

ECONOMIC LAND USE PATTERN IN CITANDUY PROJECT BY DISTRICTS

(Hectares)

District		Lowland Rice	Upland Crop	Plantation	Forest	Home Garden 1/	Other	Total 2/	Critical Area
Tasikmalaya		18,168	23,291	484	8,149	5,587	1,928	57,607	2,489
	Percent	31.5	40.4	0.8	14.1	9.7	3.4	100.0	4.3
Ciamis		43,140	71,264	38,612	15,588	13,859	7,825	190,288	42,825
	Percent	22.7	37.4	20.3	8.2	7.3	4.1	100.0	22.9
Kuningan		3,326	878	-	2,685	554	3,622	11,065	3,989
	Percent	30.1	7.9	-	24.3	5.0	32.7	100.0	36.1
Cilacap		22,168	25,075	5,452	17,627	8,192	7,878	86,392	10,211
	Percent	25.7	29.0	6.3	20.4	9.5	9.1	100.0	11.8
T o t a l	(Hectares)	86,802	120,508	44,548	44,049	28,192	21,253	345,352	59,514
	Percent	25.1	34.9	12.9	12.8	8.2	6.1	100.0	17.2

1/ Include Homes and yards.

* Source District (BAPPEMKA) Offices. Areas of districts along divide was estimated.

TABLE A-3

LAND USE PATTERN FOR TASIKMALAYA DISTRICT, 1978

(Hectares)

Subdistrict	Land Use Categories							
	Lowland Rice	Upland Crops	Plantation	Forest	Home Garden	Other	Total	Critical Area
Pager Ageung	2,431	3,381	-	1,614	417	316	8,159	844
Ciawi	2,393	2,693	-	1,791	483	79	7,439	469
Rajapolah	2,076	563	-	-	280	122	3,041	-
Cisayong	2,603	1,835	-	1,950	675	123	7,186	-
Indihiang	3,401	1,374	-	1,037	994	123	6,929	-
Tasikmalaya	582	28	-	-	538	774	1,922	-
Cibeureum	2,158	2,799	-	24	1,256	131	6,368	75
Manonjaya	1,476	4,138	47	50	529	100	6,340	369
Cineam	1,048	6,480	437	1,683	415	160	10,223	732
T O T A L	18,168	23,291	484	8,149	5,587	1,928	57,607	2,489
Percent	31.5	40.4	0.80	14.1	9.7	3.4	100.0	4.3

1/ Source: Land Use Department Tasikmalaya District 1978.

TABLE A-4

LAND USE PATTERN FOR CIAMIS DISTRICT, 1977

(Hectares)

Subdistrict	Land Use Categories*							
	Lowland Rice	Upland Crops	Plantation	Forest	Home garden 1/	Other	Total	Critical Area
Ciamis	2,394	2,064	5,743	1,144	1,155	214	12,714	1,319
Cikoneng	1,561	1,887	268	1,235	652	161	5,764	2,631
Cijeunjing	1,030	1,740	4,332	-	583	166	7,851	1,457
Panumbangan	1,137	2,334	-	206	301	382	4,360	1,806
Panjalu	2,384	6,268	-	15	393	1,679	10,739	1,085
Cihaurbeuti	1,167	1,057	224	2,534	340	158	5,480	712
Kawali	1,836	3,412	507	115	656	670	7,196	1,364
Panawangan	2,400	4,736	-	252	627	712	8,727	1,560
Buniseuri	1,495	3,959	480	274	291	958	7,467	679
Rancah	2,693	5,080	3,711	712	335	305	12,836	2,367
Cisaga	2,015	2,843	3,563	2,879	754	206	12,260	1,075
Rajadesa	1,933	4,999	-	952	728	427	9,039	712
Banjar	2,882	627	5,482	592	822	472	10,877	843
Banjarsari	2,707	11,284	514	224	2,803	325	17,857	5,615
Lakbok	6,022	628	601	-	827	211	8,289	-
Cimaragas	1,226	2,682	5,030	20	632	141	9,731	5,639
Pamarican	3,693	10,231	793	1,593	1,011	271	17,592	8,492
Padaherang	3,953	2,735	5,872	735	674	188	14,157	3,638
Kalipucang	612	2,698	1,492	2,106	275	169	7,352	1,831
Total	43,140	71,264	38,612	15,588	13,859	7,825	190,288	42,825
Percent	22.7	37.4	20.3	8.2	7.3	4.1	100.0	22.5

Source: * BAPPEMKA Ciamis District

1/ : Includes Homes and Yards.

TABLE A-5

LAND USE PATTERN FOR KUNINGAN DISTRICT, 1977

(Hectares)

Subdistrict	Land Use Categories*							
	Lowland Rice	Upland Crops	Plantation	Forest	Home Garden 1/	Others	Total	Critical Area
Selajambe	1,306	80	-	850	142	672	3,050	2,180
Subang	2,020	798	-	1,835	412	2,950	8,015	1,809
Total	3,326	878	-	2,685	554	3,622	11,065	3,989
Percent				24.3	5.0	32.7	100.0	36.1

Source : * BAPPEMKA KUNINGAN DISTRICT

1/ Include homes and yards

TABLE A-6

LAND USE PATTERN FOR CILACAP DISTRICT, 1977

(Hectares)

Subdistrict	Land Use Categories*							
	Lowland Rice	Upland Crops	Plantation	Forest	Home Garden 1/	Other	Total	Critical Area
Gandrungmangu	-	594	-	-	-	-	594	55
Sidareja	1,057	1,038	1,040	364	850	78	4,427	367
Karangpucung	4,428	4,380		2,395	47	-	11,250	1,742
Majenang	3,499	5,043	-	3,539	1,542	219	13,842	1,152
Wanareja	3,413	6,868	1,271	3,439	1,090	415	16,496	1,511
Dayeuhluhur	2,199	3,891	2,473	6,729	685	858	16,835	1,739
Cimangu	5,161	3,174	668	1,032	3,095	5,989	19,119	3,645
Kedungreja	2,411	87		129	883	319	3,829	
T o t a l (Hectares)	22,168	25,075	5,452	17,627	8,192	7,878	86,392	10,211
Percent of area	25.7	29.0	6.3	20.4	9.5	9.1	100.0	11.8

Source: * BAPPEDA Cilacap District only hectarage within the boundaries of Citanduy Watershed given

1/ Includes home and yards.

TABLE A-7

ECONOMIC LAND USE FOR CITANDUY SUBBASINS BY DISTRICT AND SUBDISTRICT

(Hectares)

District	Sub-District	Lowland Rice	Upland Crops	Plantation	Forest	Home Garden	Other	Total	Critical Area
Upper Citanduy Sub-basin									
Tasikmalaya	Pager Ageung	2,431	3,381		1,614	417	316	8,159	844
	Ciawi	2,393	2,693		1,791	483	79	7,439	469
	Rajapolah	2,076	563			280	122	3,041	
	Cisayong	2,603	1,835		1,950	675	123	7,186	
	Indihiang	3,401	1,374		1,037	994	123	6,929	
	Tasikmalaya	582	28			538	774	1,922	
	Cibeureum	2,158	2,799		24	1,256	131	6,368	73
	Manonjaya	1,351	3,788	43	46	484	92	5,804	338
	Cineam	70	432	29	112	28	11	682	49
Sub-Total		17,065	16,893	72	6,574	5,155	1,771	47,530	1,775
Ciamis	Cihaurbeuti	1,167	1,057	224	2,534	340	158	5,480	712
	Cikoneng	1,561	1,887	268	1,235	652	161	5,764	2,631
	Panumbangan	1,137	2,334		206	301	382	4,360	1,806
	Ciamis	479	412	1,149	229	231	43	2,543	264
	Panjalu	1,192	3,134		8	196	840	5,370	542
	Cijeunjing	258	435	1,083		145	42	1,963	364
Sub-Total		5,794	9,259	2,734	4,212	1,865	1,626	25,480	6,319
Total Upper Citanduy		22,859	26,152	3,796	10,786	7,020	3,397	73,010	8,094
Percent of Area		31.3	35.8	3.8	14.8	9.5	4.7	100.0	11.1
Ciamtur Sub-basin									
Ciamis	Ciamis	1,915	1,651	4,594	915	924	172	10,171	1,055
	Buniseuri	1,495	3,959	480	274	291	968	7,467	679
	Panjalu	1,192	3,133		7	196	839	5,369	543
	Panawangan	480	947		50	125	143	1,745	360
	Kawali	1,836	3,412	507	115	656	670	7,196	1,364
	Rajadesa	1,450	3,749		714	546	320	6,779	534
	Cisaga	1,343	1,895	2,375	1,919	503	138	8,173	717
	Rancah	1,346	2,540	1,855	356	168	152	6,418	1,184
	Cijeunjing	772	1,305	3,249		439	123	5,888	1,093
Total Ciamtur Sub-basin		11,829	22,593	13,060	4,350	3,848	3,526	59,206	7,529
Percent of Area		20.0	38.2	22.1	7.2	6.5	6.0	1000	12.7

TABLE A-7 (CONT'D)

ECONOMIC LAND USE FOR CITANDUY SUBBASIN BY DISTRICT AND SUBDISTRICT

(Hectares)

District	Sub-District	Lowland Rice	Upland Crops	Plantation	Forest	Home Garden	Other	Total	Critical Area
Cijolang Sub-basin									
Ciamis	Rancah	1,347	2,540	1,856	356	167	152	6,418	1,183
	Cisaga	672	948	1,188	960	251	68	4,087	358
	Rajadesa	483	1,250		238	182	107	2,250	178
	Panawangan	1,920	3,789		202	502	569	6,982	1,200
Sub-total		4,422	8,527	3,044	1,756	1,102	896	19,747	2,919
Cilacap	Dayeuhluhur	2,199	3,891	2,473	6,729	685	858	16,835	1,739
Kuningan	Selajambe	1,306	80		850	142	672	3,050	2,180
	Subang	2,020	798		1,835	412	2,950	8,015	1,809
Sub-total		3,326	878		2,685	554	3,622	11,065	3,989
Total Cijolang Sub-basin		9,947	13,296	5,517	11,170	2,341	5,376	47,647	8,647
Percent of Area		20.9	27.9	11.6	23.4	4.9	11.3	100.0	18.1
Cikawung Sub-basin									
Cilacap	Wanareja	3,413	6,868	1,271	3,439	1,090	415	16,496	1,511
	Majenang	3,499	5,043		3,539	1,542	219	13,842	1,152
	Cimanggu	5,161	3,174	668	1,032	3,095	5,989	19,119	3,645
	Sidareja	1,057	1,038	1,040	364	850	78	4,427	367
	Karangpucung	4,428	4,380		2,395	47		11,250	1,742
	Kedungreja	2,411	87		129	883	319	3,829	
	Gandrungmangu		594					594	55
Total Cikawung Sub-basin		19,969	21,184	2,979	10,898	7,507	7,020	69,557	8,472
Percent of Area		28.7	30.5	4.3	15.7	10.8	10.1	100.0	12.2

TABLE A-7 (CONT'D)

ECONOMIC LAND USE FOR CITANDUY SUBBASINS BY DISTRICT AND SUBDISTRICT

(Hectares)

District	Sub-District	Lowland Rice	Upland Crops	Plantation	Forest	Home Garden	Other	Total	Critical Area
Ciseel Sub-basin									
Tasikmalaya	Manonjaya	125	350	4	4	45	8	536	31
	Cineam	978	6,048	408	1,571	387	149	9,541	683
	Sub-Total	1,103	6,398	412	1,575	432	157	10,077	714
Ciamis	Cimaragas	1,226	2,682	5,030	20	632	141	9,731	5,639
	Pamarican	3,693	10,231	793	1,593	1,011	271	17,592	8,492
	Banjar	2,882	627	5,482	592	822	472	10,877	843
	Banjarsari	2,707	11,284	514	224	2,803	325	17,857	5,615
	Lakbok	6,022	628	601		827	211	8,289	
	Padaherang	3,953	2,735	5,872	735	674	188	14,157	3,638
	Kalipucang	612	2,698	1,492	2,106	275	169	7,352	1,831
	Sub-Total	21,095	30,885	19,784	5,270	7,044	1,777	85,855	26,058
Total Ciseel Sub-basin		22,198	37,283	20,196	6,845	7,476	1,934	95,932	26,272
Percent of Area		23.1	38.9	21.1	7.1	7.8	2.0	100.0	27.9
Summary									
Upper Citanduy Sub-basin		22,859	26,152	2,796	10,786	7,020	3,397	73,010	8,094
Cimuntur Sub-basin		11,829	22,593	13,060	4,350	3,848	3,526	59,206	7,529
Cijolang Sub-basin		9,947	13,296	5,517	11,170	2,341	5,376	47,647	8,647
Cikawung Sub-basin		19,969	21,184	2,979	10,898	7,507	7,020	69,557	8,472
Ciseel Sub-basin		22,198	37,283	20,196	6,845	7,476	1,934	95,932	26,772
Total Citanduy River Basin		86,802	120,508	44,548	44,049	28,192	21,253	345,352	59,514
Percent of Area		25.1	34.9	12.9	12.8	8.2	6.1	100.0	17.2

TABLE A-8

LAND STATUS IN CITANDUY WATERSHED BY DISTRICT

(Hectares)

Item	Privately Owned Land	Government Owned Land 2/	Forest Govt. Land	Pasture Land	Land Use Right	Land in Dispute	Total Area
Tasikmalaya 1/	46,018	398	9,390	-	1,038	763	57,607
Percent	79.9	0.7	16.3	-	1.8	1.3	100.0
Ciamis	169,258	3,543	8,710	2,923	5,854	-	190,288
Percent	88.9	1.9	4.6	1.5	3.1	-	100.0
Kuningan	6,696	1,250	2,685	434	-	-	11,065
Percent	60.5	11.3	24.3	3.9	-	-	100.0
Cilacap	58,371	1,682	26,339	-	-	-	86,392
Percent	67.6	1.9	30.5	-	-	-	100.0
Total	280,343	6,873	47,124	3,357	6,892	763	345,352
Percent	81.2	2.0	13.6	1.0	2.0	0.2	100.0

Source: District (BAPPEMKA) Offices

1/ Tasikmalaya and Manonjaya Sub-District Status Records not available - estimates prorated on the basis of other subdistrict records.

2/ Including land owned by certain communities.

TABLE A-9

LAND STATUS FOR TASIKMALAYA DISTRICT, 1978 1/

(Hectares)

Subdistrict	Private Land	Government Owned Land	Forest Gov.Land	Pasture Land	Land Use Rights	Land in Dispute	Total Area
Pager Ageung	6,197	31	1,614		185	132	8,159
Ciawi	5,558	72	1,735	-	57	17	7,439
Rajapolah	2,963	5	-	-	30	43	3,041
Cisayong	5,155	1	1,950	-	-	80	7,186
Indihiang	5,698	-	1,037	-	-	194	6,929
Tasikmalaya *	1,534	13	313	-	35	27	1,922
Cibeureum	6,090	16	24	-	181	57	6,368
Manonjaya *	5,061	44	1,033	-	114	88	6,340
Cineam	7,762	216	1,684	-	436	125	10,223
Total	46,018	398	9,390	-	1,038	763	57,607
Percent	79.9	0.7	16.3	-	1.8	1.3	100.0

* No records available-estimated prorated on basis of other subdistrict records.

1/ Source Land Use Department Tasikmalaya District 1978.

TABLE A-10

LAND STATUS FOR CIAMIS DISTRICT, 1977

(Hectares)

Subdistrict	Private Land	Government Owned land	Forest Government land	Pasture land	Land use rights	Land in dispute	Total Area
Ciamis	11,969	654	35	37	19		12,714
Cikoneng	4,515	298	951	-	-		5,764
Cijeunjing	7,630	221	-	-	-		7,851
Panumbangan	3,996	158	206	-	-		4,360
Panjalu	10,235	282	15	207	-		10,739
Cihaurbeuti	5,090	375	-	15	-		5,480
Kawali	6,326	242	50	71	507		7,196
Panawangan	8,190	182	252	103	-		8,727
Buniseuri	6,329	249	851	38	-		7,467
Rancah	11,781	170	581	304	-		12,836
Cisaga	8,779	510	2,001	56	914		12,260
Rajadesa	8,444	108	383	104	-		9,039
Banjar	9,169	4	77	-	1,627		10,877
Banjarsari	15,527	-	222	559	1,549		17,857
Lakbok	8,051	-	-	18	220		8,289
Cimaragas	9,489	39	87	116	-		9,731
Pamarican	15,395	51	1,393	483	270		17,592
Padaherang	13,277	-	-	550	330		14,157
Kalipucang	5,066	-	1,606	262	418		7,352
Total	169,258	3,543	8,710	2,923	5,854		190,288
Percent	88.9	1.9	4.6	1.5	3.1		100.0

Source : BAPPEMKA, Ciamis District

TABLE A-11

LAND STATUS FOR KUNINGAN DISTRICT, 1977

(Hectares)

Subdistrict	Private Land	Government Owned Land	Forest Government Land	Pasture Land	Land Use Rights	Land in Dispute	Total Area
Selajambe	1,922	136	850	142	-	-	3,050
Subang	4,774	1,114	1,835	292	-	-	8,015
Total	6,696	1,250	2,685	434	-	-	11,065
Percent	60.5	11.3	24.3	3.9	-	-	100.0

Source: BAPPEMKA Kuningan District.

TABLE A-12

LAND STATUS FOR CILACAP DISTRICT, 1977

(Hectares)

Subdistrict	Private Land	Government Owned Land	Forest Government Land	Pasture Land	Land Use Rights	Land in Dispute	Total Area
Gandrungmangu	394	15	185	-	-	-	594
Sidareja	2,970	110	1,347	-	-	-	4,427
Karangpucung	7,759	80	3,411	-	-	-	11,250
Cimanggu	10,900	490	7,729	-	-	-	19,119
Majenang	11,285	273	2,284	-	-	-	13,842
Wanareja	14,132	369	1,995	-	-	-	16,496
Dayeuhluhur	8,844	318	7,673	-	-	-	16,835
Kedungreja	2,087	27	1,715	-	-	-	3,829
Total	58,371	1,682	26,339	-	-	-	86,392
Percent	67.6	1.9	30.5	-	-	-	100.0

Source : BAPPEDA, Cilacap District.

TABLE A-13

DISTRIBUTION OF LAND OWNERSHIP STATUS BY DISTRICT AND SUBDISTRICT FOR CITANDUY WATERSHED SUBBASIN

(Hectares)

District	Subdistrict	Private Land	Government Land	Forest Government Land	Pasture Land	Land Use Rights	Land in Dispute	Total Area
Upper Citanduy Subbasin								
Tasikmalaya	Pager Ageung	6,197	31	1,614	-	185	131	8,159
	Ciawi	5,558	72	1,735	-	57	17	7,439
	Rajapolah	2,963	5	-	-	30	44	3,041
	Cisayong	5,155	1	1,950	-	-	80	7,186
	Indihiang	5,698	-	1,037	-	-	194	6,929
	Tasikmalaya	1,534	13	313	-	35	27	1,922
	Cibeureum	6,090	16	24	-	181	57	6,368
	Manonjaya	4,633	40	946	-	104	81	5,804
	Cineam	518	14	112	-	29	9	682
	Subtotal	38,346	192					
Ciamis	Cihaurbeuti	5,090	375					
	Cikoneng	4,515	298					
	Panumbangan	3,996	158					
	Ciamis	2,394	131					
	Panjalu	5,118	141					
	Cijeungjing	1,908	55	-	-	-	-	
	Subtotal	23,021	1,158	1,171	126	4	-	25,480

TABLE A-13

DISTRIBUTION OF LAND OWNERSHIP STATUS BY DISTRICT AND SUBDISTRICT FOR CITANDUY WATERSHED SUBBASIN

(Hectares)

District	Subdistrict	Private Land	Government Land	Forest Government Land	Pasture Land	Land Use Rights	Land in Dispute	Total Area
Total Upper Citanduy		61,367	1,350	8,902	126	625	640	73,010
	Percent	84.1	1.8	12.2	0.2	0.9	0.9	100.0
Cimuntur Subbasin								
Ciamis	Ciamis	9,575	523	28	30	15	-	10,171
	Buniseuri	6,329	249	851	38	-	-	7,467
	Panjalu	5,117	141	8	103	-	-	5,369
	Panawangan	1,638	36	50	21	-	-	1,745
	Kawali	6,326	242	50	71	507	-	7,196
	Rajadesa	6,333	81	287	78	-	-	6,779
	Cisaga	5,852	340	1,334	37	610	-	8,173
	Rancah	5,890	85	291	152	-	-	6,418
	Cijeunjing	5,722	166	-	-	-	-	5,888
Total Cimuntur Subbasin		52,782	1,863	2,899	530	1,132	-	59,206
	Percent	89.1	3.1	4.9	0.9	1.9	-	100.0

TABLE A-13

DISTRIBUTION OF LAND OWNERSHIP STATUS BY DISTRICT AND SUBDISTRICT FOR CITANDUY WATERSHED SUBBASIN

(Hectares)

District	Subdistrict	Private Land	Government Land	Forest Government Land	Pasture Land	Land Use Rights	Land in Dispute	Total Area
Cijolang Subbasin								
Ciamis	Rancah	5,891	85	290	152	-	-	6,418
	Cisaga	2,927	170	667	19	304	-	4,087
	Rajadesa	2,111	27	96	26	-	-	2,260
	Panawangar	6,552	146	202	82	-	-	6,982
	Subtotal	17,481	428	1,255	279	304	-	19,747
Cilacap	Dayeuhluhur	8,844	318	7,673	-	-	-	16,835
Kuningan	Selajambe	1,922	136	850	142	-	-	3,050
	Subang	4,774	1,114	1,835	292	-	-	8,015
	Subtotal	6,696	1,250	2,685	434	-	-	11,065
Total Cijolang Subbasin		33,021	1,996	11,613	713	304	-	47,647
	Percent	69.3	4.2	24.4	1.5	0.6	-	100.0

TABLE A-13

DISTRIBUTION OF LAND OWNERSHIP STATUS BY DISTRICT AND SUBDISTRICT FOR CITANDUY WATERSHED SUBBASIN

(Hectares)

District	Subdistrict	Private Land	Government Land	Forest Government Land	Pasture Land	Land Use Rights	Land in Dispute	Total Area
Cikawung Subbasin								
Cilacap	Wanareja	14,132	369	1,995	-	-	-	16,496
	Majenang	11,285	273	2,284	-	-	-	13,842
	Cimanggu	10,900	490	7,729	-	-	-	19,119
	Sidareja	2,970	110	1,347	-	-	-	4,427
	Karangpucung	7,759	80	3,411	-	-	-	11,250
	Kedung Reja	2,087	27	1,715	-	-	-	3,829
	Gandrungmangu	394	15	185	-	-	--	594
Total Cikawung Subbasin		49,527	1,364	18,666	-	-	-	
	Percent	71.2	2.0	26.8	-	-	-	
Ciseel Subbasin								
Tasikmalaya	Manonjaya	428	4	87	-	10	7	536
	Cineam	7,244	202	1,572	-	407	116	9,541
	Subtotal	7,672	206	1,659	-	417	123	10,077

TABLE A-13

DISTRIBUTION OF LAND OWNERSHIP STATUS BY DISTRICT AND SUBDISTRICT FOR CITANDUY WATERSHED SUBBASIN

(Hectares)

District	Subdistrict	Private Land	Government Land	Forest Government Land	Pasture Land	Land Use Rights	Land in Dispute	Total Area
Ciamis	Banjar	9,169	4	77	-	1,627	-	10,877
	Banjarsari	15,527	-	222	559	1,549	-	17,857
	Lakbok	8,051	-	-	18	220	-	8,289
	Cimaragas	9,489	39	87	116	-	-	9,731
	Pamarican	15,395	51	1,393	483	270	-	17,592
	Padaherang	13,277	-	-	550	330	-	14,157
	Kalipucang	5,066	-	1,606	262	418	-	2,352
	Subtotal	75,974	94	3,385	1,988	4,414	-	85,855
Total Ciseel Subbasin		83,646	300	5,044	1,988	4,831	123	95,932
	Percent	87.2	0.3	5.3	2.1	5.0	0.1	100.0
Summary								
Upper Citanduy Subbasin		61,367	1,350	8,902	126	625	640	73,010
Cimuntur Subbasin		52,782	1,863	2,899	530	1,132	-	59,206
Cijolang Subbasin		33,021	1,996	11,613	713	304	-	47,647
Cikawung Subbasin		49,527	1,364	18,666	-	-	-	69,557
Ciseel Subbasin		83,646	300	5,044	1,988	4,831	123	95,932
Total Citanduy Watershed		280,343	6,873	47,124	3,357	6,892	763	345,352
Percent		81.2	2.0	13.6	1.0	2.0	0.2	100.0

TABLE A-14

TECHNICAL IRRIGATION SYSTEMS IN THE CITANDUY WATERSHED - 1979 AND POTENTIAL

Project	District	Water Sources	Irrigation areas 1979	Irrigation areas Potential
			(Hectares)	(Hectares)
UPPER CITANDUY SUBBASIN				
Cimulu	Tasikmalaya	Ciloseh River	1,950	2,087
Cipalih	Ciamis	Cipeuteuy	730	730
Citanduy Indihiang	Tasikmalaya	Citanduy	309	500
Cikalong	Tasikmalaya	Cikalong River	110	156
Cigede	Tasikmalaya	Cigayam River	869	884
Cigayam	Ciamis	Cigayam River	382	382
Ciloganti	Ciamis	Ciloganti	220	220
Cimarongmong	Ciamis	Cimarongmong	189	189
Banjar Plain	Ciamis	Citanduy River		785
Total			4,759	5,933
CIMUNTUR SUBBASIN				
Wangundireja	Ciamis	Ciliung River	376	376
CIJOLANG SUBBASIN				
Jagabaya	Ciamis	Jagabaya	600	600
Rawa Onom	Ciamis	Cijolang	800	949
Panulisan	Cilacap	Cijolang		574
Total			1,400	2,123
CIKAWUNG SUBBASIN (Including Wanareja Sub area)				
Cileumeuh	Cilacap	Cileumeuh River	1,159	1,471
Cilopadang	Cilacap	Cilopadang River	221	221
Cijalu	Cilacap	Cijalu River	1,262	1,262
Cilaca	Cilacap	Cilaca River	626	839
Total			3,268	3,793
CISEEL - LOWER CITANDUY SUBBASIN				
Citalahab	Ciamis	Citalahab River	546	546
Gunung Putri 1	Ciamis	Ciseel River	433	433
Gunung Putri 2	Ciamis	Citalahab	575	575
Cikaso	Ciamis	Cikaso River	290	469
Ciputrahaji	Ciamis	Ciputrahaji River	1,385	1,385
North Lakbok	Ciamis	Citanduy River	5,700	7,033
South Lakbok	Ciamis	Citanduy River		2,500
Total			8,929	12,941
Citanduy Watershed Total			18,732	25,166

Source: From ECI Design Reports, ECI Master Plan and I&D Division Investigations.

TABLE A-15

RICELAND AREAS BY WATER SOURCE FOR CITANDUY WATERSHED

SUBBASIN BY DISTRICT AND SUBDISTRICT

District	Subdistrict	Technical	Rural	Rainfed	Total	Irrigated in Dry Season
Ciseel Subbasin						
Tasikmalaya	Manonjaya			125	125	
	Cineam		480	498	978	430
	Subtotal		480	623	1,103	430
Ciamis	Cimaragas		663	563	1,226	530
	Pamarican	1,554	1,301	838	3,693	1,789
	Banjar	1,576	295	1,011	2,882	750
	Banjarsari	1,675	212	820	2,707	1,317
	Lakbok	4,124	641	1,257	6,022	3,000
	Padaherang		799	3,154	3,953	260
	Kalipucang		123	489	612	48
	Subtotal	8,929	4,034	8,132	21,095	7,694
Total Ciseel Subbasin		8,929	4,514	8,755	22,198	8,124
Summary						
Upper Citanduy Subbasin		4,759	11,429	6,671	22,859	11,419
	Percent	20.8	50.0	29.2	100.0	50.0
Cimuntur Subbasin		376	8,342	3,111	11,829	6,271
	Percent	3.2	70.5	26.3	100.0	53.0
Cijolang Subbasin		1,400	4,101	4,446	9,947	3,439
	Percent	14.1	41.2	44.7	100.0	34.6
Cikawung Subbasin		3,268	8,381	8,320	19,969	4,658
	Percent	16.4	42.0	41.6	100.0	23.3
Ciseel Subbasin		8,929	4,514	8,755	22,198	8,124
	Percent	40.2	20.3	39.5	100.0	36.6
Total Citanduy Watershed		18,732	36,767	31,303	86,802	33,911
	Percent	21.6	42.4	36.0	100.0	39.1

TABLE A-15 (Cont'd)

RICELAND AREAS BY WATER SOURCE FOR CITANDUY WATERSHED

SUBBASIN BY DISTRICT AND SUBDISTRICT

District	Subdistrict	Technical	Rural	Rainfed	Total	Irrigated in Dry Season
Cijolang Subbasin						
Ciamis	Rancah	258	739	350	1,347	728
	Cisaga	542		130	672	251
	Rajadesa		267	216	483	211
	Panawangan	600	885	435	1,920	1,144
	Subtotal	1,400	1,891	1,131	4,422	2,334
Cilacap	Dayeuhluhur		880	1,319	2,199	440
Kuningan	Selajambe		522	784	1,306	261
	Subang		808	1,212	2,020	404
	Subtotal		1,330	1,996	3,326	665
Total Cijolang Subbasin		1.400	4,101	4,446	9,947	3,439
Cikawung Subbasin						
Cilacap	Wanareja	626	1,365	1,422	3,413	796
	Majenang	1,483	1,400	616	3,499	1,153
	Cimanggu	1,159	2,064	1,938	5,161	1,289
	Sidareja		475	582	1,057	190
	Karangpucung		1,993	2,435	4,428	800
	Kedungreja		1,084	1,327	2,411	430
	Gandrungmangu					
Total Cikawung Subbasin		3,268	8,381	8,320	19,969	4,658

TABLE A-15 (Cont'd)

RICELAND AREAS BY WATER SOURCE FOR CITANDUY WATERSHED

SUBBASIN BY DISTRICT AND SUBDISTRICT

District	Subdistrict	Technical	Rural	Rainfed	Total	Irrigated in Dry Season
Upper Citanduy Subbasin						
Tasikmalaya	Pager Ageung		1,000	1,431	2,431	400
	Ciawi		2,101	292	2,393	1,314
	Rajapolah		1,030	1,046	2,076	764
	Cisayong		1,061	1,542	2,603	815
	Indihiang	1,379	1,690	332	3,401	2,381
	Tasikmalaya	550		32	582	500
	Cibeureum	1,110	385	663	2,158	1,330
	Manonjaya	179	829	343	1,351	593
	Cineam	20		50	70	20
	Subtotal	3,238	8,096	5,731	17,065	8,117
Ciamis	Cihaurbeuti	180	684	303	1,167	431
	Cikoneng	791	598	172	1,561	1,030
	Panumbangan		1,033	104	1,137	537
	Ciamis	450		29	479	400
	Panjalu		918	274	1,192	739
	Cijeunjing	100	100	58	258	165
	Subtotal	1,521	3,333	940	5,794	3,302
Total Upper Citanduy		4,759	11,429	6,671	22,859	11,419
Cimuntur Subbasin						
Ciamis	Ciamis		1,551	364	1,915	1,104
	Buniseuri		1,304	191	1,495	1,064
	Panjalu		894	298	1,192	721
	Panawangan		480		480	270
	Kawali		1,040	796	1,836	676
	Rajadesa		971	479	1,450	768
	Cisaga	376	432	535	1,343	503
	Rancah		1,062	284	1,346	1,000
	Cijeunjing		608	164	772	165
Total Cimuntur Subbasin		376	8,342	3,111	11,829	6,271

TABLE A-16

PRODUCTION OF PALAWIJA CROPS FOR CIAMIS DISTRICT 1976-1978

(Tons)

Subdistrict	1976/1977						1977/1978						Average		
	Ha	Corn	Sweet Potato	Peanut	Soybeans	Total yield	Area ha	Corn	Sweet Potato	Peanut	Soybeans	Total yield	Ha	Total yield	Ave. Yield kg/ha
Ciamis	564	125.8	1,047.0	41.0	18.7	1,232.5	278	28.4	627.5	41.7	1.4	699.0	421	965.8	2,294
Cikoneng	260	39.2	468.6	19.8	27.3	554.9	265	10.4	676.6	13.8	30.0	730.8	263	642.9	2,444
Cijeungjing	133	30.1	220.0	26.0	7.7	283.8	281	39.0	385.5	61.9	27.5	513.9	207	398.9	1,927
Panumbangan	485	257.3	364.4	50.9	3.8	676.4	263	93.6	478.1	5.4	0.7	577.8	374	627.1	1,677
Panjalu	335	62.2	534.6	78.4		675.2	517	195.8	482.9	61.3		739.9	426	707.6	1,661
Panawangan	1,180	834.3	548.7	73.4	97.5	1,553.9	1,424	576.2	1,690.8	87.2		2,354.3	1,302	1,954.1	1,501
Rajadesa	756	296.0	722.3	125.6	30.5	1,174.4	970	234.9	266.7	218.4	12.3	732.3	863	953.4	1.105
Cihaurbeuti	207	45.9	461.8	3.5		511.2	179	34.7	447.7			482.4	193	496.8	2,574
Kawali	320	57.8	369.5	49.1		476.4	229	63.4	391.8	23.4		478.6	274	477.5	1,743
Cipaku	52	25.1		23.2		48.3	98	20.8	149.6	22.1		192.5	75	120.4	1,605
Rancah	733		1,255.8	276.0		1,531.8	716	121.8	1,006.1	227.1	23.3	1,378.3	724	1,455.1	2,010
Cisaga	1,713	404.2	3,562.5	97.5		4,064.2	1,595	73.7	4,291.0	233.4	10.4	4,608.5	1,654	4,336.4	2,622
Banjar	2,091	697.3	3,118.5	287.8	131.1	4,234.7	2,496	549.3	1,734.6	758.9	283.3	3,326.1	2,294	3,780.4	1,648
Banjarsari	4,565	3,241.8	1,243.1	465.5	395.4	5,345.8	3,755	2,453.3	447.9	562.2	278.2	3,742.3	4,160	4,544.1	1,092
Lakbok	978	178.8	768.4	328.6	218.0	1,493.8	744	184.6	158.9	219.2	283.3	846.0	861	1,169.9	1,359
Cimaragas	375	119.4	225.1	99.1	2.1	445.7	310	73.7	364.2	108.4	3.2	549.5	343	497.6	1,451
Pamarican	906	276.2	312.1	370.0	51.4	1,009.7	1,168	137.4	387.4	801.2	10.2	1,336.2	1,037	1,173.0	1,131
Padaherang	1,903	772.6	478.1	287.9	519.4	2,058.0	1,924	561.8	471.4	581.6	301.5	1,916.3	1,914	1,987.2	1,038
Kalipucang	855	490.0	233.9	124.8	22.1	870.8	1,647	708.3	129.3	479.4	107.8	1,425.1	1,251	1,148.0	918
Total	18,411	2,954.0	15,934.4	2,828.1	1,525.0	28,241.5	18,859	6,161.4	14,588.0	4,506.6	1,373.8	26,629.8	18,636	27,436.2	1,472

Source : District Planning Office Records, Ciamis

TABLE A-17
PRODUCTION AND YIELD OF CASSAVA IN THE CIAMIS DISTRICT

Subdistrict	1976/1977 Area (ha)	1976/1977 Yield kg/ha	1976/1977 Production tons	1977/1978 Area (ha)	1977/1978 Yield kg/ha	1977/1978 Production tons	Average Area (ha)	Average Yield kg/ha	Average Production tons
Ciamis	1,229	6,426	7,898.66	847	6,837	5,833.29	1,038	6,615	6,865
Cikoneng	780	6,766	5,277.90	1,205	6,464	7,789.52	992	6,586	6,534
Cijeunjing	898	7,138	6,410.64	1,239	7,272	9,010.01	1,069	7,212	7,710
Panumbangan	560	6,354	3,558.70	773	7,490	5,789.77	666	7.018	4,674
Panjalu	690	7,743	5,354.40	727	6,834	4,968.32	709	7.280	5,161
Panawangan	573	6,963	3,990.40	962	7,588	7,299.66	767	7,360	5,645
Rajadesa	1,482	7,539	11,174.84	816	7,185	5,860.96	1,149	7,413	8,518
Cihaurbeuti	370	6,867	2,541.40	479	7,184	3,440.18	425	7,037	2,991
Kawali	1,498	6,612	9,905.32	1,183	7,201	8,518.78	1,340	6,875	9,212
Cipaku	1,010	6,489	6,554.50	875	7,379	6,450.62	942	6,903	6,503
Rancah	1,342	6,222	8,349.58	794	7,310	5,804.14	1,068	6,626	7,077
Cisaga	3,706	7,757	28,749.70	784	7,780	6,099.52	2,245	7,762	17,425
Banjar	1,521	7,256	11,036.23	3,663	7,299	26,736.24	2,592	7,286	18,886
Banjarsari	2,504	7,153	17,711.11	4,053	8,237	33,384.56	3,278	7,794	25,548
Lakbok	965	7,063	7,816.00	1,015	7,640	7,754.60	990	7,864	7,785
Cimaragas	1,976	7,134	14,197.78	3,279	7,710	25,281.69	2,628	7,511	19,740
Pamarican	1,660	7,001	11,621.40	3,203	7,825	25,063.47	2,432	7,542	18,343
Padaherang	1,458	7,560	11,023.20	1,757	6,625	13,397.13	1,608	7,593	12,210
Kalipucang	1,237	7,100	8,783.24	1,719	7,710	13,253.49	1,478	7,455	11,018
Total	25,459	7,147	181,955.30	29,373	7,346	221,736.95	27,416	7,362	201,846

TABLE A-18

PRODUCTION AND YIELD OF CROPS IN CIAMIS DISTRICT
1977-78

Description	Units	1977	1988	Average
Corn				
Area Harvested	ha	6,767	9,224	7,995
Production	ton	5,515.7	7,023.6	6,269.6
Production per ha	kg	815	761	784
Cassava				
Area Harvested	ha	40,228	37,340	38,784
Production	ton	302,540	277,568	290,054
Production per ha	kg	7,521	7,433	7,479
Sweet Potato				
Area Harvested	ha	5,381	5,401	5,391
Production	ton	19,554	19,736	19,645
Production per ha	kg	3,633	3,654	3,644
Peanuts				
Area Harvested	ha	7,228	4,302	5,765
Production	ton	6,535	3,313	4,924
Production per ha	kg	904	770	854
Soybean				
Area Harvested	ha	1,314	1,084	1,199
Production	ton	1,077.7	835.8	956.7
Production per ha	ka	835	771	798
Green Bean				
Area Harvested	ha	98	40	69
Production	ton	70.0	28.4	49.2
Production per ha	kg	835	771	713
Total Area Harvested	ha	61,016	57,391	59,203

Source: Kecamatan Records from Agricultural Service Ciamis District

TABLE A-19

CITANDUY WATERSHED GREENING PROGRAM
OF TERRACING AND PLANTING FOR THE 1972-77 PERIOD

Number	District/Sub District	1972/1973 (Ha)	1973/1974 (Ha)	1974/1975 (Ha)	1975/1976 (Ha)	1976/1977 (Ha)	1977/1978 (Ha)	Total (Ha)
1	2	3	4	5	6	7	8	9
	Ciamis							
1.	Cimaragas	75	-	638	-	600	400	1,703
2.	Cisaga	165	-	-	250	1,900	100	2,415
3.	Rancah	130	180	-	-	1,650	500	2,460
4.	Panawangan	163	150	-	340	200	700	1,553
5.	Pamarican	157	250	2,072	2,201	1,500	700	6,880
6.	Banjarsari	-	-	1,790	656	1,500	-	3,946
7.	Cikoneng	153	-	-	-	-	-	153
8.	Ciamis	200	-	-	-	-	-	200
9.	Padaherang	285	-	-	1,647	1,200	-	3,132
10	Kalipucang	-	-	-	496	300	-	796
11.	Banjar	132	-	-	-	697	-	829
12.	Rajadesa	147	140	-	-	-	950	1,237
13.	Kawali	120	150	-	-	100	850	1,220
14.	Panjalu	170	180	-	-	300	600	1,250
15.	Cipaku	90	-	-	-	-	550	640
16.	Panumbangan	240	130	-	-	193	-	563
17.	Cihaurbeuti	135	-	-	-	-	-	135
	T o t a l	2,362	1,180	4,500	5,590	10,140	5,350	29,122

TABLE A-19 (Cont'd)

CITANDUY WATERSHED GREENING PROGRAM
OF TERRACING AND PLANTING FOR THE 1972-77 PERIOD

Number	District/Sub District	1972/1973 (Ha)	1973/1974 (Ha)	1974/1975 (Ha)	1975/1976 (Ha)	1976/1977 (Ha)	1977/1978 (Ha)	Total (Ha)
	Tasikmalaya							
1.	Pagerageung	583	400	-	-	900	800	2,683
2.	Ciawi	-	-	500	500	-	450	1,450
3.	Cibeureum	-	-	-	-	-	750	750
4.	Manonjaya	389	-	400	1,000	625	-	2,414
5.	Cineam	420	780	1,600	2,000	1,625	-	6,425
6.	Indihiang	-	-	-	-	100	-	100
	- - -	1,392	1,180	2,500	3,500	3,250	2,000	13,822
	Kuningan							
1.	Subang	-	-	-	-	100	1,865	1,965
2.	Ciniru	-	-	456	305	1,510	400	2,671
	T o t a l	-	-	456	305	1,610	2,265	4,636
	Cilacap							
1.	Dayeuhluhur	-	-	-	400	1,500	1,600	3,200
2.	Wanareja	-	-	450	-	100	950	1,500
3.	Majenang	-	-	-	-	-	750	750
4.	Cimanggu	-	-	-	-	-	400	400
	T o t a l	3,754	2,360	7,905	9,795	16,600	3,700	6,150
	Total Citanduy Watershed	3,754	2,360	7,905	9,795	16,600	13,315	53,730

Source: Citanduy - Cisanggarung Reforestation and Greening Program Guidance and Planning Project.

TABLE A-20

PLANNED 1978-79 GREENING PROGRAM IN THE CITANDUY WATERSHED

Number	District/Sub District	Terracing (Ha)	Planting (Ha)	Total (Ha)
	Ciamis			
1.	Cimaragas	406	45	451
2.	Cisaga	-	398	398
3.	Rancah	111	34	145
4.	Panawangan	163	102	265
5.	Rajadesa	557	397	954
6.	Kawali	45	193	238
7.	Panjalu	677	35	712
8.	Panumbangan	207	-	207
9.	Pamarican	373	176	549
10.	Padaherang	342	-	342
11.	Banjarsari	171	-	171
12.	Kalipucang	532	151	683
	T o t a l	3,584	1,531	5,115

TABLE A-20 (Cont'd)

PLANNED 1978-79 GREENING PROGRAM IN THE CITANDUY WATERSHED

Number	District/Sub District	Terracing (Ha)	Planting (Ha)	Total (Ha)
1	2	3	4	5
	Tasikmalaya			
1.	Ciawi	212	18	230
2.	Cibeureum	346	118	464
	T o t a l	558	136	694
1.		198	44	242
2.		202	17	229
		400	61	461
	Cilacap			
1.	Wanareja	1,364	543	1,907
2.	Majenang	673	342	1,016
3.	Cimanggu	3,038	1,278	4,316
4.	Karangpucung	989	362	1,351
	T o t a l	6,064	2,525	8,596
	Total Citanduy Watershed	10,606	4,253	14,860

Source: Citanduy - Cisanggarung Reforestation and Greening Program Guidance and Planning Project.

APPENDIX B

PROJECT DEVELOPMENT AND STRUCTURAL COST ESTIMATES

APPENDIX B

PROJECT DEVELOPMENT AND STRUCTURAL COST ESTIMATES

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TABLE B-1

ESTIMATED COST FOR ONE COMPLETE METEOROLOGICAL STATION

Item	Per Station Quantity	Rp. Cost
Automatic raingage with tipping b	1	230,000
Manual raingages	6	47,725
Charts for raingage (Belfort)	24 boxes	47,725
Evaporation pan inducting wall, n thermometer	1	238,625
Sunshine duration recorder (Campb	1	133,630
Wind recorder with parts	1	1,674,810
Maximum-Minimum thermometers (Tow	6	35,794
Sling Psychometer electric	2	43,907
Shelter for thermometers	1	150,437
Water supply tank (200 liters)	1	11,500
Wind direction charts C123-D	24 rolls	47,725
Wind speed charts C123-S	24 rolls	47,725
Chart 0-40 degrees 1 year C431-A	2 sets	9,545
Thermometers HM-1AC-R	6	24,544
Enclosure fence, 11 gage steel link wire metal post set in concrete (6 meters x 10 meters including foundation for each instrument)	1	287,500
		3,031,202
Contingencies 10%		454,680
Total		3,485,88[illegible]

TABLE B-2

COST ESTIMATE FOR AUDIO VISUAL EQUIPMENT FOR TRAINING PROGRAM

1. A complete Betamax Color TV Video Equipment set, comparable to the Sonny 3100 System, including Camera, Recorder, Tape Cassette Component, TV Receiver Blank Video Cassette Tapes (3 hour and 1 hour programs) and Accessory and Auxillary Equipment.

	U.S. $	Rupiah
Basic Set SL 3100	1,145.00	715,625
HVC 1100	1,145.00	715,625
TT 3100	350.00	218,750
Y	499.00	311,875
	3,139.00	1,961,875
Tapes, Color, Betamax, 3 hours and 1 hour		
175 ea, 3 hours, at 26.40	4,620.00	2,887,500
500 ea, 1 hour, at 14.30	7,150.00	4,468,750
	11,770.00	7,356,250
Accessory Equipment Sonny		
1. JX-1	315.00	196,875
3. LC-3100	65.00	40,625
5. RP-60	45.00	28,125
6. TV 301 V	210.00	131,250
7. AH 350	15.00	9,375
8. AC 301 C	100.00	62,500
9. VCR 3	175.00	109,375
10. LC 1100	28.00	17,500
13. AL 77 (2)	148.00	92,500
14. HVL 77 (2)	98.00	61,250
15. XB 250 (10)	125.00	78,125
16. SAD 250 (10)	75.00	46,875
17. CMA 110 (2)	158.00	98,750
18. ECM 31 HCV (2)	80.00	50,000
19. SAD 40 (2)	10.00	6,250
20. VCL 110 (10)	65.00	40,625
	1,712.00	1,070,000
2. Overhead Projector		
Gakken, GDJ 628w	600.00	375,000
Transparencies		
5 boxes	140.00	87,500
5 rolls	160.00	100,000
	900.00	562,500
3. 8 MM Sound Movie Equipment		
Canon 514 XLS Sound Movie Camera with carryring case	388.00	242,500
Canon PS 100 Sound Projector with carrying case	377.00	235,625
Goko PM 2 Sound Editor with carrying case	184.00	115,000
Stitz Tripod, TP 3 CDX	110.00	68,750
	1,059.00	661,875
Total estimated Cost	18,580.00	11,612,500
Contingencies (30 percent)	5,570.00	3,481,250
T o t a l	24,150.00	15,093,750

Note : Items to be purchased by USAID direct purchase are to be of American Manufacture and of comparable quality and performance to the following listed equipment from Japanese Catalogs. Equipment should operate on 110 Volts, 50 cycle electric current.

TABLE B-3

ESTIMATED COST OF MISCELLANEOUS TOOLS FOR KABUPATEN CIAMIS

(Rupiah)

Equipment	Cost per Unit	Units	Total Cost
Cangkul	1,500	650	975,000
Other Tools for Terracing	2,500	100	250,000
Survey instruments (level with tripod Model Kern GKT)	498,000	9	4,482,000
Abney Hand Levels	80,000	40	3,200,000
Simple Water Levels	4,000	80	320,000
Hand Scales 50 kg	30,000	20	600,000
Measuring Tape 50 m	30,000	20	600,000
Subtotal			10,427,000
Contingencies @ 25%			2,607,000
Total			13,034,000

TABLE B-4

COST ESTIMATE FOR DETAILED SOIL SURVEYS 1/

		Rupiah
1. Labor Cost		
One technical (Team Leader) for one day		1,600
Two non-technical for one day (700 Rp./day x 2)		1,400
	Labor Cost	3,000
2. Equipment Cost 2/		
Utilize one Pickup for one day and soil survey equipment estimated at 5,000 Rp./day		5,000
3. Laboratory Analysis 3/		
Assume 5 ha. per sample to be analyzed $= \frac{4 \text{ has./day}}{5 \text{ has/sample}} \times \frac{3{,}000 \text{ Rp./sample}}{}$		2,400
	Total Estimated Cost	10,400
	Contingencies (7%)	728
	Superv. & Adm. (10%)	1,112
	Total Cost	12,240
Average Cost per Hectare $= \frac{12{,}240}{4} =$		3,060

4. Assuming 200 field days per year, each soil survey team could provide detailed soil surveys on 800 ha per year at the rate of 4 ha per day.

1/ Auger boring density is 20 borings per hectare, for noncropland 10 borings per hectare. A team could accomplished an average area of 4 hectares per day.

2/ Includes transport vehicle and soil survey equipment.

3/ Laboratory analysis includes chemical, physical & engineering analysis.

TABLE B-5

BENCH TERRACING COST ESTIMATE
25% SLOPE AND 120 cm VERTICAL INTERVAL

Item	Unit	Unit Cost Rp.	Quantity	Cost Rp/ha
Labor				
Field Preparation-Surveying	md	500	64	32,000
Staking Fields	md	500	8	4,000
Terrace Construction 1/		500	455	227,500
Constructing Waterways and Diversions	md	500	55	27,500
Constructing Drop Structures	md	500	65	32,500
Revegetating Waterways and Terrace Risers	md	500	73	36,500
Total Labor			720	360,000
Materials				
Bamboo for Drops and Staking	pc	50	600	30,000
Stone 2/	m^3	3,700	7.0	25,900
Grass for Sodding Risers and Waterways	m^2	12	3,000	36,000
Total Materials				91,900
Total Cost Estimate				451,900
Contingencies (5%)				22,600
Engineering Design (5%)				23,700
Engineering Supervision and Administration (10%)				49,800
Total Cost				548,000

1/ Based on 455 md/ha from Panawangan terracing, on approximately 1/2 of 1,356 m^3/ha at the rate of 1.5 m^3/md, based on the fact that most areas are partially terraced.

2/ Stone cost estimated at 1,200 Rp/m^3 cost, plus hauling 10 km @ 250 Rp/km/m^3 = 2,500 Rp, for total of 3,700 Rp/m^3.

TABLE B-6

COST ESTIMATE PER HECTARE FOR CRITICAL AREA PLANTING

WITH GRASS AND BRANCH CUTTINGS

Item	Unit	Unit Cost	Quantity	Cost Rp./Ha
Materials				
Grass for sprigging	m^2	12	10,000	120,000
Brushwood	pc	5	25,000	125,000
Fertilizer	kg	70	500	35,000
Hauling materials for 10 km @ 250 Rp/m^3/km	m^3	2,500	25	62,500
Total Materials				342,500
Labor				
Land Preparation	md	500	100	50,000
Sprigging	md	500	117	58,500
Brushwood planting	md	500	100	50,000
Total Labor			317	158,500
Total Estimated Cost				501,000
Contingencies (5%)				25,050
Engineering Design (1%)				5,260
Eng. Supervision & Adm. (2%)				10,630
Total Cost				541,940

This is equivalent to Rp. 55 per m^3 for critical area planting on small areas.

TABLE B-7

COST ESTIMATE FOR A KILOMETER OF DIVERSION 1/

	Rupiah/km
Materials	
Grass for sodding 2,000 m^2 @ 1. Rp./m^2	24,000
Stone for drops 3.0 m^3 @ 5,000 Rp./m^3	15,000
Bamboo 135 pcs. @ 200 Rp./pc.	27,000
Hauling materials 6 m^3 for 20 km @ 250 Rp./km/m^3	30,000
Total Materials	96,000
Labor	
Excavation 408 m^3 @ 2 m^3/md = 204 md @ 500 Rp. 2/	102,000
Trimming estimated at 26 md @ 500 Rp.	13,000
Sprigging 2,000 m^2 @ 50m^2/md = 40 md @ 500 Rp.	20,000
Total Labor	135,000
Total Estimated Cost	231,000
Contingencies (5%)	11,550
Engineering Design (5%)	12,100
Engineering Supervision and Administration (10%)	25,450
Total Cost	280,100

1/ Design criteria was 10 year frequency rainfall of 76 mm/hr and a runoff coefficient of 0.25 (Q = 2.78 CIA) = 52.8 l/s/ha. Assuming the average area drained by the diversion to be 5.5 ha the capacity requirement would be 290 L/S.

2/ Typical parabolic grassed waterway with a top width (t) of 1.7 meters and a channel depth (d) of 0.30 meters that would have an area of 0.34 m^2 (A = 2/3 td) and a peak discharge capacity (Q) of about 300 L/S with a velocity of 0.88 m/s.

TABLE B-8

GULLY HEADCUT TREATMENT 1/

DETAILED ESTIMATE FOR RUBBLE MASONRY

(ESTIMATED AVERAGE VOLUME 7.0 m^3)

Materials		
Cement	= 40 kg sks @ 2,000 Rp./sk x 6 sks	12,000
Sand	= 2 m^3 @ 2,200 Rp./m^3	4,400
Rubbles	7 m^3 @ 2900 Rp./m^3	29,300
Delivery of materials 20 km @ 225 Rp./km/m^3 for an estimated 9 m^3		40,500
		86,200
Labor Cost		
Hauling of material from the main dump to the site 4 mandays at 500 Rp.		2,000
Construction of rubble masonry 1 mason with 4 helpers @ 3.5 days = 17.5 md at 500 Rp.		8,750
Excavation est. 10 m^3 1 foremen + 5 laborers for 2 days = 12 md at 500 Rp.		6,000
Backfilling, 2 mandays at 500 Rp.		1,000
	Labor Cost	17,750
	Total Estimated Cost	103,950
Contingencies (5%)		5,200
Engineering Design (5%)		5,450
Engineering Supervision & Administration (10%)		11,500
	Total	126,100

1/ Headcut treatment structures assumed to control a gully head with an average depth of 2 meters and 7 meters wide with an average volume of 7 m^3.

TABLE B-9

COST ESTIMATES FOR GULLY CONTROL LOOSE ROCK DROP/CHECKS 1/

(ESTIMATED AVERAGE VOLUME 4.5 M^3)

Materials	Rupiah/Structure
4.5 m^3 of boulders @ 5000 Rp./m^3 2/	22,500
Labor	
1. Excavation and Triming of surfaces, Vol. = 3,0 m^3 utilize 3 laborers @ 1m^3/md = 3 md.	
2. Hauling of boulders from dumping area to the site utilize 3 laborers @ 1.5m^3/d for 4.5 m^3 = 3 md	
3. Laying of boulders 3 laborers @ 1.5 m^3/d for 4.5 m^3= 3 md	
4. Backfilling, compaction and revegetation 2 man days	
Total 11 man days at 500 Rp./manday	5,500
Total Estimated Cost	28,000
Contingencies 5%	1,400
Engineering Designs 5%	1,470
Eng'g Supervision & Administration 10%	3,090
Total	33,960

1/ This loose rock check/drop structure has an average effective dam height of 1.20 meters; average dimensional values taken from .30 m to 2.10 m, as minimum and maximum height respectively, and with an average volume of 4.5 m^3/ structure.

2/ Based on a cost of 2,900 Rp./m^3 plus 2,100 Rp./m^3 for hauling to dump site

TABLE B-10

COST ESTIMATES FOR GULLY CONTROL BY SMALL ROCK DROP/CHECKS (1.0 m^3)

	Rupiah/Structure
Materials	
1 cu. m. of boulders 5,000 Rp. at site 1/	5,000
Labor	
Excavation and trimming of surfaces vol. = 0.7 m^3, will require about 1 manday of labor	
Hauling of boulders from dumping to the site will utilize 1 laborer @ 1.5 cu. m. per day per laborer = 0.67 manday	
Laying of boulders, backfilling and compaction will require approximately 1.33 mandays labor.	
Total labor 2.7 md at 500 Rp.	1,350
Total Estimated Cost	6,350
Contingencies (5%)	320
Engineering Design (5%)	330
Engineering Supervision and Administration (10%)	700
Total Cost	7,700

1/ Based on a cost of 2,900 Rp./m^3, plus 2,100 Rp./m^3 for hauling to the dump site.

TABLE B-11

GULLY HEADCUT OR STREAMBANK EROSION TREATMENT 1/
COST ESTIMATE FOR GABION RETAINING WALL
(Estimated Volume 7 m^3)

	Rupiah/structure
Material Costs	
Boulders at 2,900/Rp/m^3 x 7 m^3	20,300
Material for Gabions	
Dimension = 1.2 m x 0.80 m x 0.50 m = 0.40 m^3	
No. of Gabions = $\frac{7}{0.48}$ = 14.6 units say 15 units	
Estimated at 7 kg of wire/gabion @ 400 Rp./kg	2,800
Total Cost of Materials	23,100
Hauling	
Estimated hauling of 7.5 m^3 for 20 km @ 225 Rp/km/m^3	33,750
Labor Cost	
Cost of excavation (3 man-days @ 500 Rp.)	1,500
Fabrication of 15 gabions, 4 laborers with output of 5 gabions/day(4 x $\frac{15}{5}$ x Rp. 500)	6,000
Hauling boulders to site from main dump, 4 laborers with capacity of 1.5 m^3 per laborer = 4 x 1.5 x Rp. 500/md	3,000
Filling and laying of gabions, one supervisor and 5 laborers with a capacity of 5 gabions per day (Labor = 6 x $\frac{15}{5}$ x 500 Rp.)	9,000
Backfilling & Compaction	
Backfilling 2 laborers, (V = 3 m^3) $\frac{3}{1.5}$ (m^3/d/laborer)= 2 mandays at 500 Rp.	1,000
Total Labor Cost	17,500
Total Estimated Cost	74,350
Contingencies (5%)	3,700
Engineering Design (5%)	3,900
Engineering Supervision & Administration (10%)	8,200
Total	90,150

1/ A gully headcut with average dimensions of 2 m deep by 6 m wide will require an average volume of 7 m^3 of gabions.

TABLE B-12
COST ESTIMATE FOR THE CONSTRUCTION
BAMBOO WATTLE CHECKS[1/]

Average height and width of check = 0.40 m x 2 m

	Rupiah/structure
Materials	
16 pcs. of bamboo at 200 Rp./pc.	3,200
2.5 kg of tie wire at 400 Rp./kg	1,000
Cost of Materials	4,200
Hauling	
Regular load per truck is 250 pcs. of bamboo hauled an estimated 25 km @ 250 Rp./km = 5,000 Rp./load or $\frac{5,000}{250} \times 16$	325
Labor	
Excavation Volume 0.25 m^3	
Installation of wattles 1 1/2 manday Total Labor est. at 1.75 md at 500 Rp.	875
Total estimated cost	5,400
Contingencies (5%)	270
Engineering Design (5%)	280
Engineering Supervision & Administration (10%)	595
Total	6,545

1/ A bamboo wattle check with average effective dam height of 0.4 m. made of native bamboo.

TABLE B-13
COST ESTIMATE FOR THE CONSTRUCTION
OF BAMBOO WATTLE CHECKS WITH STONE DISSIPATORS

Average height and width of check = .04 meter and 2 meters

	Rupiah/structure
Materials	
16 pcs. of bamboo at 200 Rp./pc.	3,200
2.5 kgs. of tie wire at 400 Rp./kg	1,000
0.25 m^3 of stone at 2,900 Rp./m^3	725
Cost of Materials	4,925
Hauling	
Regular load per truck is 250 pcs. of bamboo hauled an average of 20 km @ 250 Rp./km = 5,000/load or $\frac{5,000}{250} \times 16$	325
Hauling stone 20 km @ 225 Rp./km/m^3 for 0.25 m^3	1,125
Total hauling	1,450
Labor	
Excavation Volume = 0.25 m^3	
Utilize 1 laborer at 500 Rp./day with one (1) cubic meter/day output	
Labor Cost = 0.25 m^3 x $\frac{\text{man-day}}{1\ m^3}$ x 500/manday	125
Installation of wattles & stone dissipators	
Utilize 2 laborer for 1 day at 500 Rp./day wage rate	1,000
Labor Cost	1,125
Total Estimated Cost	7,500
Contingencies (5%)	375
Engineering Design (5%)	390
Engineering Supervision & Administration (10%)	825
Total Cost	9,090

TABLE B - 14

COST ESTIMATE PER KILOMETER FOR EROSION PROOFING
EXISTING ROAD SYSTEMS

Item	Project	Villages	Total
Labor			
Field Surveying and Staking (20 md)	10,000		10,000
Smoothing Shoulders and Ditches (80 md)	7,600	32,400	40,000
Collecting Stone for Surface and Drop Structures (1,000 md)	200,000	300,000	500,000
Installing Culverts and Drops or Checks	150,000		150,000
Sodding cutbanks and roadsides		100,000	100,000
Road Surfacing (Stone) 2,000 m^2/km	100,000	600,000	700,000
Total Labor	467,600	1,032,400	1,500,000
Hauling			
Hauling 500 m^3 for 7 km @ 250 Rp/m^3/km	875,000		875,000
Hauling other Materials 20 m^3 for 20 km @ 225 Rp/m^3/km	90,000		90,000
	965,000		965,000
Materials			
Culverts	200,000		200,000
Cement 40 kg sks @ 2,000 Rp/x 5	10,000		10,000
Sand 3 m^3 @ 2,200 Rp/m^3	6,600		6,600
Total Materials	216,600		216,600
Total Estimated Cost	1,649,220	1,032,400	2,681,600
Contingencies (5%)	82,460	51,620	134,080
Engineering Design (5%)	140,780		140,780
Engineering Supervision and Administration (10%)	295,650		295,650
Total Cost	2,168,090	1,284,020	3,252,110
Percent	66.7	33.3	100.0

TABLE B - 15

COST ESTIMATE PER KILOMETER OF DISTRICT ROAD
FOR NEW CONSTRUCTION

Item	Project	Villagers	Total
Labor (at 500 Rp/md)			
Field Surveying and Staking (30 md)	15,000		15,000
Construction Road Embankment (5,400 md)	1,500,000 1/	1,200,000	2,700,000
Installing Culvert and Drops or Checks to Erosion Proof Road (300 md) 2/	30,000	120,000	150,000
Collecting Stone for Surfacing and Drop Structures (2,100 md)	500,000 1/	600,000	1,100,000
Road Surfacing (Stone) 3,000 m^2 (2,400 md)	500,000 1/	700,000	1,200,000
Total Labor	2,545,000	2,620,000	5,165,000
Hauling			
Hauling Stone 1,100 m^3 for 7 km @ 250 Rp/m^3/km	1,925,000		1,925,000
Hauling other Materials 50 m^3 for 20 km @ 225 Rp/km/m^3	225,000		225,000
Total Materials	2,150,000		2,150,000
Materials			
Culverts	432,000		432,000
Cement 40 kg sks @ 2,000 Rp/sk x 10	20,000		20,000
Sand 5 m^3 @ 2,200 Rp/m^3	11,000		11,000
Total Materials	463,000		463,000
Total Estimated Cost	5,158,000	2,620,000	7,778,000
Contingencies (5%)	257,900	131,000	388,900
Engineering Design (5%)	408,300		408,300
Engineering Supervision and Administration (10%)	857,500		857,500
Total Cost	6,681,700	2,751,000	9,432,700
Percent	70.8	29.2	100.0

1/ Current road subsidy rates in the Ciamis District obtained from Mr. Rachlan on 10 July, 1979.

2/ Includes sodding of cut slopes and road shoulders with local grasses.

APPENDIX C

ECONOMIC AND PROJECT FEASIBILITY TABLES

APPENDIX C

ECONOMIC AND PROJECT FEASIBILITY TABLES

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TABLE C-1

PRESENT CONDITION (1979) LAND USE BY DISTRICT

(Hectares)

Land Use	Tasikmalaya	Ciamis	Kuningan	Cilacap	Total
Crop Land					
Irrigated Riceland					
Technical Systems	3,238	12,226		3,268	18,732
Rural Systems	8,576	17,600	1,330	9,261	36,767
Rainfed Riceland	6,354	13,314	1,996	9,639	31,303
Subtotal	18,168	43,140	3,326	22,168	86,802
Upland Cropland	23,291	71,264	878	25,075	120,508
Home Gardens 1/	5,587	13,859	554	8,192	28,192
Total Cropland	47,046	128,263	4,758	55,435	235,502
Plantations	484	38,612		5,452	44,548
Forest	8,149	15,588	2,685	17,627	44,049
Other Uses					
Residential	1,150	3,700	130	2,280	7,260
Roads and Trails	341	862	43	538	1,784
Rivers and Streams	293	3,712	35	608	4,648
Other 2/	437	3,263	3,449	5,060	12,209
Subtotal	2,221	11,537	3,657	8,486	25,901
Total	57,900	194,000	11,100	87,000	350,000
Percent	16.5	55.4	3.2	24.9	100.0

1/ Includes homes and yards

2/ Includes fishponds, swamps, marshes, and other undefined Land Uses

Source : Based on data from District (BAPPEDA) Offices and Consultant Staff Estimates.

TABLE C-2

PROJECT COSTS FOR BENCH TERRACING BY LOCATION

(Thousand Rupiah)

Location	Year 1	Year 2	Year 3	Year 4	Year 5	Total
District						
Tasikmalaya		6,725	23,537	54,473	97,512	182,247
Ciamis	10,760	39,005	94,823	189,645	347,010	681,243
Kuningan		2,690	9,415	20,175	33,625	65,905
Cilacap	2,690	12,105	33,625	71,957	127,103	247,480
Total	13,450	60,525	161,400	336,250	605,250	1,176,875
Subbasins						
Upper Citanduy		10,760	37,660	87,425	154,002	289,847
Cimuntur	10,760	32,280	61,870	99,530	145,260	349,700
Cijolang		4,035	23,538	59,180	102,220	188,973
Cikawung	2,690	10,760	25,572	57,163	102,220	200,405
Ciseel-Lower Citanduy		2,690	10,760	32,952	101,548	147,950
Total	13,450	60,525	161,400	336,250	605,250	1,176,875

Note : This is the calculation of project cost by district and subbasin for Tables VII-7 and VII-9.

TABLE C-3

ESTIMATED METERS OF CRITICAL ROAD EROSION TREATMENT

NEEDS AND COST OF EROSION PROOFING

Location	Year 1	2	3	4	5	Total
Estimated Meters Erosion Proofing Required :						
Tasikmalaya	300	1,500	3,000	4,000	6,000	14,800
Ciamis	1,500	3,000	7,000	10,000	12,000	33,500
Kuningan		800	1,000	1,200	2,000	5,000
Cilacap	1,200	2,200	4,000	7,300	10,000	24,700
Total	3,000	7,500	15,000	22,500	30,000	78,000
Project Cost of Erosion Proofing (Thousand Rupiah)						
Tasikmalaya	650	3,252	6,504	8,672	13,008	32,086
Ciamis	3,252	6,504	15,176	21,680	26,016	72,628
Kuningan		1,734	2,168	2,602	4,336	10,840
Cilacap	2,602	4,770	8,672	15,826	21,680	53,550
Total Project Cost	6,504	16,260	32,520	48,780	65,040	169,104
Village Cost of Erosion Proofing (Thousand Rupiah)						
Tasikmalaya	325	1,626	3,252	4,336	6,504	16,043
Ciamis	1,626	3,252	7,588	10,840	13,008	36,314
Kuningan		867	1,084	1,301	2,168	5,420
Cilacap	1,301	2,385	4,336	7,913	10,840	26,775
Total Village Cost	3,252	8,130	16,260	24,390	32,520	84,552
Total Cost	9,756	24,390	48,780	73,170	97,560	253,656

TABLE C-4

ESTIMATED FERTILIZER USE AND ECONOMIC COST OF FERTILIZER SUBSIDY FOR PROJECT MEASURES

Item	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Fertilizer Use (tons)						
Demonstration Farm	7.1	17.9	32.6	51.2	73.6	182.4
Terracing (Bench)	15.0	67.5	180.0	375.0	675.0	1,312.5
Other Cons. Measures	3.0	14.0	36.0	75.0	135.0	263.0
Total	25.1	99.4	248.6	501.2	883.6	1,757.9
Economic Cost of Fertilizer Subsidy 1/ (Thousand Rupiah)	1,506	5,964	14,916	30,072	53,016	105,474

1/ Based on an average fertilizer subsidy of 60 Rupiah/kg from Table VIII-

TABLE C-5

REFORESTATION AND GREENING DURING PELITA II
(1974/75 - 1978/79)

Year	Hectares			Budget (million Rupiah)		
	Reforestation	Greening	Total	Inpres/ Assistance	Sector*	Total
I. (1974/1975)	37,103	52,529	89,632	-	2,377.2	2,377.2
II. (1975/1976)	42,376	82,285	124,661	-	4,905.0	4,905.0
III. (1976/1977)	122,189	302,597	424,786	16,000.0	2,163.5	18,163.5
IV. (1977/1978)	203,095	632,689	835,784	24,476.6	1,824.7	26,301.3
V. (1978/1979)	288,058	689,291	977,349	36,000.0	2,000.5	38,000.5
Total	692,821	1,759,391	2,452,212	76,476.6	13,270.9	89,747.5
Pelita II Target	1,690,000	1,750,000	3,440,000	-	-	60,400.0

* Since the Assistance/Inpres System by Sector Budget, which is valid, is for planning and managing (technical) Implementation/Support projects except Training and Education project and Forest Inventory and Consolidation.

Source: Laporan Kualitas Lingkungan Hidup Indonesia 1979 by Menteri Negara Pengawasan dan Lingkungan Hidup. P. 40. Table 2.

TABLE C-6

FOREIGN TRAINING COMPONENT

* The estimated average monthly cost include travel, per diem, study fees, etc. as follows :

	Cost/Year
Travel Costs (USA)	$ 2,500
Tuition	5,000
Travel Per Diem, $50 x 10	500
Residence Per Diem $ 600 x 12	7,200
Consultant Personnel and Out-of-Pocket Costs	500
Book and Incidentals	1,000
	$ 16,700

$ 16,700 x 10 man-years = $167,000

or Rp. 104,375,000

* Cost estimates based on state intitutions in the United States, with the length of course and type of training to be tailored to fit the qualifications and requirements of each candidate. Where possible training in upland agriculture, forestry and conservation practices will be conducted at the University of the Philippines or another acceptable school in a tropical country with problems similar to Indonesia's. Estimate based on trainees attending formal courses at recognized institutions. Should the needed courses not be available, Consultant will provide similar instruction at his home office or with government agencies and will be reimbursed for manpower expended, subject to prior approval by the Ministry of the programs and cost estimates.

TABLE C-7

INTERNATIONAL PRICES OF PRODUCTS

Year	Rice	Corn	Grain Sorghum	Soybeans	Groundnuts	Copra	Tea	Rubber	Timber Logs
	($/t)	($/t)	($/t)	($/t)	($/t)	($/t)	(¢/Lb)	(¢/Lb)	($/M^3)
1960	124.7	43.4	37.7	92	197	202	64.5	38.2	32.0
1961	136.5	45.9	42.6	111	196	165	61.7	29.5	33.1
1962	152.8	51.4	45.6	100	171	164	62.4	28.6	36.4
1963	143.3	54.7	48.6	110	172	184	59.2	26.3	35.5
1964	137.7	55.8	48.2	110	187	194	60.1	25.3	30.3
1965	136.3	55.0	47.2	117	206	227	58.6	25.7	35.0
1966	163.2	59.4	51.7	126	190	185	57.0	23.6	36.8
1967	205.8	49.9	50.4	112	180	204	57.5	19.9	39.3
1968	201.6	49.1	46.5	106	167	232	47.4	19.9	40.3
1969	186.9	53.9	50.1	103	207	202	44.1	26.2	38.9
1970	144.0	58.4	51.8	117	230	225	49.7	21.0	43.2
1971	129.0	58.4	55.7	126	249	189	47.8	18.1	43.1
1972	147.1	56.0	56.0	140	261	141	47.7	18.3	40.5
1973	350.0	98.0	93.0	290	393	353	48.0	35.7	68.1
1974	542.0	132.0	121.0	277	607	662	63.6	39.3	81.5
1975	363.1	119.6	111.9	220	452	256	62.8	29.9	67.5
1976	254.5	112.4	105.2	231	424	275	69.7	39.6	92.0
1977	268.0	95.3	88.4	280	551	402	121.9	41.6	90.0
Projected									
1978	308.0	115.0	105.0	257	538	385	95.0	43.0	100.0
1979	357.5	140.0	125.0	288	493	475	92.0	47.0	115.0
1980	405.0	160.0	140.0	286	481	468	89.5	52.5	127.0
1981	439.0	170.0	150.0	339	562	591	93.5	55.7	141.0
1982	486.0	183.0	160.0	319	552	592	97.5	59.7	152.0
1985	620.0	225.0	195.0	476	737	698	111.5	71.9	210.0
1990	820.5	289.0	249.0	668	954	893	146.5	92.8	310.0

Rice - Thai 5% broken, FOB Bangkok
Corn - US No. 2 yellow, FOB Gulf Parts
Sorghum - US No. 2 Yellow grain, FOB Gulf Parts
Soybeans - US, CIF Rotterdam
Groundnuts - Any orogon, shelled, CIF Rotterdam
Copra - Philippine/Indonesia, bulk, CIF N.W. European Parts
Tea - Average all teas London auctions
Rubber - RSSI, CIF New York
Timber Logs Philippines Lauan, 316 or more x 60 cm, imported sale price to wholesalers, delivered Tokyo.

Source : World Bank, Economic analysis and Projections Department

TABLE C-8

CALCULATION OF THE EFFECT ON PROJECT FEASIBILITY FROM A REDUCTION OF 20 AND 50 PERCENT IN PROJECT BENEFITS FOR SENSITIVITY ANALYSIS

(Million Rupiah - 1979 Values)

Year	20% Reduction in Benefits 1/			50% Reduction in Benefits 1/		
	Project Benefits	Project Costs	Net Benefits	Project Benefits	Project Costs	Net Benefits
0	0.0	1,681.9	-1,681.9	0.0	1,681.9	-1,681.9
1	0.0	1,732.2	-1,732.2	0.0	1,732.2	-1,732.2
2	428.5	1,543.8	-1,115.2	267.8	1,543.8	-1,276.0
3	857.0	1,524.7	-667.7	535.6	1,524.7	-989.1
4	1,285.5	2,057.3	-771.8	803.4	2,057.3	-1,253.9
5	1,714.0	176.9	1,537.1	1,071.2	176.9	894.3
6	2,142.5	176.9	1,965.6	1,339.1	176.9	1,162.2
7	2,571.0	176.9	2,394.1	1,606.9	176.9	1,430.0
8	2,999.5	176.9	2,822.6	1,874.7	176.9	1,697.8
9	3,428.0	176.9	3,251.1	2,142.5	176.9	1,965.6
10	3,856.5	176.9	3,679.6	2,410.3	176.9	2,233.4
11-25	3,856.5	176.9	3,679.6	2,410.3	176.9	2,233.4
Total	77,130.0	12,254.8	64,875.2	48,206.0	12,254.8	35,951.2
Net Present Value at 12%	17,135.9	7,702.1	9,433.8	10,709.9	7,702.1	3,007.8
Benefit Cost Ratio at 12% = 2.22						1.39
Internal Rate of Return = 24.6%						16.6%

1/ Calculated from year 10 through 25 with a linear interpolation from year 1 through 10.

TABLE C-9

CALCULATION OF THE EFFECT ON PROJECT FEASIBILITY FROM AN INCREASE OF 25% IN PROJECT COSTS, AND FOR A 50% REDUCTION IN BENEFITS WITH A 25% INCREASE IN PROJECT COSTS FOR SENSITIVITY ANALYSIS

(Million Rupiah - 1979 Values)

Year	Project Costs Increased 25%			Project Benefits Reduced 50% and Project Costs Increased by 25%		
	Project Benefits	Project Costs	Net Benfits	Project Benefits	Project Costs	Net Benefits
0	0.0	2,102.4	-2,102.4	0.0	2,102.4	-2,102.4
1	0.0	2,165.3	-2,165.3	0.0	2,165.3	-2,165.3
2	535.6	1,929.2	-1,394.2	267.8	1,929.8	-1,662.0
3	1,071.2	1,905.9	-834.7	535.6	1,905.9	-1,370.3
4	1,606.9	2,571.6	-964.7	803.4	2,571.6	-1,768.2
5	2,142.5	221.1	1,921.4	1,071.2	221.1	850.1
6	2,678.1	221.1	2,457.0	1,339.1	221.1	1,118.0
7	3,213.7	221.1	2,992.6	1,606.9	221.1	1,385.8
8	3,749.4	221.1	3,528.3	1,874.7	221.1	1,653.6
9	4,285.0	221.1	4,063.9	2,142.5	221.1	1,921.4
10	4,820.6	221.1	4,599.5	2,410.3	221.1	2,189.2
11-25	4,820.6	221.1	4,599.5	2,410.3	221.1	2,189.2
Total	96,412.0	15,318.1	81,093.9	48,206.0	15,318.1	32,887.9
Net Present Value at 12%	21,419.7	9,627.6	11,792.1	10,709.9	9,627.6	1,082.3
Benefit Cost Ratio at 12% = 2.22						1.11
Internal Rate of Return = 24.6						13.3

TABLE C-10

ESTIMATED FOREIGN EXCHANGE COSTS OF PROJECT COMPONENTS

	Year					Total
	1	2	3	4	5	
National Level						
Administration	20,000	20,000	10,000	10,000	10,000	70,000
Research Exp. Station	27,000	33,600	7,000	11,400	7,000	86,000
Subtotal	47,000	53,600	17,000	21,400	17,000	156,000
Provincial Level	48,750	55,350	10,875	10,875	10,500	136,350
Kabupaten Level	34,650	38,250	61,875	39,600	26,550	200,925
Conservation Works	27,834	30,435	58,404	94,514	132,913	344,100
Infrastructure Improvement	17,200	25,000	25,000	25,000	25,000	177,200
Reforestation and Greening	93,200	86,700	44,800			224,700
Fertilizer Subsidy						
Consultants (90%)	60,100	182,070	156,060	104,040	78.030	780,300
Foreign Training	41,750	41,750	20,875			104,375
Total Foreign	570,484	513,155	394,889	295,429	289,993	2,063,950
Domestic	1,111,375	1,219,055	1,148,871	1,229,334	1,767,349	6,475,984
Total	1,681,859	1,732,210	1,543,760	1,524,763	2,057,342	8,539,934
% Foreign Exchange	33.9	29.6	25.6	19.4	14.1	24.2

APPENDIX D

PROTECTION OF CULTIVATED SLOPES

APPENDIX D

PROTECTION OF CULTIVATED SLOPES

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Appendix D

PROTECTION OF CULTIVATED SLOPES

Introduction

The cultivation of any land in the humid areas of the world will cause the erosion and degradation of the soils. The steeper the land form the higher the potential rate of erosion. Various forms of protection may be used to reduce erosion rates. Erosion not only results in the deterioration of the productivity of the land but, also, the aggravation of silting and flood damage in the downstream areas.

The problems of erosion from cultivated lands are further compounded by the fact that the cultivators are mostly poor farmers operating very small parcels or tracts, generally less than 1 ha in size, and often on areas of only 0.1 ha. The tracts are usually operated as individual units and not in conjunction or in cooperation with adjacent tracts. The social dilemma is always there. The resettlement or relocation of people from the land is a very difficult process even when they are illegally squatting and/or when it is economically or socially acceptable to do so. The country's land and water resources are under constant threat by the cultivation of its steeper lands.

In general, the lowland areas have been leveled and divided into a multitude of small rice fields ranging from 0.05 to 0.5 ha in size. Erosion on flat areas is minimal because water is trapped in the paddies and runoff rate is reduced by time, i.e., although under normal monsoon conditions little rainfall is actually stored in the paddies, the time it takes to move the excess rainfall through them is sufficiently long so as to reduce suspended sediment movement to a minimum. The elevation and slopes on which irrigated paddies are constructed is generally limited by the source of water, soil types and soil stability under saturated conditions. Failure of flooded paddies on steeper slopes generally results in increased sediment loads in the drains and natural waterways.

Where hillside slopes are still relatively flat (<8%), the ground is either leveled for rainfed rice production or planted on the slope to a wide variety of diversified crops. Diversified crops are produced on an interplanted basis although, occasionally, pure stand plantings do occur. The farmer hesitates to place his faith in an upland crop monoculture. Slopes up to 15-20 percent are planted to diversified crops with the rows planted perpendicular to the contour, i.e., up and downhill. In the typical shifting cultivation areas, slopes as steep as 100% or better are planted with rows going up and downhill and/or with a completely disturbed soil surface. This condition can provide tremendous rates of erosion that have, on occasions, exceeded 20 cm in 6 days, which translates to an 6 day erosion rate of roughly 290,000 tons/km^2 (1.45 g/cm^3 x 0.2 m x 1,000,000 m^2). Fortunately, this type of erosion rate occurs only on small shifting cultivated areas during relatively rare highly intense rainfall events. This erosion rate serves to point out how detrimental/dangerous upland farming can be to a watershed when a conservation program is not utilized or enforced.

Upland farming differs from shifting cultivation in that the farmer uses the same plot of ground year after year. The slopes used by upland farmers are usually less than 50%, but there are occasionally areas found with slopes greater than 50%. Population pressures and topography force the cultivation of the steeper slopes. Few conservation techniques are used on upland farms.

Upland Farm Conservation Planning

Upland farm conservation programs involve the use of all technologies to prevent the loss of soil particles from a watershed, and to increase production of agricultural crops. It is an integrated program developed for a farm or area alresdy under cultivation, or is scheduled to be cultivated by a group of farmers, and incorporates land capability, water management, soil improvements, crops, and erosion control features to achieve this goal.

General

One of the major objectives of conservation farm planning is to help the farmers to understand what the erosion and water problems are on their farms, and how they can correct these problems and still use the land in accordance with its capabilities. Land use and land capability maps are used by the technicians in assisting the farmer to decide how to best utilize his land and what conservation practices will be required.

Experience has proven that it is necessary to explain to the farmer how he can continue to farm his land and still correct the soil and water problems. A locally adapted plan for each conservation unit or sub-watershed is required to illustrate to the farmer how his land should be managed, and how it fits into a large unit area.

In the Citanduy and other watersheds, the two most frequent kinds of land misuse are burning and cultivation of steep slopes. The steeper the slope, the greater the land damage from cultivation. The steep slopes that are being cultivated today are already badly damaged and gullied. Many of these gullies started as small inlets on the banks of natural waterways and have now eroded uphill to great depths. They grow deeper as they advance up to the slope. This branching continues until a network of gullies (current condition) covers the watersheds.

The first step in controlling erosion in a watershed is to plan farms so as to make the best possible use of the land. This includes making an inventory of the steep and eroded lands which could be properly terraced, and converting slopes steeper than 35 to 40 percent to permanent cover. Only moderately sloping land should be used for cultivated crops. Waterways or natural depressions should be planted to close-growing perennial vegetation. Recommended species of trees, fruit trees, legumes and grasses are known.

The best known methods of controlling or preventing erosion are vegetative controls such as mixture of grass and legumes, and the combination of vegetation and engineering controls. The use of engineering

controls such as terracing, contour cultivation, contour strip-cropping, graded waterways, drop structures and check dams should always be used in combination with good and proper vegetative practices.

The cost of controlling steep, gullied land, and the protection required, should be considered in relation to the use that can be made of the land according to the farmer's needs and his willingness to apply conservation practices. In many cases, his needs are not compatible with the land capability, and where his needs and the land capability are compatible, the required resources are beyond the farmer's economic ability. It is also possible, under certain conditions or constraints, that the required measures for conservation farming are not economically viable. This then requires a decision by Government as to whether subsidization is feasible, or desirable, in order to stabilize the agricultural activity, and attempt to control erosion and deterioration of the land.

It is emphasized that the farmer must be trained and educated to assume the responsibility to install and follow a conservation plan. It is essential that he understands that it is his responsibility to prevent fires, to maintain terraces, waterways, drops, etc., and to repair any damage that occurs. Where farmers do not understand their responsibilities, or are not willing to cooperate, conservation practices become damaged to the point that they are no longer effective. Government may be willing to initiate conservation farming practices, but if the farmers are not willing to cooperate, then all efforts become futile.

Some of the necessary steps in preparing a conservation farm plan for a sub-watershed or unit of farms are:

1. The technician should point out the ability of the soil to produce crops, what the erosion problems are, and practices that must be followed to properly manage the soil and water.

2. The technician should explain what is meant by land capability, and why it is necessary to make changes in land and soil management.

3. A sub-watershed or conservation unit map should be prepared showing land ownership, boundaries of each farm lot, topography, and land capability. A companion plan is prepared showing how to control erosion; changes necessary to manage water; changes in cropping systems; engineering structures required; what Government will do or supply; and, finally, what will be expected of each land owner or land operator upon implementation.

4. A map and instructions on how the plan will be accomplished should be prepared, and each land owner/operator in the unit given a copy. This plan should show what will be done on each field, when it will be done, crops to be grown, trees and shrubs to be planted; and locations, designs, etc., of structures, terraces, and other engineering measures needed to meet the conservation objectives.

Water Management

Water management is an indispensable part of modern upland agriculture. In water management, the ultimate target of any knowledge transfer must be the farmers; for it is on farm land where production resources including water, climate, soil, crops, fertilizer and management are all integrated into an upland agricultural system. The transition from traditional upland farming to conservation upland farming will be difficult and costly, however, it is absolutely necessary if land degredation, runoff and erosion are to be controlled. Part of this expensive process will be the preparation of farm land to receive and store rainfall without soil erosion which may include: land levelling, contour farming, conservation terraces, bench terraces, diversion channels and waterways to dispose of the runoff. Improvement of the entire physical system is a necessary requisite to a soil and water conservation management program.

The ultimate objective of an upland agricultural water management program is to convince the upland farmer he has a major problem, and that the program will assist him in solving this problem and increase his profits. To obtain this objective, it will be necessary to train farm advisors, technicians and administrators. The farmer can be provided with necessary technical advice, seed, fertilizer, and management procedures but unless he understands, and can see a profit from his efforts, it will be difficult to get him to alter his traditional methods. Capital is scarce, and labor relatively abundant, therefore, the focus of the conservation farming and watershed program must be on adaptability of technology to conditions that the farmer understands and can achieve.

A particular advantage of a modern upland water management program is that it has a considerable amount of management built into it, and the farmer is automatically led to the correct decision(s) in the application of soil and conservation measures. A farmer will make fewer mistakes with a well planned system than a farmer who does not have the technical and management inputs regarding water management. Continued focus on improved water management must become a new way of life for the upland farmer if he is to continue using the shallow upper watershed soils.

The design and construction of mechanical structures in the farmer's water conservation program presents a number of administrative problems. Basically, it will be necessary to include in the conservation farm plan all the elements of the different programs. The conservation farm planner must be acquainted with all extension service programs, reforestation programs, agro-forestry programs, agricultural and conservation programs in order to build this help into a coordinated financial plan for the farmers.

Crops

Terracing or any other type of mechanical practice, by itself, generally will not increase crop yields. Because of the depleted condition of the soils, the use of commercial fertilizers and green manures

will be required. Crop rotation(s) adaptable to the locality will have to be developed. In addition to the traditional crops such as sweet potato, cassava, upland rice, corn and peanuts, it would be advisable to include some of the other dry season crops that are more drought resistant, such as sorghum, beans or other pulses.

Root crops should not be planted on the lip of the terraces, as this will damage the terrace lip when the crop is harvested. The riser, which includes the forward edge of the lip, should be planted to a grass and legume mixture. This can be used for cut and carry forage for the work animals.

Crop rotations will have to be planned with the farmer after taking into consideration the soil conditions, net arable land, steepness of the land, and the needs of the family. The farmer should understand why it is necessary to retire some land to grass and trees, and why it is necessary to use conservation measures to conserve soil and improve its fertility, structure and moisture holding capacity.

Intercropping should be given preference over sequential monoculture planting, as it usually insures greater economic returns and better income stability for the farmer by protecting him against the risk of a total crop failure and wide price fluctuations of one or more crops each year. Intercropping provides almost the same benefits as a legume crop inserted in the rotation, with regards to its effects on the soil. This is especially true if a legume is involved in the combination; even though the legumes may be removed for fodder, the entire root system including the nodules remain in the soil to decay and supply nutrients to subsequent crops.

Fertilizer and Lime

Because mixing of thin surface soil with subsoils during terrace construction, as well as the inherent low soil fertility level of upland soils, it will be necessary to apply relatively heavy rates of fertilizer

and lime to obtain even low yields. Fertilizer and liming trials will have to be established to determine the rates of application necessary for various levels of production in a series of representative upland soils. Data is presently unavailable at the farm level, for fertilizer inputs on upland soils for specific crops.

These two inputs could be provided by Government at a subsidized price for a predetermined number of years as an incentive for the farmers to participate in a conservation program.

Rates of application will probably change after experimental data are available, however, it is expected that the farmers will recognize the benefits of fertilizer and lime, particularly if they are crop and soil specific.

Types of Mechanical Protection

Mechanical protection is modification of the land surface to reduce erosion rates. The basic components are: 1) the prevention of overland flow from reaching cultivated land by constructing a diversion channel (storm water drain); 2) conveying excess water to a drain without soil erosion; and 3) the removal of excess water from the cultivated area and conveying it to a natural waterway without soil erosion. The basic components are presented in Figure D-1.

There are five types of mechanical protection that can be used to prevent or reduce erosion.

1. Level basins.
2. Contour planting.
3. Contour strip cropping.
4. Conservation terraces.
5. Bench terraces.

The first two types are considered mechanical protection because they still meet the definition, even though actual physical construction is minimal.

There are many variations of these five methods that can be used, depending on the slope of the land and crops to be grown. In general, slopes of 3% or less can be farmed with the rows perpendicular to the contour. This will allow adequate drainage without appreciable erosion even on the more erosion prone soils.

Contour farming can be used on slopes between 3% and 15%. For slopes above 7%, the use of conservation terraces in conjunction with contour farming is recommended where downslope spacing is adequate. It is also recommended that mulching be used with crops on slopes greater than 10%. Bench terraces should be utilized on all slopes above 15%. Terracing on slopes above 50% tends to be impractical due to narrow widths, limited amount of arable land on a per hectare basis, and the high cost of establishing terraces on steep slopes. Also, terraced slopes may become unstable on slopes exceeding 50% to 55%. The engineering soils data for the soils are not available, however, rapid and simple field and laboratory tests can be made.

Application of Mechanical Protection

The principles involved in soil erosion control are as follows:

1. Reduce the velocity of the runoff. Long slopes encourage runoff to increase its eroding capacity. Therefore, practices that reduce cross slope runoff will reduce erosion.

2. Maintain high infiltration rates. Soil structure can be improved by management although soil texture cannot. Proper cultivation practices and utilization of soil residue will promote increased infiltration rates and reduce runoff.

3. Reduce the force of raindrops. The interception of raindrops by crops reduces the energy of the raindrops prior to their reaching the ground. Therefore, crop cover is important in reducing erosion.

The length of farm fields or rows should be limited to 40-50 m on slopes in the range of 2-5%. On slopes of less than 2%, the length of row is not limited by the erosive nature of the runoff but by the capacity of furrows between rows to remove excess water into the field drains. For practical reasons, fields should be limited to 300 m or less on flat slopes. In most cases, this will not be a problem because nearly all flat areas will be planted to flooded rice and/or ownership will limit field size. In hilly areas fields in excess of 50 m in length on a grade of 5%, more or less, are not common if the area is already under cultivation.

Contour cropping should be practiced on all slopes greater than 3%. As indicated above, slopes of 5% or less could be farmed without regard to slope direction if row length is limited to 40 m or less. It is recommended that contour cropping be established as a general practice on all land with slopes greater than 3%, and to limit row gradients on contour plantings to about 1% to allow for adequate drainage and still reduce runoff velocities. The contour gradient can be varied to improve field and row alignments. Because of local conditions, it is recommended that contour rows be limited to 125 m in length. Assuming a flip-flop drain system, a field length of 250 m could be used. Contour farming can be accomplished on slopes up to 15% provided the downslope distances do not exceed 30 m.

Contour strip cropping is recommended on slopes of 8 to 15%. Contour strip cropping is the alternate planting of row crops and strips of crops with a close-growing habit. Thus, if water breaks through a series of rows it is spread out in the close-growing crop and sediments are dropped. In the Philippines, the Bureau of Soils gave the following recommendations with respect to strip widths:

Slope (Percent)	Strip Width-Measured Down the Slope (m)
0-5	40-50
5-8	36-45
8-10.5	32-40
10.5-13.5	28-35
13.5-16.5	24-30
16.5-19.0	20-25
19.0-22.0	16-20
22.0-25.0	12-15
25	12

Although the Philippine Bureau of Soils allows contour strip cropping on slopes between 15% and 25%, it is believed that conservation terraces would be a better erosion control practice. However, the strip cropping is preferable to present practices. The growing of commercially viable close-growing crops is limited as it is not expected that this practice will be widely adopted by upland farmers. Conservation terracing does require some construction work.

Conservation terracing is an alternative to contour strip cropping. The conservation terracing and drainage ditch may replace the strip of close growing crops. The terrace is built on a grade of 1%. The advantage is that less area per hectare is removed from the production of row crops. Only the slopes of the terrace riser and the waterway are protected by grass or grass/legume mixture. It is recommended that the upper limit of land slope for conservation terracing not exceed 15%, although is is possible to construct them on steep slopes of up to 25%. The crop area between terraces follows the same recommendation as contour strip cropping.

Conventional bench terracing, either level or graded, must be constructed on all slopes exceeding 15% except under very limited circumstances. The details of terrace design and construction are the subject of the following sections.

The grades for contour farming are laid out the same as those for terraces. The grades will have to be laid out for the farmers as they do not have the necessary equipment to do so. Once laid out, the farmer should be able to plow and carry on all other farming operations on the necessary grade.

Waterways and other drainage facilities will be the same as those constructed for bench terraces.

Conservation Program

A conservation program/plan must be established for each farm or cultivated area where the ownerships are small and intermixed. Where small plots are encountered it will be extremely important for extension personnel to obtain group participation. This will not be difficult to do provided the extension agent goes into the field to talk to the farmers, individually and as a group. Most farmers (cultivators) are accustomed to trading work and working together, therefore the conservation program can be made part of this group interaction. Extreme care must be made to be sure that ownership boundaries, paths and roads are observed, and not disturbed unless absolutely necessary. In this respect, it is also possible to use the waterways for access, in which case, they will have to be paved and protected with an increased number of structures.

The conservation program must explain in detail what the farmers (cultivators) must do to maintain the specific type of recommended mechanical protection, the crop rotation, crop inputs, weed and insect control, expected yields for a period of five years, etc. The extension worker must continually monitor this program and assist the farmer(s) in making any necessary adjustment. The initial program cannot be left without continuous monitoring and updating as the program progresses. A lack of monitoring will almost guarantee failure. Not enough data is available to make precise soil fertility recommendations.

If Government decides to provide an incentive program for implementing a conservation program, the amount of the Government's contribution must be determined and fully explained to the farmers. Also, the farmers contribution must be explained and fully understood, including what controls the Government will require to see that the work is accomplished to specifications before allowing payment. If the Government decides to do the work itself, then the timing of the work and the amount of work to be done must be agreed to by both parties so that no question exists in the recipient's mind. The follow-up by the extension workers in the field is necessary. Without this continuous follow-up, interest, and cajolling (social engineering) the program will not attain the desired agricultural and sociological achievements.

Suggestions for Implemementation

To initiate and implement a soil-water-plant conservation program in a watershed, the following suggestions are offered:

1. Initiate the program in an area where there is a definite need, the problems are real and the farmers and the people of the community are in need of help.

2. Meet with the leaders, farmers, community and local Government. Involvement and awareness are the key items. Discuss the conditions and problems they think are responsible for their erosion problems. Do some checking in the community and find some real active citizens who are concerned about the people and the dwindling resources of the area. These people are there; take the problems to the people.

3. Have the leaders visit with project management in the field and let them point out and locate the problems as they see them. During this visit take inventory of conditions, available resources, and the problems of the area. Have the leaders discuss their ideas of possible solutions for erosion control and how the solutions

should be approached.

4. The technical staff should then study and identify the problems and possible solutions based on research and local technical knowledge, if available, or by proven, adapted and successful international techniques. Be sure to give consideration to the specific problems the leaders think are responsible for their erosion troubles.

5. After completion of the above staff studies, meet with the citizen group and analyze and apprise them of the situation, based upon your findings and their imputs. Have available technical materials maps, inventory of problems and alternate solutions that are technically sound. Develop a program of action with the community (desa or village), with the citizens taking an active part in the decision making.

6. When the leaders are fully aware and understand that there are solutions to most of the problems, manage the discussion so that they request assistance for an upland conservation farming program.

7. At the inception of the proposed conservation activities have some type of publicity in process to keep the people informed on what is being done. Support will be required from the entire community if a successful project is desired, as a small group of dissidents can cause the project to be a failure.

8. For a soil-water-plant conservation program, let the village people choose 3 to 5 ha watersheds for model demonstration farms. Larger areas are more costly, harder and unwieldy to implement and manage and, thus, have less chance of being successful. Two or three demonstration farms in the most needed areas are adequate.

9. Develop with the village leaders and the land owners, within the boundary of the model demonstration farms, a complete farm plan (soil conservation and extension service approach).

10. A little Government assistance is required at this point in conservation planning. Government will have to decide as to whether they want to subsidize this activity. Cost sharing for the demonstration farms is suggested as this gives a good feeling of community development; the people feel that they can take care of their own problems and are not getting charity. Government assistance should be an incentive to farmer groups to participate.

11. For upland bench terracing, farmers must cooperate and participate as a group so that common outlets for terraces, diversion ditches, gulley control, etc., can be designed in a practical and economically feasible manner with a minimum of future maintenance problems.

12. At the time the plan is being developed, stress the "complete package" approach. That is, high yielding varieties, fertilizer and lime usage, improved cultural practices, minimum and timely tillage, stubble mulching, green manuring, weed control and plant protection measures. All these practices will have to be employed on heavy or clayey soils to prevent oxygen stress.

13. A Government agency should be assigned or created to specifically assist the farmers in applying soil-water-plant conservation practices to each miniature watershed.

14. Awareness and involvement by the community, particularly the farmers, is required if successful implementation of soil-water-plant conservation practices are desired. Public cooperation and involvement are necessary for projects of this type. Taking the problems to the people and their participation in solving the problems make them a part of the project, thereby eliminating many of the potential reasons for failure.

Terracing

General

A terrace is defined as an earth embankment, or ridge, and channel constructed across the slope at a suitable location to intercept surface runoff.

Terraces are constructed to reduce erosion by shortening the length of slope and conducting the runoff water on a non-erosive grade to a stable outlet and, hence, down a stable waterway to a natural channel. They are used to conserve moisture, reduce floods by means of trapping the water on the terrace, or by increasing the time of concentration with graded terraces.

Terracing is one of the best mechanical erosion control practices. To be acceptable to farmers, terraces must have the desirable shape and alignments to fit local practices. The use of modern equipment with either animal or internal combustion engine power will reduce the slope on which terraces can be utilized by requiring wider terraces of more uniform width.

There are two basic types of terrace systems: level and gradient. Level terraces are not recommended in the humid tropics except where used for rice fields. Gradient terraces come in two forms: bench terraces and conservation terraces. Bench terraces require movement of a considerable amount of earth through cut and fill operations with the end result looking like a series of stair steps. Conservation terraces only move enough earth to construct a ridge and shallow drainage channel on grade across the land slope; crops are still planted on undisturbed soil parallel to the terrace.

Function of Terraces in a Conservation Program

Terraces that are properly located, constructed and maintained reduce runoff and soil losses, and prevent the forming of rills and gullies. They assist in reclaiming badly gullied fields by intercepting the runoff before it becomes concentrated and attains an eroding velocity. To be effective, they must be used in combination with the other practices such as stubble mulching, contour planting, and contour strip cropping.

Terraces are of value on practically all soils except those that are too stony, sandy or shallow to permit practical and economic construction and maintenance. They are normally used only for cultivated land, but there are occasions on badly eroded lands where terraces can be used to establish grass. Frequently, the less productive soils are not terraced until the soil has become so badly eroded that construction is costly, maintenance is excessive and farming operations are difficult. Terraces pay the smallest returns when used to reclaim lands that are already badly eroded and gullied.

The depth of soil (this does not include the depth of decomposed parent materials) is one of the chief factors that determine the practicability of terraces. If a true soil is not available, terraces should not be constructed.

The steepness of the land is another major factor that determines the practicability of terraces. As the slope of the land increases, soil loss from erosion increases. However, the cost of construction, cost of maintenance and difficulty of farming terraces all increase with the steeper slopes to the point where these factors may eventually far outweigh the benefits derived, even when all farming is accomplished by hand methods. When this point is reached, terracing is not advisable. The steepest slope on which terracing is practical is not determined by formula but by economics, industry of the operator and the accompanying conservation practices applied. Terraces are being employed on slopes as steep as 50% on some soils, and using 100% hand labor farm technology.

It is difficult to lay out a farmable terrace system on very irregular slopes. Curves are very sharp and cuts and fills become excessive which increases the construction costs. Terraces with the effective farmable area of less than about 1.5 m in width should not be considered even for hand methods of cultivation, and the width should be increased to a minimum of 2.0 m for animal powered and 2.5 for two wheel tractor powered land preparation. Most soils in this type of topography are too shallow to permit deep cuts. Hence, spacing between terraces will vary and result in many point rows.

Planning Techniques

A major requirement of a good terrace system for diversified crops is that the terraces must have the best possible alignment and, whenever possible, be parallel. With a parallel terrace system, each terrace is planned as part of a total system. A parallel terrace system can have correction areas, provided they occur between sets of parallel terraces and are carefully located.

A number of techniques can be used to improve farmability and to assist in paralleling terraces. These are:

1. Choice of outlets. Grass waterways will be used to convey excess water away from terrace outlets in a majority of cases. The outlet from the terrace to the drain may be grassed or protected by stone or rock lining. Terrace drain channels are normally clean, compacted soil. In some cases, a more complicated outlet structure may be required so that mortared rock, brick, concrete or other permanent materials will be used. In a few cases, an underground pipe could be used for the outlet.

2. Choice of terrace cross section. The cross section may be either horizontal or reversed sloped although the latter is always preferred. The slope of the risers can be changed although soil conditions may limit the slope. The gradient may also be adjusted

somewhat, particularly on the upper end of the terrace where it can be steepened.

3. Design techniques. The cut and fill method may be used in some areas. In other areas, parallel layout may be achieved by varying the grade, using grass turning strips or other techniques.

All of these techniques should be considered in the layout of any terrace system. A well planned system requires thoughtful and detailed planning.

Objectives

There are several general objectives to be kept in mind in terrace planning. These are erosion control, farmability, topography improvement, moisture conservation, drainage, protected waterways, observe ownership boundaries, access, riser protection and soil conservation.

Erosion control is the primary objective in terracing. The design should consider the allowable soil loss, the most intensive use expected for the land, and the expected level of management in planning terraces. The drains must be adequate to handle the expected 10-year rainfall without erosion. This means the terraces must generally fit the contour, and deviations from the selected grade must be held to a minimum. The risers must be protected from erosion by vegetative cover and the slope stabilized against slumping.

Farmability is a second important objective. Terraces must be as farmable as possible in order to have them accepted and maintained. A terrace system with good farmabilty will:

1. Have the best possible alignment and be parallel whenever possible. This will reduce short rows, save time in plowing, planting and harvesting, and reduce crop damage.

2. Be spaced to fit the equipment in the area, including animal and two-wheeled tractors.

3. Have the widest possible planting surface, which is commensurate with available soil depths and riser stability.

4. Have an adequate, workable cross section.

5. Provide adequate access to the terraced area with roads and paths.

6. After construction, have an adequate remaining soil depth to provide a good growing medium, not just soil-sized subsoil or decomposed rock particles.

Topography can be improved when terraces are laid out fairly straight, and taking them directly across minor gullies and drains. Subsequent farming will help eliminate minor irregularities in grade; this must be done in such a way so as to retain the reverse slope.

Types of Terrace Systems

There are two general types of terrace systems, based on the disposal of runoff. One is the graded terrace system and the other is the level terrace system. The level terrace system is not used in humid areas except for the construction of flooded rice paddies. Level terraces (paddies) are not recommended on slopes above 30% unless stability studies are conducted using the engineering soil properties of the specific soils where they are to be constructed. Paddies built on slopes greater than 30% tend to be plagued with too many failures and drainage problems. Part of the failure process is caused by using vertical or nearly vertical risers without surface protection such as grass. Diversified crops require the use of a gradient system, as excess moisture must be removed.

There are two general types of terrace systems that are constructed on a gradient: conservation terraces and bench terraces. Conservation terraces are the construction of a series of low ridges and waterways perpendicular to the slope wherein the crop land remains, more or less, on the original ground slope, but is cultivated on the same grade (contour) as the ridges. Bench terraces are constructed by cut and fill, leaving a nearly horizontal bench and a steep riser so that the system looks like stair steps. There are three cross sections used with graded bench terraces: horizontal, forward slope, and reverse slope. These are presented in Figure D-2. Only the reverse slope terraces tend to approach the horizontal terraces with time and settlement. The forward slope terrace should never be used in humid climates even when an outer lip is used. Horizontal slope terraces tend to become forward sloping with time and settlement and, thus, prone to excessive erosion under heavy rainfall.

In humid areas, except for flooded rice production, only a graded system with conservation terraces or reverse slope bench terraces are recommended. With small ownerships, the bench terrace is more practical, and will provide better erosion control. It is often very difficult to convince local farmers to plant on the contour, as required for conservation terraces.

All terraces constructed in humid areas must have an outlet of suitable capacity that can be protected by well maintained vegetative cover and, when necessary, by structures. Even level benches with rice fields must have a drainage system to remove excess rainfall after preselected depths are reached. Graded terraces must remove water relatively rapidly to reduce the accumulation of excess soil moisture, particularly on the steeper and potentially less stable slopes. Gullies developing at an outlet can extend up the terrace channel causing failure of the entire system.

Design Criteria

Bench Terraces

The design criteria for bench terraces are given below and the necessary equations and definition of terms are presented in Figure D-3.

Vertical Interval

The vertical interval (VI) is the most important dimension in terrace construction. Except in deep soils, the vertical interval is determined by the depth of soil available on the hillside. In non-mechanized agriculture, where the width of terraces is not so important, a uniform riser height is more practical for construction purposes than a fixed terrace width. If shallow soils are encountered where deep cuts (steep slopes) are required, then a construction technique is required that allows the stripping of the surface soil from one area to be placed on top of the finished bench on the adjacent area. This technique increases the construction cost but does allow their construction.

The vertical interval (VI) is the elevation difference between two succeeding terraces. It is used as a guide in staking terraces. The practical limit for VI is 1.8 to 2.0 m.

Horizontal Interval

The horizontal interval (HI) or width of the terrace is the next most important dimension and, under certain circumstances, it may govern the design of the terraces. A minimum effective crop width of terrace (We), where all hand labor is

used, is 1.5 m. Where animal power or two-wheel tractors are used for land preparation, the minimum width must be increased to 2.0 m and 2.5 m, respectively, unless planting equipment is used. For orchards, a minimum width of 1.8 m is adequate. Where multi-row mechanical planters are used, the width of the terrace must be in multiples of the planter width and, hence, this width will govern terrace design.

Machine built terraces require a minimum width of 3.5 m. This will limit the maximum slope on which terraces can be constructed to 35%.

To assure farmer acceptance, the cropping pattern, row widths, tools, soil depth, as well as other interests he may have should be considered. Without the farmer's interest, terrace maintenance will be difficult.

Wide bench terraces will not be too costly, but the high costs of constructing deep cuts, high risers and extra soil movement, may make them undesirable.

Length

The length of a terrace is limited by the size and shape of the field, topography, the degree of dissection and the permeability and erodibility of the soil. The location of ownership boundaries, roads, paths, etc., may influence length. Longer terraces will increase operation efficiency, especially for mechanized operations (which includes animal power) as well as reduce construction costs. However, too great a length in one direction may cause accelerated runoff and erosion. Based on current experience, a maximum of 100 m in one direction is recommended in humid areas.

Grade

The grade of a terrace must be controlled and maintained. The minimum grade should not be less than 0.5% with a preferable channel grade of 1.0%, in order to get rid of excess rainfall. The grades on the reach furthest away from the outlet may be slightly steepened in order to maintain parallel terraces and facilitate designs.

A reverse grade of 5% is also required on bench terraces in order to keep the runoff in the cut area (terrace channel) rather than on the loose fill area, which is susceptible to sliding.

During initial construction, the fill area should be constructed to a height at the lip which is 15 to 20% higher than the final elevation to allow for soil bulking during construction and consolidation (settlement) with time. The height allowed for bulking depends on the soil structure, compaction and Atterberg limits.

Riser

The height of a riser may be dependent on the width of the terrace. In most cases, it will be fixed by the depth of the available soil. Riser heights of 1.8 to 2.0 m after settlement are considered as the practical upper limits. Protection and maintenance become more difficult as the riser height increases. With the cut and carry forage crop system used to protect the riser, the height to which the local people can cut the grass limits the riser height.

The slope of the riser depends on the texture of the soil, soil structure, Atterberg limits and the tools and materials to be used for building the terraces. Hand constructed terraces,

with proper compaction, generally will have a 200% slope (0.5H:1.0V), although in some instances, the soils will allow a 400% (0.25H:1.0V) slope. The establishment of a forage cover on the risers becomes more difficult as the slope increases. For machine construction methods (this includes those using animal powered fresno scrapers and/or slips), an average riser slope of 100% (1.0H:1.0V) is recommended. Again, under certain circumstances, it may be possible to use a 150% (0.75H:1.0V). Rock wall construction will allow somewhat steeper risers, but the stability should be checked using site conditions when slopes steeper than 0.25H:1.0V are desired.

Soil Depth

The soil depth for the bench terraces can be obtained by dividing the vertical interval by two and adding 30 cm. The minimum depth of soil that diversified crops can be grown on is 30 cm, and a minimum depth of 50 cm is preferable. Therefore, without special construction techniques a minimum soil depth of 50 cm is required for a 40 cm vertical interval. If the top soil is removed from the slope and placed in a 30 cm deep layer on the bench, deeper cuts can be allowed into subsoils or partially decomposed parent material provided the cut material did not exceed sand size particles.

Slope Limit

Bench terraces can be constructed on slopes up to 50% using hand methods. The normal range of slopes would be 15-50%. For practical large scale construction efforts, 35% slopes are the upper limit as risers have to equal or exceed 150 cm for all slopes above 35%. Hillside stability and landslide problems begin to appear on slopes steeper than 50%. Machine built terraces would be limited to 35% slopes or less due to terrace width limitations.

It is generally not recommended to use bench terracing on slopes less than 12-15% because simpler and cheaper conservation treatments can be used.

Net Crop Area

The net area is the area on which crops are grown and excludes the riser, lip and terrace channel. The steeper the slope the less net crop area. With a 180 cm riser, the net area declines from 81.7% to 46.2% as the land slope increases from 15% to 50%, assuming continuous terraces.

Terrace Channels

Terrace channels are located at the heel of the terraces in the cut area. The channel section is to be located 10 cm from the true heel and the cultivated area is 10 cm from the front of the channel (Figure D-3). The average depth from the front of the channel is 20 cm varying from 15 cm at the head and to 25 cm at the outlet. The average width on the terrace channel is 55 cm.

The terrace channel will basically have a 0.5 to 1.0% slope when constructed. Erosion will eventually slightly steepen this if the two changes in depth are not structured.

Specification Tables

A specification table can be computed, step-by-step, according to the equations presented in Figure D-3, for various vertical intervals and/or terrace widths on different slopes for planning and field uses. The volume of cut and fill and net crop area can be determined and tabulated. A sample of

this type of data is in Table D-1. Programmable calculations can be used to prepare the desired specification table.

Conservation Terraces

Conservation terraces are constructed on slopes of 4 to 25%, but are generally not recommended for slopes above 15%. The design of a conservation terrace is a special case of the general problem of storm water drain design. The channel, or waterway, is usually considered to be parabolic, so the hydraulic radius is fairly constant. Variations in terrace cross sections are presented in Figure D-4.

Vertical Interval

The vertical interval between conservation terraces depends primarily upon land slope. However, it also depends upon the soil and climate. The cross section will have some effect on the horizontal spacing. The crops to be grown and the machinery (if any) that will be used should also be considered. The preliminary terraces spacing is determined by the equation:

$$VI = (XS + Y)0.305$$

Where:

VI = Vertical interval in meters.

X = Variable with values of 0.3 to 0.8 for graded terraces, and 0.8 for level terraces.

S = Land slope in meters per 100 meters.

Y = Variable with values of 1.6 to 4.0 as influenced by soil erodibility, cropping systems and crop management practices.

For humid areas, a value of X = 0.3 should be used due to heavy, high-intensity rainfall. The values of X increases as rainfall decreases. The values of Y generally used are as follows:

Y = 1.0 for soils with below average intake rates and cropping systems that provide little cover during intense rainfall periods.

Y = 4.0 for soils with average or above intake rates for cropping systems that provide good cover during periods of intense rainfall.

Y = 2.5 where one of the above features is favorable and the other unfavorable.

For humid climates with interplanted cropping systems, a value of Y = 2.0 is acceptable. The vertical interval is used for staking terraces. The variation obtained with various values of X and Y are presented in Figure D-5 .

Horizontal Interval

The spacing of horizontal interval (HI) between hillside ditches and terraces is computed as follows:

$$HI = \frac{VI}{S}(100)$$

The spacing should be rounded to even meters. Spacing may be decreased as much as 25% and increased 10% to allow for farming needs.

Maximum Length

After the spacing has been determined, the next design factor to consider is length. The necessity for designing the terrace layout so that the maximum length is not exceeded is of little consequence in some cases, i.e., where the topography is highly eroded and crossed by numerous water courses; but a major complication where the area to be protected is on uniformly sloping land with few natural stream or water courses. The recommended maximum lengths, in meters, of the terrace channels are as follows:

	Sandy Soils	Clay Soils
Normal Maximum	250	400
Absolute Maximum	400	450
Gullied Land	100	250

The maximum length refers to the maximum length of flow. A channel which sheds runoff on both sides from a high point can have the maximum length on either side of the high point. Where the runoff must be discharged into artificially excavated waterways, costs will be increased. In most cases, the additional cost would be small in proportion to the total cost and easily justified if it is going to mean a more efficient system with a long life. The temptation to exceed the maximum allowable length must be resisted by the dictum that bad protection works are worse than no protection works.

Gradient

If the gradient of the channel is too steep it will scour, if too flat it will flow sluggishly and, thus, will require a large cross section that may be in danger of silting. However, the selection of a grade which will result in non-scouring, non-silting velocities under all conditions is not easy. A

special feature about the flow of water in the channels of terraces is that the quantity of water increases along the channel. At the discharge point, the flow in the channel is the runoff from the entire area served by the terraces, but half way along its length only half the area is contributing. There are two different approaches to selecting the gradient of terrace channel; the variable gradient and constant gradient.

1. Variable Gradient

It is not practical to design for increasing flow by making the cross section of the channel bigger towards the outlet end because it is impossible with machine construction and difficult to control with hand labor except by deepening the channel at given locations. The capacity of the channel may be increased by maintaining the same cross section and increasing the gradient. The required gradients that result in an increased capacity are as follows:

Length = L	Slope - Gradient
First 1/3 L	0.005
Second 1/3 L	0.0075
Third 1/3 L	0.01

2. Constant Gradient

The use of a constant grade and a constant cross section, based on the required channel capacity at the outlet, results in considerable overdesign of the beginning end of the terrace. This method assures a suitable velocity and it is easier to stake the terraces in the field. The latter consideration is extremely important when the field work is being carried out by unskilled staff. The recommended grade for uniform terraces is 0.01.

Cross Section Area

The cross sectional area of the drain in the channel terrace is less precisely defined and specified than that for a bench terrace because the section will change with farming operations and, also, they are not cleaned. This is particularly true with mechanical cultivation. Generalized minimum dimensions are a cross sectional area of roughly 1.0 m^2 with a minimum channel width of 2.1 m, minimum channel depth of 0.25 m below original ground level and a bank 0.25 m above the original ground surface. The design condition should be checked for a runoff based on a 10-year return period.

Channel Velocity

The limits or range of velocities for bare earth channels between non-scouring and non-silting is small. The maximum safe velocities for bare soil are:

Material	m/s
Very Light Silty Sand	0.3
Light Loose Sand	0.5
Coarse Sand	0.75
Sandy Soil	0.75
Firm Clay Loam	1.0
Clay or Stiff Gravelly Soil	1.5
Coarse Gravels	1.5
Shale, Hardpan, Softrock	1.8

Estimation of Surface Runoff

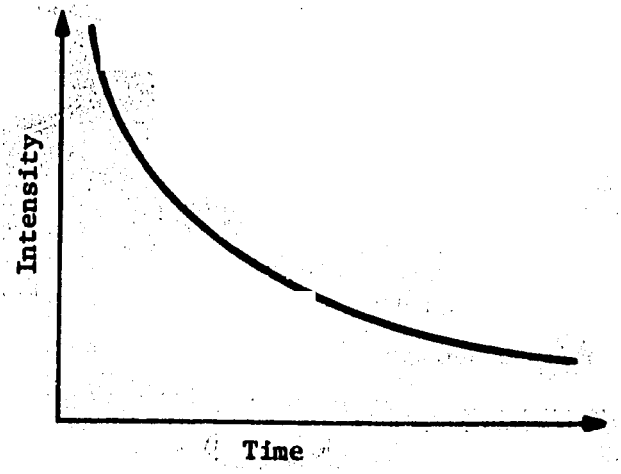
The design of channels, ditches and terraces and other works which deal with surface runoff, requires information on the probable quantity of water. If the object is to impound or store the water it may be

sufficient to know the total volume of water expected, but the usual construction problem is the removal or conveying of water from one place to another and, in this case, the rate of runoff is important and, particularly, the maximum rate at which runoff is likely to occur. This maximum rate is the flow rate that the channel must be designed to handle.

Runoff is some portion of the total rainfall but, unfortunately, is not directly proportional to it. There are many factors which affect runoff such as: some rain is intercepted by vegetation; some infiltrates into the soil; some starts moving over the ground surface, but is trapped in depressions; some is lost by evaporation and many other factors that determine the amount of surface runoff. Estimates of the rate of surface runoff all depend on two processes: an estimate of the rate of rainfall, and an estimate of how much of the rainfall becomes runoff.

Intensity and Duration of Rainfall

It is common experience that the most severe rainfall only lasts for a short time, although it may occur during any part of a storm. A storm which lasts several hours will usually have a greater total amount of rain than a storm which lasts only a few minutes, but the average rate, expressed in millimeters per hour, will usually be less than the average rate for the short period storm. The length of a storm is called its duration and the relationship between intensity and duration is of the form shown below:



A common form for mathematically expressing the relationship between intensity and duration is:

$$I = \frac{a}{D} + b$$

Where: I = Average intensity of the storm.

D = Duration of the storm.

a = Constant.

b = Constant.

Generalized average values of a and b are 3,000 and 40, respectively.

For any given duration, the graph or equation will indicate the highest average intensity which is probable for a storm of that duration. Having introduced the element of probability, the degree of probability must be specified. Given adequate records, the maximum intensities can be calculated for various return periods (recurrence interval) and the results shown as family of curves similar in shape to those in Figure D-6, with separate curves for different return periods.

Another variable is that the intensity-duration curve for one meteorological station will not be the same curve for another station or a different part of the country with a different rainfall. In general, the greater the mean annual rainfall the higher the probable intensity for any given duration and return period. A family of curves can, therefore, be drawn for different mean annual rainfall of any given probability. Figure D-7 presents an example of the variation of intensity-duration for various mean annual rainfalls.

In the case where intensity-duration data are limited, another form of data evaluation can be used. The available depth-duration data can be plotted and then enveloped. The smooth envelope curve can then be used to prepare an intensity-duration curve with known probability.

In Indonesia, intensity-duration data is not processed as part of the routine rainfall evaluation process. Data was not available for Banjar. Therefore, the data available at Gombong, to the east of Banjar ("The Karangsambung/Wadaslintang Multi-purpose Project Hydrology Appendix", ECI 1978) was used. This data was plotted and an envelope curve drawn (Figure D-8). The data is of very short duration so that no probability estimates could be made. In view of the limited data, it was assumed that an envelope curve of the Watubelah intensity data would approximate a 10-year return period (Figure D-9). The envelope curve adequately represents the variation in rainfall intensities and duration for periods of 5-minutes to 10-hours (600 minutes). A one hour design storm was defined as 110 mm by Figure D-9. This would be adequate for the design of terraces, diversion ditches and other drainage and waterway features.

Time of Concentration

Since intensity rates are linked to storm duration, they also have an appreciable affect on runoff. The storm duration, which corresponds to the maximum rate of runoff, is known as the time of concentration. It is defined as the longest time taken for water to travel by overland surface flow from any point in the catchment to the outlet. This can be illustrated by a storm occurring near the outlet, but not covering the watershed. The intensity could be high, but only a portion of the watershed is receiving rainfall and yielding runoff. If a more widespread belt of rain covers the entire watershed the intensity will probably be less, but the entire watershed will be yielding the runoff. Under most conditions, a storm covering an entire watershed gives the greater rate of runoff. Maximum runoff will occur when the entire watershed is yielding runoff at the maximum rate. Since intensity-duration curves show that intensity decreases as duration increases the maximum rate of rainfall and, hence, the maximum rate of runoff will occur in a storm with the shortest duration, which will still allow the whole watershed (catchment) to contribute runoff. The shortest time for the entire watershed to contribute is the time it will take water to flow

from the point which is the farthest away in time, hence, the definition of time of concentration. The longest time may not necessarily be that taken by runoff from the farthest point to reach the outlet because there may be a nearer point which, due to flatter grade or storage, has a slower route to the outlet.

The main variables affecting the time of concentration are: 1) size, the larger the catchment the longer will be the time of concentration; 2) topography, steep topography will cause faster runoff and a shorter time of concentration; and 3) shape, with catchments of the same size the shape can effect the time of concentration such that long, narrow catchments have a longer time of concentration than either square or short, squat catchments.

Two approximate methods for estimating the time of concentration are the "Bransby-Williams" formula and the "Kirpich" formula. The Bransby-Williams formula is defined as:

$$T = \frac{L}{1.5d}\left[\frac{M^2}{F}\right]^{0.02}$$

Where:
- T = Time of concentration in hours.
- L = Longest distance to outlet in kilometers.
- d = Diameter of a circle equal in area to the catchment area in kilometers.
- M = Actual area in square kilometers.
- F = Average fall or slope of the main water course in m/100 m.

The Kirpich formula is defined as:

$$= 0.2\ (L)^{0.77}\ (S)^{0.385}$$

Where:
- T = Time of concentration in minutes.
- L = Maximum length of flow in meters.
- S = Average stream gradient in m/m.

Infiltration

Not all the rainfall reaching the ground becomes surface runoff. Part of the rainfall infiltrates the soil. The infiltration rate varies with time, with high initial rates and low protracted rates during long periods of rainfall. The infiltration rate varies with soils and the fraction of sand, silt and clay. Where measured infiltration data is lacking, the following minimum rates may be used:

Well Drained Land	40 mm/hr
Medium Drained Land	20 mm/hr
Poorly Drained Land	10 mm/hr

Estimating Maximum Runoff Rates

There are at least 100 different methods or formulas that have been proposed for estimating peak discharges from small watersheds. Most of these were developed for special situations and are not universal in application. In general, for areas in excess of 5 hectares, it is advisable to use a method involving hydrographs, unless a specific method has been proved or locally calibrated.

Small Catchments

Small catchments are defined as those containing less than 10 hectares. The simplest method for estimating the maximum rate of runoff is the "Rational" formula which is:

$$= 2.78\ ACI$$

Where:

- Q = Design flow in liters per second (l/s).
- A = Drainage area in hectares (ha).
- C = Runoff coefficient, depending on character of runoff.
- I = Rainfall intensity, in millimeters per hour (mm/hr) for a 1-hour storm as modi-

fied by required storm duration to concentrate flow at desired location.

2.78 = Metric conversion factor.

The application of the formula consists of selecting appropriate values of C, I and A. The area A can be measured by a surveyor, taken from maps or aerial photos. The value of I may be determined by one of the methods discussed above.

The virtue and weakness of the rational formula is that all the factors that determine the proportion of rainfall which becomes runoff are combined into the single runoff coefficient C. The factors included are topography, vegetation, infiltration rate, soil storage capacity, drainage pattern, etc. Many tables have been proposed for estimating C and their use depends on experience. Table D-2 is a composite of C values that are applicable to the tropics.

The rational method is adequate for the design of terraces in small watersheds. The limitations in available data are not critical, as only the maximum discharge is required and the terraces have sufficient capacity to store a portion of the excess rainfall until it can be drained off, therefore, acting as a buffer. The design of terrace drains is made on the premise of minimizing drain size to reduce cost of construction without overflowing the riser. For example: an average terrace of 4 x 100 m = 400 m^2 is to be drained, the intensity is 100 mm/hr and a C value of 0.6 for bare clay soil is estimated so that the maximum rate of runoff is calculated to be $Q = 2.78(0.04)(0.6)(100) = 6.6$ l/s.

Medium Catchments

Medium catchments are defined as those containing more than 10 hectares and less than 2,600 hectares. A practical method has been developed of representing a runoff hydrograph by a triangle, for determining peak discharge. Figure D-10 shows the schematic

representation of a triangle unit graph. The runoff hydrograph is equal in volume to the excess rainfall, and the time to peak and peak rate are equivalent to a typical unit graph.

From Figure D-10, the total runoff is defined as:

$$Q = \frac{qi\ Tp}{2} + \frac{qi\ Tr}{2}$$

Where:

Q	=	Total runoff in centimeters.
qi	=	Peak rate in centimeters per hour.
Tp	=	Time, in hours, from start of rise to peak rate.
Tr	=	Time, in hours, from peak rate to end of runoff.

The peak rate is then defined as:

$$qi = \frac{2Q}{Tp + Tr}$$

The values of Tr and Tp are related so that:

$$Tr = H\ Tp$$

Where H is a constant to be determined for each watershed. It can be determined from recorded hydrographs. In lieu of recorded data a value of H = 1.67 may be used for an average value in ungaged watersheds. The peak rate can now be defined as:

$$qi = \frac{2}{(1+H)} \frac{Q}{Tp} \quad \text{(in centimeters/hour)}$$

Converting the peak rate from cm/hr to liter per second (l/s) and introducing the drainage area (A) in hectares, the peak rate can be defined as:

$$qp = \frac{2(27.78)AQ}{(1+1.67)Tp} = 20.8\frac{AQ}{Tp} \quad \text{(in liters/second)}$$

The lag time is defined as the time from center of excess rainfall to time of peak discharge. An empirical relationship adopted by many hydrologists for ungaged watersheds is defined as:

$$Tp = D/2 + 0.6Tc$$

Where:
- D = Period of excess rainfall, in hours.
- 0.6 = Empirical constant.
- Tc = Time of concentration-travel time of water from hydraulically most distant point to point of interest (outlet), in hours.

A time of concentration from which a lag time can be computed must be obtained for hydrograph construction representing runoff from a watershed. Two methods of estimating Tc from individual watersheds are as follows:

1. The time of concentration can be estimated from stream hydraulics wherein channel cross-sections are taken and bank-full discharges are measured so that an average velocity can be determined for each reach of the stream. Then, using the average velocity and valley length of each reach, compute the travel time for each reach and sum the travel time of all reaches to get Tc.

2. The time of concentration can be estimated by estimating velocities and watercourse lengths. Various methods have been used to obtain average velocities in natural streams, based on average slope in each reach and, in some cases, on the watershed cover and conditions.

Generalized lag curves can be worked out for a region so that lag time (Tc) and drainage area are plotted. If a large number of Tc determinations are expected, the development of such a curve will save considerable time in engineering designs.

These data are, admittedly, generalized because concentration of runoff is affected by storm distribution over the watershed and storm intensity, as well as by the watershed hydraulic characteristics. If data are available, more than one method of estimating Tc should be used to select a representative value for a particular watershed. Whenever it is possible to obtain a Tc value from streamflow records of the stream of interest, or by detailed field inspection of stream channel and watershed characteristics, that value should be used. When it is necessary to estimate a Tc value, the following equation can be used:

$$Tc = \left[0.87 \frac{L^3}{E}\right]^{0.385} \quad \text{(in hours)}$$

Where: L = Length of longest water course in kilometers.

E = Difference in elevation, in meters, between the outlet point and watershed divide.

The Bransby-Williams or the Kirpich formulas could also be used to estimate Tc, but the time units will have to be consistent with unit graph. Additional work must be done to verify equations for Tc under humid, tropical conditions.

A curvelinear hydrograph may be constructed from values of qp and Tp by using the ratios tabulated on Figure D-10.

An <u>example</u> of the application of the triangle hydro concept follows:

Given:	Drainage Area	=	50 ha
	Rainfall	=	200 mm = 20 cm

Infiltration (Medium)	=	20 mm/h = 2.0 cm/hr
Duration	=	1 hour
Excess Rainfall	=	18.0 cm

From a map, the length of the longest watercourse was measured at 12,750 m (12.75 km) and the difference in elevation from the divide at the farthest point to the outlet was estimated to be 145 m.

Therefore:

$$Tc = \left[0.87 \frac{L^3}{E}\right]^{0.385} = \left[0.87 \frac{(12.75)^3}{145}\right]^{0.385} = 2.64 \text{ hr}$$

$$Tp = D/2 + 0.6Tc = 1/2 + 0.6(2.64) = 2.08 \text{ hr}$$

$$Tb = 2.67Tp = 2.67(2.08) = 5.56 \text{ hr} \quad \text{(Use 5.6 hr)}$$

$$qp = \frac{20.8AQ}{Tp} = \frac{20.8(50)(18)}{2.08} = 9{,}000 \text{ l/s}$$

The Design of Hydraulic Channels

Most of the mechanical works used in the control of erosion are required to collect, divert or lead streams of water, and the basis of their design is the application of the principles of the hydraulics of flow in open channels. The following are the four problems most frequently encountered:

1. Estimating the flow in a channel when the cross section, gradient, depth, etc., are known.

2. Estimating the depth of flow at which a given channel will carry a given rate of flow.

3. Designing a channel which will carry away a given rate of flow without exceeding certain velocity limitations.

4. Designing a system including structures which will carry away a given rate of flow on steep slopes where velocity limitations would otherwise be exceeded.

Inter-Relation of the Variable Factors

The basic formula for the rate of flow in a channel is:

$$Q = V A$$

Where: Q = Rate of flow (l/s or m^3/s).
V = Average velocity (cm/s or m/s).
A = Cross sectional area of flow (cm^2 or m^2).

Many factors influence the velocity and area of flow, and they react upon each other in a complicated inter-relation. The main factors are:

1. Size

Obviously, large channels will will carry more water than small ones.

2. Shape

Channels of the same cross sectional area, but of different shapes will carry different amounts of water. Water close to the sides and bottom of the channel is slowed by the friction effect, so a channel whose shape provides the least area of contact with the water will have the least frictional resistance, and so a greater capacity. The unit to measure this affect of shape is called the "hydraulic radius" of the channel. It is defined by the cross sectional area divided by the "wetted perimeter", which is the

length of the cross section of the channel which is in contact with the water. The hydraulic radius is defined by the formula:

$$R = \frac{A}{P}$$

Where: R = Hydraulic radius.
A = Area of flow.
P = Wetted perimeter.

The basic dimensions of common channel sections are shown on Figure D-11. If all other factors are constant the lower the value of R, the lower will be the velocity.

Earth channels are usually given a cross section which is trapezoidal, or a smooth curve approximating a parabola. Channels originally excavated in earth as trapezoidal sections tend towards a parabolic shape, in time. V-shaped sections are undesirable for earth channels because the lowest point is liable to scour.

3. Gradient

Velocity is, naturally, affected by the gradient and increases as the channel gradient steepens.

4. Roughness

The contact between the water and the channel exercises a frictional resistance, and this is affected, like any friction effect, by the smoothness or roughness of the channel. A concrete lined channel has less resistance than one whose sides are choked with vegetation. It may be desirable to minimize roughness when it is required to pass as much water as possible, or to increase the roughness when it is desired to slow the water down below a non-scouring velocity.

The quantity and rate at which water will flow in an open channel is determined by all these factors, which are all linked together in complicated relationships. The result is that there is seldom one unique solution to a channel design. Frequently, there are a number of alternative solutions from which one can be selected as the most suitable for the job.

Estimates of Velocity

The most commonly used method for the estimation of velocity in open channels is the "Manning" formula. The formula is defined as follows:

$$V = \frac{R^{2/3} S^{1/2}}{n}$$

Where:
- V = Average velocity of flow (cm/s or m/s).
- R = Hydraulic radius (cm or m).
- S = Average channel gradient (m/m).
- n = A coefficient, known as "Manning n". The values for "Manning n" are shown in Table D-3.

Design Criteria

Maximum safe velocity is the highest velocity that can be allowed in an unpaved channel without scour or erosion. It varies for different soil conditions, vegetal cover and bank protection. Acceptable maximum velocities for various soil conditions are as follows:

Material	Maximum Velocity (m/s)
Very light silty sand	0.3
Light loose sand	0.5
Coarse sand	0.75
Sandy soil	0.75
Firm clay loam	1.0
Stiff clay, or stiff gravelly soil	1.5
Coarse gravels	1.5

Shale, hardpan, softrock	1.8
Hand cemented conglomerate	2.5

Maximum safe velocities are not exceeded under any circumstances.

The shape of the section is normally trapezoidal for two reasons: 1) construction is easier and it's easier to check in the field; and 2) the top width is roughly 2/3 that of a parabolic channel. Efficient channel shapes vary according to purpose. A trapezoidal channel where the depth of flow is 1/2 the bottom width is the most efficient hydraulic section. To prevent siltation, the most efficient channel is where the ratio of depth to bottom width is roughly 1/5. Generally, increasing the depth or reducing the width reduces the volume of excavation.

Freeboard is an extra allowance added onto the design depth to allow for turbulence and construction irregularities. A nominal freeboard of 0.2 d (depth of flow) is suggested with design depths rounded off to nearest 10 cm.

Grass Lined Waterway

A grassed waterway is a natural or man-made drainageway of parabolic or trapezoidal cross section that is below adjacent ground level, and is stabilized by suitable vegetation. The flow is normally wide and shallow and conveys the runoff down the slope. The purpose of the structure is to convey runoff without causing damage by erosion. Grassed waterways are used where added channel capacity and/or stabilization is required to control erosion resulting from concentrated runoff and where such control can be achieved by this practice alone, or in combination with others.

Two types of channels are used for artificially constructed waterways. Type A consists of raised banks which contain the water in a flat-bottomed channel; in Type B channels, the soil is excavated to form a shallow-dished drain and the excavated soil is either carted away or used to form low banks on either side. The advantage of Type A is that the

natural vegetation is undisturbed in the bottom of the channel, and it is particularly useful where water has to be discharged down the channel as soon as it is constructed, without waiting for grass to be sown or planted. The disadvantage is that the soil for the raised banks may be difficult to obtain. If the soil is taken from outside the banks, one, and more often two, parallel channels are dug down the slope resulting in, and/or accompanied by, excessive gullying. The transport of soil to the channel from protected borrow areas is expensive.

Type B is preferable, provided a good grass cover can be established before the channel has to carry water. The ideal solution is for the waterways to be established one or two seasons ahead of the construction of the drains and terraces which will discharge into it. There are methods to increase the rate of vegetation establishment, thus, reducing channel erosion to a minimum if all construction has to be accomplished at the same time.

Design Criteria

The design of the cross section is a specialized case in the design of hydraulic channels. The waterway must run straight down the slope or the water would pile up on the lower side, therefore the gradient is determined by ground conditions. Since a good grass cover is required, the roughness coefficient is within narrow limitations for the size and shape which, for the given slope, will pass the required rate of flow.

Capacity

The minimum capacity shall be that required to confine the peak rate of runoff expected from the design storm corresponding to the hazard involved. A 10-year return period will be adequate for terracing and gully control. Where there is baseflow, it shall be handled by a stone center or other

suitable means, since sustained wetness usually prevents adequate vegetative cover. The cross sectional area of the stone center shall be determined by using a flow rate of 7 l/s/ha, or by actual measurement of the maximum baseflow.

Cross Section

The design water surface elevation of a waterway receiving water from diversion, terrace channels or other tributary channels shall be equal to, or lower than, the design water surface elevation in these tributary channels.

The top width of parabolic waterways shall not exceed 10 m and the bottom width of trapezoidal waterways shall not exceed 5 m unless multiple or divided waterways, stone centers or other means are provided to control meandering or low flows.

Outlet

Each waterway shall have a stable outlet. In all cases, the outlet must discharge in such a way as not to cause erosion. Outlets shall be constructed and stabilized prior to operation of the waterway.

Velocity

Maximum permissible velocities of flow for various stated conditions of stabilization are as follows:

Cover	Range of Channel Gradients (%)	Permissible Velocity (m/s)
Type I	0.0 to 5.0	1.8
Tall, close growing	5.1 to 10.0	1.5
grasses	Over 10.0	1.2

Type II Clipped close growing grasses	0.0 to 5.0 5.1 to 10.0 Over 10.0	1.5 1.2 1.0
Type III Poorly established vegetation	0.0 to 5.0	0.75
Type IV Bare soil	0.0 to 5.0	0.60

Vegetative Cover

There are a number of grasses, both native and introduced, that can be used to protect grassed waterways. Not all grasses or legumes should be used, as there are many that are not adaptive to wet soil conditions. No experimental data appears available on tropical grasses and legumes with respect to adaptability to waterways and their degree of water retardance. In lieu of this, an estimate of these qualities have been made, based on agronomists' recommendations and knowledge of the plant material. These are shown on Table D-4.

Channel Roughness

The most common method for the estimation of velocity in open channels is the "Manning" formula. The retardance (roughness) coefficient "n" is a measure of channel roughness with values ranging as follows:

	Manning's "n"
1. Channels free from vegetation:	
Smooth and uniform cross section	0.016-0.020
Small variation in section; fairly reglar alignment to some irregularities	0.0225-0.035
Irregular alignment with grass sides; variable section	0.036-0.045

2. Vegetated channels:

Short grass (5-15 cm)	0.030-0.060
Medium grass (15-25 cm)	0.030-0.085
Tall grass (25 cm and above)	0.040-0.150

The presence of grass or vegetation in a waterway will result in considerable turbulence, which means loss of energy and retardance of flow. This has the effect of stabilizing the body of the channel, consolidating the soil mass of the bed, checking erosion along the bottom and causing the suspended soil particles to settle out in areas of low velocity. Investigations by the U.S. Soil Conservation Service found that the retardance coefficient for just one kind of grass varied over a wide range, depending on the depth of flow and the shape and slope of the channel. Thus, the selection of a design value for "n" would be nearly impossible. Fortunately, it was discovered that the retardance coefficient "n" has a relationship with the product of the mean velocity of flow "V" and the hydraulic radius "R". This relationship is characteristic of the vegetation, and practically independent of channel slope and shape. A number of experimental curves for "n" vs. VR (Figure D-12) were developed for five different degrees of retardance: very high, high, moderate, low and very low. The classification of retardance is based on the kind of vegetation and condition of growth. The original work used temperate climate and vegetation common with the United States. Little correlary work is available on tropical grasses and legumes. To allow usage of Figure D-12, an estimate of the degree of retardance for tropical vegetation (Table D-5) has been prepared and was based on known characteristics, and may be used as a guide in the selection of appropriate vegetation. Stem length and density of growth are particularly important in determining degree of retardance.

Procedure of Design

It is suggested that the hydraulic design of a grassed waterway consist of two stages: A) Design for channel stability, i.e., to determine channel dimensions under conditions of a lower degree of retardance; and B) Review for maximum capacity, i.e., to determine the increase in depth of flow necessary to maintain maximum capacity under conditions of a higher degree of retardance. Finally, a proper freeboard is added to the computed depth of the channel flow, which will further increase the maximum design capacity. The design procedure is as follows:

A. Design for Stability

Given the discharge, channel slope and kind of grass, the first stage of design may proceed in the following steps:

1. Assume a value of "n", and determine the corresponding values of "VR" from the n-VR curve (Figure D-12).

2. Select the permissible velocity and compute the value of R.

3. Using the Manning formula, compute the value of:

$$VR = \frac{R^{5/3} S^{1/2}}{n}$$

and check this value against the value of VR obtained in step 1.

4. Make other trials until the computed value of VR is equal to the VR value obatined from the n-VR curve.

5. Compute the water area, or A = Q/V.

6. Since the correct values of A and R have been obtained, the section dimensions may be determined.

B. Design for Maximum Capacity

The second stage in design is to determine the additional depth necessary to sustain the maximum capacity of a fully developed lining. The procedure is as follows:

1. Assume the depth "d", and compute the water area A and the hydraulic radius R.

2. Compute the velocity V by V = Q/A and the value of VR.

3. From the n/VR curve of a higher degree of retardance for the selected lining, determine the value of n.

4. Compute the velocity by the Manning formula, and check this value of V against the value obtained in step 2.

5. Make trial computations until the computed V in step 4 is equal to the computed V in step 2. It should be noted that this velocity is always less than the permissible velocity assumed in the first stage of design (design for stability) since the

cross section has been enlarged in the second stage of the design.

6. Add proper freeboard to the computed depth.

Riprap Lined Waterway

Riprap is a layer of loose rock or aggregate placed over an erodible soil surface. Riprap is used where the soil conditons, water turbulence, velocity, expected vegetative cover and groundwater conditions are such that the soil may erode, even under design flow conditions. Riprap may be used at such places as storm drain outlets, channel banks and/or bottoms, roadside ditches and below drop structures. Other than for erosion protection for structures, the use of riprap should be avoided, if at all possible, due to the high cost of placement.

Riprap shall be composed of a well-graded mixture of rock down to the 2.5 cm size particles, such that 50% of the mixture, by weight, does not exceed that of the d_{50} size. Thus, for a riprap size d_{50} of 10 cm, this means that the total weight of all stones greater than 10 cm cannot exceed 50% of the total weight of the entire mixture.

Design Criteria

The design criteria for riprap lined channels are similar to those of other channels with respect to gradient and design capacity. The riprap size is determined empirically.

The d_{50} diameter for a trapezoidal channel is determined from the equation:

$$d_{50} = 30 \left[\frac{4.167\ R\ Q\ S^{13/6}}{P} \right]^{2/5}$$

Where: Q = Flow, in m^3/s.

S = Gradient, in mm.

P = Wetted perimeter.

R = Hydraulic radius.

The above equation is valid for discharges up to 30 m^3/s.

The roughness coefficient (n) is estimated from the formula:

$$n = 0.0223 (d_{50})^{1/6}$$

If the roughness coefficient used to determine the channel dimensions and that determined for d_{50} are not in reasonable agreement, another trial must be made to establish channel dimensions using the d_{50} value of n.

Parabolic channels should not be riprapped due to increased amount of riprap required over that for a trapezoidal channel to convey the same amount of flow.

Erosive forces of flowing water are greater in bends than in straight channels. For channels with bends, calculate the ratio Bs/Ro, where Bs is the channel surface width, and Ro is the radius of the bend. Use Figure D-13 to find the bend factor (F_b), and multiply the d_{50} for straight channels by the bend factor to determine the riprap size to be used in bends. If the d_{50} for the bend is less than 1.1 times the d_{50} for straight channel, then the size for the straight channel may be used in the bend; otherwise, the stone size calculated for the bend shall be used. The riprap shall extend across the full channel section and shall extend upstream and downstream from the ends of the curve a distance equal to five times the bottom width.

The maximum stable slope of a riprapped channel side is determined from Figure D-13. The channel bank will not be steeper than 2.5H:1V.

The riprap size shown on plans shall be defined as the largest stone in the mixture and the largest stone is limited to 1.5 times the d_{50} size. The minimum thickness of the riprap layer is defined as 1.5 times the largest stone in the mixture, or 2.25 times the d_{50} size, but not less than 15 cm. Riprap shall extend up the side slopes to a height equal to the maximum depth of flow, or to a point where vegetation can be established to adequately protect the channel banks.

The determination of the riprap size that will be stable under flow conditions defines what is then considered to be the minimum size. Then, based on riprap gradations actually available in the area, the specifications will reflect the sizes that equal or exceed the minimum. The possibility of damage by children should be considered in selecting riprap size, especially if there is water nearby to toss the stones into.

In channels where there is no riprap or paving on the bottom, the toe of the bank riprap shall extend below the channel bottom a distance at least 1.5 times the maximum stone size, but in no case less than 30 cm. The only exception to this would be in the event that there is a non-erodible hard rock bottom.

Riprap shall have a filter, or filter layer, placed under it when either of the following two conditions exist:

1. Where the riprap is not well-graded down to the 2.5 cm size particle.

2. Where the riprap is placed on the side slopes of a channel and the soil is sand-size or finer with a plasticity index (PI) less than 10. This requirement applies to slopes having the soil in lenses or layers greater than 7.5 cm in thickness.

A filter can be of two general forms: (1) a simple layer of plastic filter cloth manufactured for that purpose, and (2) a properly graded layer of sand, gravel or stone.

The criteria for the design of an aggregate filter are as follows:

$$\frac{d_{15}\ \text{riprap}}{d_{85}\ \text{filter}} \leq 5 \qquad \frac{d_{15}\ \text{filter}}{d_{85}\ \text{base}} \leq 5$$

in which d_{15} and d_{85} refer to the diameter of material, where 15 and 85 percent, respectively, are finer. The base is the soil layer underneath the proposed filter. The filter shall be graded down to sand size particles. The soil sizes refer to the unified soil classification system.

Control Structures

There are two types of control structures required in drainage and terracing. These are outlet protection and drop structures. Outlet protection is the providing of de-energizing devices and erosion resistant channel sections to allow the flow to reach a stable existing downstream channel without causing erosion. The outlet protection can be designed according to the methods shown for riprap. The depth is established by the downstream channel conditions.

Drop structures are required where the natural slope causes velocities to exceed the maximum allowable. Either stone or bamboo drop structures may be used. The structures must be extended into the banks far enough to prevent water coming around the ends.

Layout and Construction

Field Surveys

Prior to planning and designing the terrace project there are three basic surveys which should be made on the proposed area: land, soil and drainage. If suitable site maps are not available, the surveyor should prepare a rough sketch map of the site showing existing waterways, major gullies, large obstacles, roads, trails, existing cultivation, houses, slides, general direction of slopes, etc. The three surveys are defined as follows:

Land Survey

Measurement of the general slope of the land, if there are more than one slope or if the slope is not even (slopes may considerably vary at different parts of the area), separate measurements of each different slope will be made. Slopes are to be expressed in percent and not degrees. The measured slope of the land will be used with other information in arriving at the construction dimensions of the terraces. Length of slope, width of slope and topography of the area are to be recorded. This information is used in determning whether the area is suitable for terracing and, if so, the length of terraces.

Soil Survey

A simple soil survey should be conducted to obtain:

Soil Texture

Clay loam, silty clay loam, silty loam, sand clay loam, etc. Very coarse soils and very fine soils should be avoided for bench terracing. Clay soils can be terraced for upland rice production if all other conditions are optimum.

Soil Depth

For terrace constructiuon, soil depth (topsoil and subsoil) should be measured down to the depth of the parent material. This depth is recorded as the maximum effective soil depth (terraceable depth), and the depth of cut should not exceed this depth.

There may be an allowable exception to this rule, that is, in areas where the parent material is highly weathered and effectively disintegrated so that it may be considered as a part of the so-called "B" horizon and may be included in the terraceable soil depth. The minimum soil depth needed for terracing is 30 - 40 cm.

Small pits, at various points or locations in the area, can be dug with a pick to observe the soil profile and determine field texture, structure, depth of horizons and a field estimate of permeability. The depth of the pit to be dug should be about 75 cm; deeper observations can be made with an auger. The soil profile can also be studied from road cuts, banks or gullies, slides and other natural or man-made depressions.

Another important observation to be made is the rock content and stoniness of the soil. Soils with too many stones should be avoided. Size of stones or rocks in the soil should be recorded, as this will dictate whether the terrace risers will be made of stones or earth.

Surface Drainage Survey

One of the primary concerns of the technicians involved in terracing is to determine the availability of proper drainage outlets. Existing gullies with active erosion cannot be considered or used as a proper drainage outlet for terraces. Only stabilized

waterways with no apparent gully formation, and with grass cover, can be used as an outlet or drainageway for the excess water from terraces. If such natural and safe outlets do not exist, then construction of control structures will have to be designed and provided in order to have a non-eroding outlet channel.

Layout of Terraces

Terraces are not laid out until a water management plan for the entire sub-watershed (unit) has been developed and the outlet locations and types of outlets have been selected. A soil and land capability classification is also a prequalification for terracing so that sufficient knowledge is available on soil depths and future capabilities.

Systems of mechanical protection need to be built in the right order. When water is to be carried by a channel which has been designed as a vegetated waterway it will almost certainly erode if it tries to carry the water before the vegetation is established. Any grass-lined diversion drains or grass waterways should, therefore, be put in first, preferably the season before they have to start work on terrace construction.

The next point is that diversion drains should be put in before the terrace channels, and building of the channels should start from the top. The reason is that the terrace channels have been designed so that each can carry its own share of the runoff and no more. They cannot properly function unless all the other protection works higher up the slope are in place. Even when it is the intention to build all the works within a short time there is always the possibility of tractors breaking down or sudden storms catching the job half completed, it is a good practice to always start construction at the top and work downhill.

Non-Parallel Terraces

No set procedure exists that will give the best terrace layout on all fields or units; consequently, the final location of the terraces will depend, to a great extent, on the judgement of the engineer preparing the layout. The following is a suggested procedure for those with little or no experience in terrace layout. As experience is gained and judgement is developed, modifications of this procedure to reduce the time required and to improve the layout will be made.

1. Locate the high point of the area to be terraced. A level should be used to locate this point, for it is often impossible to judge the highest elevation in an area by the eye.

2. Determine the land slope above the first terrace. Measure this slope from the high point. In measuring land slope it is convenient to use a distance of 25 m between points; however, on steep land it may be advisable to use a 15 m distance.

3. Select the vertical interval for the first terrace. Use the steepest slope from the high point and substitute the applicable equation for vertical interval (VI).

4. Locate the first stake on the top terrace. This stake is usually located directly down from the high point. The difference in elevation between this point and the high point is equal to the vertical interval computed in item 3.

5. Stake out the terrace to grade. Stakes are usually set at 25 m intervals on uniformly sloping land with less than 5 percent slope. A 15 m distance is used on land with irregular slopes and land with slopes greater than 5 percent. If level terraces are being staked out, all stakes are set at the

same elevation as the first stake. If graded terraces are being staked out, care should be taken to see that the rod reading is increased when approaching the outlet end of the terrace and decreased when approaching the upper end.

6. Check the location of the top terrace. Due to variations in topography on some fields, it may be found that the top terrace, located as suggested above, will not be as near the recommended spacing in all parts of the field as would be desired. For this reason, it is important to check the location of the top terrace before proceeding with the layout of additional terraces. To accomplish this, measure the land slope from the top of the ridge to the first terrace at additional points in the field. Compute the recommended vertical interval or surface distance for terraces on these slopes. Measure either the vertical interval or the surface distance between the top of the ridge and the top terrace at the points where the land slope was measured and compare this with the recommended interval or distance.

7. Shift the location of the top terrace, if necessary, to give a more desirable spacing. In some cases, the top terrace may be moved downslope to give a more desirable spacing in some sections of the field, even though this may result in a spacing that is wider than recommended in another section of the field. A somewhat wider spacing above a certain section of a terrace is permissible if the area involved is limited. In general, if the topography of the area is such that the runoff water can be spread over a wider area rather than being concentrated, and the wide spacing is usually near the upper end of the terrace.

8. Measure the slope of the land draining into the second terrace. A sufficient number of slope readings should be made to determine the average slope of the land draining into the second terrace. If the terrace is short and the slope uniform, one reading would be adequate. If, however, the terrace is

long and the slope irregular, several readings will be necessary to obtain an average.

9. Select the vertical interval for the average slope. Use the average slope and substitute in the applicable equation for VI.

10. Locate the first stake on the second terrace at the given vertical interval below the first terrace. If the second terrace will be the same length as the first terrace and is to be staked to the same grade, the vertical interval between the two terraces will be the same at all points along them, in which case, the first stake on the second terrace can be located below any point on the first terrace. If the second terrace is not the same length as the first one, then judgement must be exercised in selecting the first point on the second terrace so that the most desirable spacing between them is obtained.

11. Stake out the terrace to grade.

12. Additional terraces are located in the same manner as the second terrace.

It can be observed from the above comparisons that the terraces are closer together than recommended in that section of a field with slopes greater than the average, and are farther apart than recommended in that section of the field with slopes less than the average. This variation in terrace spacing in different sections of the field results in 1) point row areas between terraces, thus, increasing the difficulty of farming the land; 2) increased difficulty of farming between the closely spaced terraces on the steeper slopes; and 3) increased erosion between the widely spaced terraces on the flatter slopes. Also, if a uniform depth of cut is made during the construction of the terraces on irregular topography, the terraces will usually be quite crooked.

Diversion drains or channel terraces, if marked out strictly on grade, will have many wiggles and irregularities at localized low or high points. Since these will be a nuisance both in construction and in later farming operations, any straightening out will be desirable. It is in order to do some adjusting provided the changes are explained and understood by whoever is going to construct the terraces. A contour-line passing through a small local depression will bend towards the uphill side, and the kink may be straightened provided the bank is specially raised and straightened at this point. When a staked line goes over a high area it will bend towards the downhill side. In this case, the line can be straightened if the channel is cut extra deep at this point. In such cases, a diagram and clear dimensioned sketches must be given to the person responsible for constructing earthworks. Even on the fairly even land it is sometimes desirable to move the stakes to give a better layout, and the distances which stakes can be moved laterally on different slopes are shown as follows:

Lateral Adjustment of Stakes

Slope (%)	Tol 25 mm	50 mm	100 mm
1	2.5 m	5 m	10 m
2	1.25 m	2.5 m	5 m
3	0.833 m	1.67 m	3.33 m
4	0.625 m	1.25 m	2.5 m
5	0.500 m	1.0 m	2.0 m
6	0.416 m	0.833 m	1.67 m

For a carefully graded irrigation canal on a gentle grade, the maximum departure from grade would be 25 mm. The tolerance of 50 mm would be appropriate for a terrace channel, and 100 mm for a large diversion drain.

Parallel Terraces

The adjustments just discussed above will reduce minor local irregularities, but unless the land is even there will still be large variations in the distance between terraces. In the case of broad-based terraces which can be crossed by tractors and implements, this is a minor disadvantage, but on steeper slopes or when the ridges or risers cannot easily be crossed, this becomes more serious. Short rows in the odd segments between terraces reduce the efficiency of mechanization, and the extra turning in limited space is likely to cause damage to the banks. If the odd areas are left uncultivated, this is both a waste of land and a breeding ground for weeds, insects, etc.

In some cases, it is possible to avoid these difficulties by constructing the terraces parallel to each other. This can be done if the channel gradation is allowed to vary from the design gradient in some places. A smooth curve is preferable. Smooth curves also can be obtained by increasing cut and fill areas. It is, therefore, possible to straighten out terraces into regular parallel patterns, but only at the sacrifice of having more terraces or larger terraces.

The layout of parallel systems is a trial and error process. It can be done in the field, but is usually easier in the office on the contour map. First a "keyline" is selected by eye and drawn in, and this is the smooth line of a channel following a line thought to be typical for that part of the field. The distance between parallel terraces must be less than for normal layouts, and a commonly used figure is two-thirds of the normal length, and that the gradient is nowhere excessive. The maximum permissible gradient can be found from Manning's formula.

Further parallel lines are then drawn in and checked. When a line is unsatisfactory because it has an uphill grade at some point, or is too steep a section, then it is rubbed out and a new keyline is drawn in its place. Next a new set of parallel lines are laid off from the new keyline, and checked as before.

The final result is several groups of parallel terraces, each group following its keyline. Even with this system, short rows (called point rows in America) are only reduced, not eliminated, because there are still some odd shaped areas in between. One solution is to put these areas into permanent pasture.

The design, layout and construction of parallel systems is considerably more complicated than conventional uniform gradient channels, but the advantages make them well worthwhile.

Terraces should be made parallel with long uniform curves whenever practical. This is extremely important for mechanized agriculture, as the trend is to narrower rows and wider equipment. Following are some of the practices that may be used to improve alignment, reduce curvature, decrease the area of point rows (short rows), and improve the farmability of a terraced field:

1. Shape or smooth land prior to construction. If the land surface is rough and irregular, terrace layout will be improved if earth from the ridges is used to fill in depressions. This land smoothing will also reduce the concentration of runoff between terraces, and will make it easier to farm the land after the terraces are constructed.

   The amount of shaping and smoothing that is done prior to terrace construction depends on the depth of the soil and the amount of money that will be spent. On shallow soils, the extent of land shaping is limited, since much of the topsoil may be used to fill depressions. On these soils, it may be more desirable to make deeper cuts in the terrace channel

during construction and use this subsoil to fill the depressions in the field between terraces.

2. Use good judgement in selecting location and number of outlets. In general, the greater the number of outlets used, the easier it is to make the terraces parallel. However, if grassed waterways are used as outlets, the additional outlets will take land out of production and interfere with the operation of farm machinery.

The type of soil and the cropping system to be followed must be considered in selecting the outlet location. Consider the following situations:

a. A farmer grows only row crops and has no need for the forage produced in a grassed waterway. His soil is relatively deep and productive. This man would prefer to have a limited number of outlets and improve the alignment between terraces by a greater variation in cut in the terrace channel.

b. A livestock farmer can use the forage produced in the waterways. His soil is relatively shallow and the subsoil unproductive. This man would prefer to have additional grassed waterways and improved the alignment between terraces by varying the grade in the terrace channels.

On any field a number of alternatives should be considered in arriving at the number and location of outlets that will produce the best system of terraces.

3. Use narrow ridges with flat slopes as turn strips. If terraces are staked to carry water around a narrow ridge with a slope much less than the rest of the field, there will be sharp turns in the terraces with large areas of point rows between them. Whenever possible, the system should be planned so the terraces will drain away from the ridges.

4. Plan fence and outlet locations to facilitate farming the terraces. Terraces are more farmable if they approach a fence or an outlet at a right angle. In some cases, terraces can be made parallel to fences or property lines; this will eliminate odd areas and point rows.

5. Shift the location of terraces. To reduce the curvature of terraces and make them more nearly parallel, it is necessary to shift sections of terraces up or down the slope. The location of graded terraces can be shifted by varying the depth of cut in the terrace channel, varying the grade along the terrace, or by a combination of these two.

In general, varying the depth of cut is more effective in moving short sections of a terrace up or down the slope to reduce the sharpness of curvature. Varying the grade along the terrace is a method used to shift longer sections of a terrace up or down the slope to make terraces more nearly parallel.

When it is necessary to vary the depth of cut, earth is moved from the sections of greater cut to those of lesser cut to maintain the terrace cross-section. The allowable range in the depth of cut will vary with the type of soil, the type of equipment used in constructing the terrace, and the amount of money that the individual is willing to spend.

The extent to which the curvature of the terraces and the point row area between them can be reduced will vary with the topography, the type of soil, the type of equipment to be used in construction, and the amount of money to be spent on construction. The greatest improvement can be made on fields which have relatively uniform topography, moderate slopes and a deep permeable soil. However, some improvement can be made on any field; the amount will be influenced by the crops to be grown in the field. Many farmers would be willing to spend more to have uniformly spaced terraces with little

curvature in a field to be farmed to row crops than they would in a field of upland rice.

Whenever possible, uniform spacing between terraces should be obtained by varying the grade, as this will result in very little to no extra cost. Whenever the depth of cut is varied, the cost will be increased because of the additional earth movement.

One additional technique that can be used to shift the location of level terraces to make them parallel is to split the terraces into segments that are on different levels. The terrace will be continuous, with the different segments separated by channel blocks to prevent water from flowing to that segment of the terrace on a lower level. This technique makes it possible to shift a terrace away from the true contour in order to make it parallel to another terrace. It also prevents excessive earthmoving that would be necessary to bring the entire length of terrace to the same level. The channel blocks should be made with flat side slopes so that they can be farmed.

Good planning and layout cannot be overemphasized. The additional time that may be required to make the best possible layout will be repaid many times by the reduction in cost of construction.

Additional aids in designing terraces are presented in Annexes D-1 through D-4.

Construction of Terraces

Terraces must be properly constructed if they are to control erosion and not unnecessarily interfere with farming operations. Various kinds of tools or equipment can be used. In general, there are three methods used for construction: 1) manual labor, 2) draught animal tools and 3) machines. Manual labor is limited to the steep areas or narrower terraces. Machinery should be limited to small- to medium-sized equip-

ment. Unless there is a definite expertise in the use of mechanical equipment in terracing and land leveling, it should not be used in terrace construction. Poorly used construction equipment will cause more erosion and problems than it will ever prevent. For this reason, no additional discussion will be made on mechanized terrace construction, this includes broad based or other types of conservation terraces for which it is well-suited.

Terraces should be constructed when the land is neither too dry or too wet. This will allow better compaction in the fill areas. The initial cut should be made right below the top, or cut stakes. Fill work should be started against the bottom stakes. By doing so, the fill section will reach the desired grade without over-cutting. Rocks can sometimes be placed along the bottom line, although it is generally better to save the rocks for use in water control structures, unless they are plentiful in the area. Terraces should be constructed in 10 cm lifts with each lift being firmly compacted before the next lift is placed. When a lift (fill) is too thick, it cannot be properly compacted. Terraces going across existing depressions should have particular care taken in their construction and compaction.

When constructing terraces in shallow soils, where unfavorable subsoil is exposed during construction of the terraces, it may be desirable to stockpile topsoil and later spread it over the exposed subsoil areas. When the topsoil treatment is practiced, it may be necessary to build terraces from the bottom up. Temporary protection measures should then be practiced, particularly with respect to removal of surface runoff.

If a new artificial waterway is required, the technician must determine whether the waterway must be constructed and adequate vegetative cover established before terraces are constructed. Where it is determined that the waterway must be vegetated first, the terraces should not be constructed until this has been accomplished.

In general, terrace construction begins with the top-most terrace and at the point of outlet. After the surveying and staking have been completed, the following steps are suggested:

Step 1

Bench Terrace No. 1 (top-most terrace): prepare the site for construction by removing from the topsoil all live and dead vegetation. This debris must not be included as fill material in terrace construction. Including this vegetative debris in the fill would make it difficult to compact. It would result in poor bonding of the fill to the subsoil in the earthfill and excessive settlements. This would cause earth slides and increased seepage of water through the riser. Do not disturb the stakes set by the survey crew at the time the vegetation and debris are being removed. The stakes must be in place until each portion of the terrace is completed.

When practical and not time consuming, a narrow bed of sod, about 5 cm in width, should be temporarily left along the "zero" line of the terraces to indicate cut and fill areas. This will help the laborers in making better excavation and filling. This sod is to be removed during the last touches of levelling and compacting.

Step 2

On the area to be filled, scarify (rough-up) the surface with a hoe so a good bond will be obtained.

Step 3

Riser slopes: use a simple wood frame, Figure D-14, to give correct slope to risers. Using the wood frame, align two bamboo pegs on horizontal centerline for correct riser slope by using a plumb bob. Then drive the pegs into the ground 30 cm deep. The pegs should be 2.25 meters long for a 2 meter bench. These markers will guide the laborers in alignment of correct riser slope. Do not remove the bamboo markers after the first segment of terrace and riser are completed.

Step 4

Proceed making fill from cut area. The subsoil must be placed in horizontal layers and wedged into scarified marks in layers not more than 10 cm deep, and compacted by trampling or tamping with a beater. A thin strip, 6 cm, of topsoil is placed on the outside edge of the finished riser would help in the establishment of grass or vegetation on the riser (Figure D-15).

Step 5

The area immediately below and including the lip should be filled with subsoil. This should discourage planting crops too near the ridge and destroying the lip of the terrace.

Step 6

Waterway shaping and terrace channel work should commence only after the terrace is cut. Be sure that all terrace channel outlets are higher than the waterway bottom to ensure that flows do not back-up onto the terrace.

Step 7

Proceed to the next segment as outlined in Step 1 through 6, until the top terrace is finished, that is, ending at the ridge top, or pathway. Pathways on the drainage break need be constructed only if needed for access to terraces and farming operations. Otherwise, terraces will butt together at the guidelines. We must accept the fact that bench terracing is a precision type job. Proper initial construction will eliminate many repair problems and reduce the regular maintenance job.

Construction of terraces using draught animals, be they oxen, buffalo or horses and plows, scrapers, fresnos or other implements, require some modification to design and construction techniques. In general, terraces will have to be wider, 2.0 m or more, to allow animals to turn around, or turn areas will have to be incorporated on the ends of the terraces. Fresno scrapers require a minimum terrace width of 3.0 m. Also, fresnos are not suitable for rocky soils.

Plows can be used to turn sod cover so that scrapers can be used to pick up the material. Animal power is normally not sufficient to allow a scraper to cut through a heavy sod. Plowing will also allow the wet soils to dry out, as scrapers cannot be used in wet, sticky soils.

Scrapers (Fresnos) are loaded at the high point of the cutting area, and as soon as they are filled turn the animal at once and dump the soil parallel along the fill stakes. The terrace is constructed from the fill line uphill, as was done by hand methods. Better efficiency can be obtained if cutting and filling operations are done by turning the animal continuously without stopping. The use of draught animals accomplishes two things: 1) it allows faster construction and 2) it makes it easier to build parallel terraces and wider terraces because haul distances for cut and fill operations can be increased over those where hand methods, i.e., head baskets, are used. Disadvantages to the use of draught animals is that the terrace widths must be wider and, hence, the terraceable slopes are reduced to 35% or less. Practical considerations would put the upper limit at about 25% slopes. Compaction of fill is a problem.

The use of modern construction equipment is also limited to slopes of 25% or less.

The productivity of manual laborers varies from one area to another. Experience shows that daily hire labor can move from 1.75 to 4.0 m^3 in an 8-hour day. Needless to say, local production rates must be investigated and established since a 4-fold variation cannot be absorbed in contingencies. Farm labor working for itself, even on a community or share basis, is more productive than daily hire labor.

A team of 3 men on narrower terraces and 4 men of wider ones will be a good unit for efficient terracing work. As the work proceeds, several teams can be employed to work on sub-watershed units. Stoney or rocky soil will require additional labor to move the rocks, or a reduction in the individual productivity will result.

Inspection of Finished Terraces

Each segment of the bench terrace must be checked as it is completed. There is no better time to make corrections; earth availability is the handiest and nearest to make additional fills, if needed. High and low points should be marked with pegs and proper corrections made.

In checking bench terraces, the riser and outer area of bench and lip are the critical points, and must be constructed to proper slope and elevation. Terrace checking is as important as the laying out of the bench terraces. As in terrace layout, the important task should not be delegated unless the checker has proven competence.

Access to Terraces

Roads or other forms of access are essential and required for a terracing program. No attempt is made herein to design access roads for vehicles or animals. Mechanization, 4-wheel tractors, require road widths of 3.4 m, while animals or 2-wheel tractors require about 2.0 m. The maximum grade for 4-wheel vehicles is 12 to 14%, and 27 to 30% for animals. Bench terraces can be used for roads. If the benches are wide enough for U-turning, only a single access road is required for each terrace, otherwise, turning facilities are required.

Generally speaking, mechanization requires about 200 m of road per hectare, even in rugged and steep terrain. This can be reduced to 100 to 150 m for animal-powered systems.

Where possible access to terraces should be made at the ends of the terraces. This is usually relatively easy where single ownerships are involved. Where ownerships are small and, thus, there will be several owners to each terrace system (sub-watershed, etc.), difficulties are often encountered. One method that can be used to solve this problem is to build the access paths along the vertical property lines (boundaries), taking a little land out of production from each owner (operator). A footpath should be roughly 50 cm wide, while animal paths (without carts, etc.) would require about 1.0 m. An example of this is shown in Figure D-16. The important item to remember is to provide drainage under the path. This can be accomplished by using giant bamboo tubes or clay or concrete tile sections. Paths can be constructed on the riser lip by widening the lip to 50 cm, and raising it another 5 to 10 cm. Paths should have a slight concave shape when perpendicular to the hill slope, and should be cambered to drain into the terrace when situated on the lip. If the paths become steep enough, they may require the construction of steps.

Protection Measures on Newly-Built Terraces

Protection measures on newly constructed terraces, waterways, access roads, and, thereafter, the maintenance of these items are very essential to the success of a terracing program. A major area of concern will be the settlement of the fill sections immediately after construction, and the protection of terrace risers, waterways and road banks with vegetation.

Risers must be protected by planting a permanent-type sod grass-legume mixture as soon as the earth placement on the terrace is completed. Sod strips should be used on the risers, on pathways and slopes for soil conservation purposes. Legumes may be seeded in between the sod strips after the beginning of the rainy season. *Stylosanthes gracilis* and/or *Centrosema Pubescens* may be planted between the sod strips. Attention should be given to the method of sprigging and seeding of the lip, riser, pathway and the slopes joining the pathway and riser.

Vegetative planting may be needed on the outlet edge of the terrace where it spills into the natural waterway. Plans should be made in advance for adequate supply of sod, sprigs and/or seed for all these plantings. Only sod grasses and legumes should be considered for these plantings. Non-sodding grasses are definitely not suitable because they grow in bunches and are tall-growing, and would shade the crops planted on the bench, resulting in decreased yields. Also, frequent mowing of tall grasses, if planted, would reduce the vigor of the grasses planted unless heavy application of fertilizer is applied, and the effectiveness in erosion control on the riser.

After the bench system is completed, and during the first rainy season, the farmers should constantly observe (inspect) the benches, and take immediate corrective actions should weak points appear. Even with the best construction methods, some uneven earth settlement will take place when exposed to heavy rains. Should low spots or high spots develop, care should be taken to relieve the problem area by making a temporary ditch to connect up with the drain next to the riser. The low and high spots should be marked with bamboo pegs. After the wet season crop has been harvested, and before the land is prepared for the next crop, the problem spots should be corrected. Care should be taken so that rainwater does not accidentally overtop the lip of the terrace.

The revegetation of waterways and other disturbed areas will be completed immediately after those structures are built. It is essential that this revegetation take place immediately after construction to protect the soil against water erosion, and to take advantage of the better seedbed preparation after the soil disturbance.

Growth habit characteristics of grasses and tolerance to problems such as soil acidity, low phosphate, calcium and potash, with high aluminum and maganesse, are very important in revegetation. Also, the forage production, palatability and nutritional value of grasses and legumes used in the watershed will be of great importance. All these factors will determine the criteria by which grasses and legumes will be selected to perform different functions in the watershed, such as:

1. For waterway stabilization rhizomatous, stoloniferous and sod-forming types of grasses are required.

2. For terrace riser stabilization use a sod-forming short grass, to avoid shading the crops. However, the rhizomatous and stoloniferous grass species would be undesirable for this particular use, since they could become a weed problem in the tillable area of the terraces.

3. For a productive forage grass under a forest or tree canopy, good palatability and high nutritional value are desirable. It is important that these grasses grow well under heavy grazing or mowing, and that they are able to tolerate some shading.

Legumes are also recommended to be used in association with grasses for all of the above conditions. The main function for the legumes is as a N-fixer to build up the soil nitrogen, and for increasing the protein value of the forage for livestock production.

Grass monocultures should also be avoided for protection against plant diseases or insect infection. Following is a suggested list of grasses and legumes that can be used for different stabilization purposes.

For Waterway revegetation:

Bahia grass (Paspalum notatum)
Kikuyu grass (Pennisetum clandestinum)
Setaria grass (Setaria sphacelata)
Pangola grass (Digitaria decumbens)

For Terrace Riser Stabilization:

Bahia grass (Paspalum notatum)

Setaria grass (Setaria sphacelata)
Guinea grass (Panicum maxzimum)
Legume (Centrosema pubescens)

For Forage Production on Wooded Areas:

Guinea grass (Panicum maximum)
Elephant grass (Pannisetum purpureum)
Kikuyu grass (Pannisetum clandestinum)
Setaria grass (Setaria sphacelata)
Pangola grass (Digitaria decumbens)
Kudzu (Pueraria phaseloides)
Centro (Centrosema pubescens)
(Calopogonium mucunoides)
(Centrosema plumieri)
(Psophocarpus palustris)

Following is a quick check list of areas requiring protection upon completion of normal construction.

Terraces

1. After the risers are properly shaped, grasses should be planted or hydro-seeded on the risers. Local grasses of rhizome-type are much more desirable than tall grasses, although the latter may produce forage for cattle. Use stones for protecting risers, if available.

2. The terrace outlets, which are always critical, should be well protected either by sod-forming grasses or by small checks (using rocks or pieces of brick to from a check).

3. On that part of the bench where the stepped waterway is crossing, grasses should also be established.

4. Auxiliary conservation treatments or grasses should be well-established between the discontinuous-type of terraces.

Waterways

1. In most cases, grasses are planted to protect the channel, or part of the channel. In the rainy season, mechanical support is sometimes needed, such as using pegs to anchor sods or mulching for seeding during the initial stage.

2. Waterways should be protected from other use such as paths, or for transporting materials.

Roads

1. Unstable road banks should be protected by various methods, i.e., wattling and staking, sodding or hydro-seeding, etc.

2. Steep road surfaces should be protected either by grass, marl or stones. In any case, cross-drains are needed. The distance between two drains can be decided by the following formula:

$$I = \frac{240}{S}$$

Where: I = Interval along the road surface, in meters.
S = Slope in percent (%).

3. Steep road ditches should be protected by ballasting, or a combination of grass and small, loose rock checks.

Maintenance of Terrace Systems

Adequate maintenance to retain the ridge or riser height and shape is absolutely necessary for proper functioning of terraces. Erosion by normal tillage operations tend to fill terrace channels, reduce bank slopes and eliminate the terrace lip. Terrace channels should be reshaped after each crop to assure adequate drainage.

This subject can be very elaborate. However, only a few cautions are mentioned at this time. Terraces must be kept in good condition year-after-year if they are to serve for crop production and soil conservation purposes. Water must not flow over the riser. In addition to regular maintenance of risers, lips, pick-up ditches, waterways and backslopes, which are usually disturbed during farming operations, requires a careful periodic inspection of the terraces. During the first year after the terraces are built, they should be thoroughly inspected every few weeks, especially during the rainy season. It is also necessary to inspect the terraces after heavy rains and immediately repair any breaks, low spots or clogged waterways, and any possible erosion conditions.

Crops should be planted parallel to the edge of the riser, where practical, as it is easier to maintain the backslope than when crops are planted perpendicular to the riser. The rows parallel to the riser also allow for longer times of concentration for infiltration of excess rainfall, thus increasing the overall soil moisture level.

Once the terrace system has been established and soil settlement is stabilized, the potential for major terrace problems are minimal. However, regular inspections must be made by the farmers for rodent burrows, especially before the rainy season. These burrows or ant holes should be tamped shut with soil fill material. The latosol soils, when dry, develop large "cracks". The "cracks" may permit water to tunnel through the terrace risers, causing very severe damage to the terrace system. At the start of the rainy season, the farmer must be careful to inspect for tunneling in his terraces, and make immediate repairs. As the old saying goes, "Prepare the umbrella before the rains come".

The practice causing the greatest trouble in terrace maintenance is that the farmers clip or cut the grass protecting the riser too short. Nearly all farmers use a machete to cut this grass, and usually it is cut to where it is only 1 centimeter long. For many species of grass, this is too short, and it is difficult for the plant to vegetatively recover rapidly. Where the grass on the riser is to be used for animal fodder it should be cut at least 5 cm above the soil surface to facilitate rapid re-growth. During the wet season, fodder grass could be cut every 45 days, depending upon the variety grown.

It is estimated that it will require about 32 man-days per year to maintain one hectare of bench terrace. If the risers are used to produce fodder then this number can be reduced to about 16 man-days. It is difficult to estimate the time necessary for maintenance, as it should be done as soon as repairs are required. The farmer cannot wait for some predetermined time period to make repairs because by then what was a very small problem could become very large. Water acts very rapidly in destroying terraces, or causing excess erosion.

Some guidelines for maintaining bench terrace systems are provided as follows:

Terraces

1. For Benches:

a. Always keep the channel drains open and properly graded, do not permit any accumulation of water on any part of the terrace.

b. Allow all runoff to collect at the channel drains for safe disposal to the protected waterway. Obstacles like continuous mounds or beds should be broken to permit water to pass to the drains.

c. Keep grasses and weeds away from the benches.

d. Maintain proper reverse slopes on the benches or basins, and reshape them immediately after crops are harvested. Plowing should be carefully done so as not to destroy the channel drains and the reverse grade.

2. For Risers:

a. Do not allow any runoff to flow over the risers.

b. Keep the riser surface protected with grass. Weeds and vines which threaten the survival of the grasses should be cut back or uprooted. Grasses should be kept reasonably low and fertilizer applied if it is needed.

c. Any small break or fall from the riser should be immediately repaired.

d. Keep cattle away to avoid walking on risers or eating the grass.

3. For Outlets:

a. Check the outlets and see whether they are adequately protected.

b. Any silt or sediment in the outlets should be removed.

4. For Soil Productivity:

a. Deep plowing, ripping or sub-soiling is needed on the cut part of the benches to improve the structure of the soils.

b. Green manuring, composting or sludge application is also recommended, especially in the initial period for improving soil tilth, soil fertility and soil moisture.

c. Maintain soil productivity by proper crop rotation and fertilizing and use of compost or green manures.

Waterways

1. Keep the water flowing through or over the waterway structures instead of going around or underneath the structure. Any detectable breaks should be immediately repaired.

2. Brush or large weeds should be removed before they shade out the grass. The whole waterway should be kept in dense and low grass cover and as uniform as possible.

3. Structures should be checked as often as necessary but at least twice a year, before the onset of the rainy season and after the rains. Any minor cracks, tunnels and breaks around or on the structure should be repaired.

4. Remove sediment trapped in the stilling basins. Silt can be put back on the terraces.

5. Keep stones properly fastened in ballasted waterways.

Roads

1. Maintain a proper profile of the cross-drains and remove silt and sediment from the drains after heavy rains.

2. Prevent use of the roads by heavy vehicles or tractors when they are too wet or soft.

3. Culverts and side ditches should always be kept open.

4. Reshape road surface if there appears to be track erosion either by wheels or by animal hoofs.

Costs of Terracing

The costs of terracing per unit area depends on slope, soil, type of terrace, width of bench, presence of rocks or tree stumps, and tools to be used. If the width is fixed, the steeper the slope the more expensive the terracing work will be. If volumes to be cut are the same, machine-built terraces are generally cheaper than labor intensive ones, but the type of road and waterway required for mechanization may greatly affect the total cost.

Table D-1 presents examples of volumes of soil to be cut and filled per hectare and per acre for one kind of terrace, bench terraces. The equation for calculating the volume is shown in Figure D-3. In design and construction of terraces, the volume to be cut should be equal to the fill so that no extra soil is needed to be borrowed, or excess soil disposed of. In calculating the volume, therefore, only one part, the cut part, needs to be calculated. Figures D-17, D-18 and D-19 can be used for estimating purposes.

Once the volumes are calculated or found from the specifications, Table D-1, the cost of cutting various types of terraces can be readily obtained from the following equation:

$$C = \frac{V}{T} \times R$$

Where: C = Cost of cutting terraces.

V = Volume of cut and fill.

T = Output per man-day or per machine-hour.

R = Wage per man-day or rate per machine-hour.

The output per man-day or per machine-hour depends on the site, efficiency of work and tools to be used. On the average, a man with hand tools can cut and fill 4 m^3 in one day (8 hours); a D-6 bulldozer can build 42 m^3 an hour; and a man with draught animal tools (plow and Fresno scraper) can cut an fill about 16 m^3 per day. Care must be taken in costing draught animals because many animals only work an half-day (4 hours). The draught animal rates may or may not include the handler.

TABLE D-1

SPECIFICATIONS FOR REVERSE SLOPE TERRACES
$c = 30$ cm: $b_1 = 55$ cm: $b_2 = 20$ cm
$S_2 = S_3 = 200\%$: $S_4 = 5\%$

S_1 (%)	VI (cm)	HI (cm)	h (cm)	b_x (cm)	W (cm)	K_1 (cm)	K_2 (cm)	b_4 (cm)	b (cm)	a (cm)	W_e (cm)	A_e (m^2/ha)	V_c (m^3/ha)
15 (8.5°)	60	400.00	27.75	13.88	342.24	4.50	17.11	18.15	333.70	185.00	258.70	6,467.50	776.90
	80	533.33	37.75	18.88	465.57	4.50	23.28	24.70	453.93	251.67	378.93	7,104.98	1,077.83
	100	666.67	47.75	23.88	588.91	4.50	29.45	31.24	574.19	318.34	499.19	7,487.81	1,380.07
	120	800.00	57.75	28.88	712.24	4.50	35.61	37.78	694.44	385.00	619.44	7,743.00	1,681.60
	150	1,000.00	72.75	86.88	896.24	4.50	44.81	47.58	874.84	485.00	799.84	7,998.40	2,134.69
	180	1,200.00	87.75	43.88	1,082.24	4.50	54.11	57.40	1,055.20	585.00	980.20	8,168.33	2,588.38
20 (11.3°)	60	300.00	27.00	13.50	243.00	6.00	12.15	16.54	236.92	135.00	161.92	5,397.33	670.13
	80	400.00	37.00	18.50	333.00	6.00	16.65	22.66	324.68	185.00	249.68	6,242.00	943.23
	100	500.00	47.00	23.50	423.00	6.00	21.15	28.79	412.42	235.00	337.42	6,748.40	1,217.68
	120	600.00	57.00	28.50	513.00	6.00	25.65	34.91	500.18	285.00	425.18	7,086.33	1,493.96
	150	750.00	72.00	36.00	648.00	6.00	32.40	44.10	631.80	360.00	556.80	7,424.00	1,905.18
	180	900.00	87.00	43.50	783.00	6.00	39.15	53.29	763.42	435.00	688.42	7,649.11	2,318.13
25 (14.0°)	80	320.00	36.25	18.13	253.74	7.50	12.69	21.30	247.40	145.00	172.40	5,387.50	844.29
	100	400.00	46.25	23.13	323.74	7.50	16.19	27.17	315.66	185.00	240.66	6,016.50	1,100.06
	120	480.00	56.25	28.13	393.74	7.50	19.69	33.05	383.90	225.00	308.90	6,435.42	1,355.52
	150	600.00	71.25	35.63	498.74	7.50	24.94	41.85	486.30	285.00	411.30	6,855.00	1,739.96
	180	720.00	86.25	43.13	603.74	7.50	30.19	50.67	588.66	345.00	513.66	7,134.17	2,125.00
30 (16.7°)	100	333.33	45.50	22.75	257.83	9.00	12.89	25.97	251.39	151.67	176.39	5,291.75	1,004.72
	120	400.00	55.50	27.75	314.50	9.00	15.73	31.68	306.64	185.00	231.64	5,791.00	1,245.68
	150	500.00	70.50	35.25	399.50	9.00	19.98	40.25	389.50	235.00	314.50	6,290.00	1,608.02
	180	600.00	85.50	42.75	484.50	9.00	24.23	48.81	472.38	285.00	397.38	6,623.00	1,970.91
35 (18.3°)	120	342.86	54.75	27.38	258.10	10.50	12.91	30.60	251.66	156.43	176.66	5,152.54	1,152.10
	150	428.57	69.75	34.88	328.81	10.50	16.44	38.99	320.50	199.29	245.59	5,730.45	1,496.01
	180	514.29	84.75	42.38	399.53	10.50	19.98	47.37	389.55	242.15	314.55	6,116.20	1,840.42

TABLE D-1
(Continued)

SPECIFICATIONS FOR REVERSE SLOPE TERRACES
$c = 30$ cm: $b_1 = 55$ cm: $b_2 = 20$ cm
$S_2 = S_3 = 200\%$: $S_4 = 5\%$

S_1 (%)	VI (cm)	HI (cm)	h (cm)	b_x (cm)	W (cm)	K_1 (cm)	K_2 (cm)	b_4 (cm)	b (cm)	a (cm)	W_e (cm)	A_e (m^2/ha)	V_c (m^3/ha)
40	150	375.00	69.00	34.50	276.00	12.00	13.80	37.95	269.10	172.50	194.10	5,176.00	1,396.63
(21.8°)	180	450.00	84.00	42.00	336.00	12.00	16.80	46.20	327.60	210.00	252.60	5,613.33	1,725.26
45	150	333.33	68.25	34.13	235.07	13.50	11.75	37.06	229.21	151.67	154.21	4,626.35	1,307.20
(24.2°)	180	400.00	83.25	41.63	286.74	13.50	14.34	45.21	279.58	185.00	204.58	5,114.50	1,620.65
50 (26.6°)	180	360.00	82.50	41.25	247.50	15.00	12.38	44.35	241.30	165.00	166.30	4,619.44	1,524.58

TABLE D-2

VALUES OF RUNOFF COEFFICIENT (C)
RATIONAL EQUATION

Surfaces		C-Values Min.	C-Values Max.
Roofs		0.90	1.00
Pavements:			
Concrete or Asphalt		0.90	1.00
Bituminous macadam, open & closed		0.70	0.90
Gravel, from clean & loose to clayey & compact		0.25	0.70
Earth Surfaces:			
Sand, from uniform grain size, no fines to well graded, some clay or silt	Bare	0.15	0.50
	Light Vegetation	0.10	0.40
	Dense Vegetation	0.05	0.30
Loam, from clean gravel and gravel sand mixtures, to silt or clay to high clay or silt content	Bare	0.25	0.65
	Light Vegetation	0.15	0.50
	Dense Vegetation	0.10	0.40
Clay, from coarse sandy or silty to pure colloidal clays	Bare	0.30	0.75
	Light Vegetation	0.20	0.60
	Dense Vegetation	0.15	0.50
Composite Areas:			
City, business		0.60	0.75
City, dense residential		0.50	0.65
Suburban residential		0.35	0.55
Rural districts		0.10	0.25

TABLE D-3

MANNING'S ROUGHNESS COEFFICIENT

	Normal n	Range
A. Lined or built-up channels:		
Metal, smooth steel	0.012	0.011-0.017
Metal, corrugated	0.025	0.021-0.030
Wood, planed	0.012	0.011-0.014
Wood, unplaned	0.013	0.011-0.015
Wood, plank with battens	0.015	0.012-0.018
Concrete, trowel finish	0.013	0.011-0.015
Float finish	0.015	0.013-0.018
Unfinished	0.017	0.015-0.020
Gunite	0.019	0.016-0.027
Concrete bottom, float finish with sides of:		
Dressed stone in mortar	0.017	0.015-0.020
Random stone in mortar	0.020	0.017-0.024
Rubble masonry	0.025	0.016-0.030
Dry riprap	0.030	0.020-0.035
Gravel bottom, with sides of:		
Formed concrete	0.020	0.017-0.025
Random stone in mortar	0.023	0.020-0.026
Dry riprap	0.033	0.023-0.036
Brick, in cement mortar	0.015	0.013-0.020
Masonry, cemented stone	0.025	0.017-0.030
Dry riprap	0.032	0.023-0.035
B. Clean, excavated channels:		
Earth, straight and uniform:		
Clean after construction	0.018	0.016-0.020
Clean, weathered	0.022	0.018-0.025
Gravel, clean	0.025	0.022-0.030
Short grass, few weeds	0.027	0.022-0.035
Earth, small variation in alignment:		
Clean, weathered	0.024	0.022-0.030
Short grass, few weeds	0.030	0.025-0.035
Earth, winding sluggish:		
No vegetation	0.025	0.023-0.030
Grass, some weeds	0.032	0.025-0.038
Dense weeds, or aquatic weeds	0.035	0.030-0.040
Riprap sides	0.030	0.028-0.035
Stony bottom, weedy sides	0.035	0.025-0.040
Cobble bottom, clean sides	0.040	0.030-0.050
Dense weeds, no maintenance	0.060	0.050-0.110
Clean bottom, brush & weeds	0.050	0.040-0.080
Dense aquatic weeds	0.080	0.050-0.120

NOTE: Lined channel values do not account for aging.

TABLE D-4

CHARACTERISTICS OF COMMONLY USED GRASSES AND LEGUMES FOR REVEGETATION PURPOSES

Common Name	Botanic Name	Annual Rainfall Range - mm	Tolerance to: Drought	Tolerance to: Water-logging	Tolerance to: Low Fertility Soils	Establish-ment	Use Suitability: Erodible Areas	Use Suitability: Channels	Use Suitability: Agri-culture	Height m
Grasses										
Napier	Pennisetum purpureum	1015+	G	F	P	VP			VG	1.8-4.6
Bahia	Paspalum notatum	1015-1525	F	P	F	S	X		F	
Para	Bracharia mutica	1015+	F	VG	P	S	X	X	VG	0.6-0.9
African Star	Cynodon plectostachyus	500-700					X			
Pangola	Digitaria decumbens	1015+	F	G	G	VP	X	X	VG	0.6-1.2
Guinea cv common	Panicum maximum	1015-2540	F	F	P	S			VG	1.5-2.4
Creeping			F	F	P	S			VG	1.5
Hamil			F	G	P	S		X	VG	2.4-3.0
Coloniao			F	F	P	S			VG	3.6
Gatton		760-1015	F	F	P	S			VG	1.5-1.8
Bermuda	Cynodon dactylon	510-1270	VG	F	G	S/VP	X	X	G	0.3
Rhodes	Chloris gayana	635-1015	G	F	F	S	X		G	1.5
Setaria cv common	Setaria anceps syn S. sphacelata	890-1575	F	G	P	S		X	G	1.5-2.0
Nandi		890-1575	F	G	P	S		X	G	1.5-2.0
Kikuyu	Pennisetum clandestinum	890-1525	G	F	P	VP		X	G	0.3
Buffel	Cenchrus ciliaris	305-890	VG	P	F	S	X		G	0.3-1.5
Mineola	Cappilipedium assimile									
Green Panic	Panicum maximum var. trichoglume	560-1780	G	F	F	S	X		VG	1.5-1.8
Tolalla	Saccharum spontanum		F	G	F	S		X	P	2.0-2.5
Agentgrass	Rottboellia exaltata									
Kalapo	Paspalum conjugatum									
Annerseed	Chrysopogon aciculatus									
Alibang X	Dicanthium aristatum		P	G	F	VP	X	X	G	0.5
[illegible]	Themeda gigantea								P	
[illegible]	Themeda triandra								P	
Cogon	Imperata cylindrica								P	1.0-1.5
[illegible]	Echinochloa colonum								F	
Rice	Miscanthus sinnsis									
Crowfoot	Eleusine indica									
Legumes										
[illegible]	Macrotyloma axillare syn Dolichos axillaris	1015+	G	P	F	S	X		G	
[illegible]	Centrosema pubescens	1525+	F	G	F	S		X	VG	
[illegible] desmodium	Desmodium intortum	890-1270	G	G	F	S	X	X	G	
[illegible] desmodium	Desmodium uncinatum	890-1270	F	F	F	S	X		F	
[illegible]	Macroptilium atropurpureum syn. Phaseolus atropurpureus	760-1780	VG	F	G	S	X	X	VG	
[illegible]	Stylosanthes guyanensis syn. S. gracilis	1525+	G	F	G	S	X	X	F	0.6-1.8
[illegible]	Pueraria phaseoloides									

NOTES:

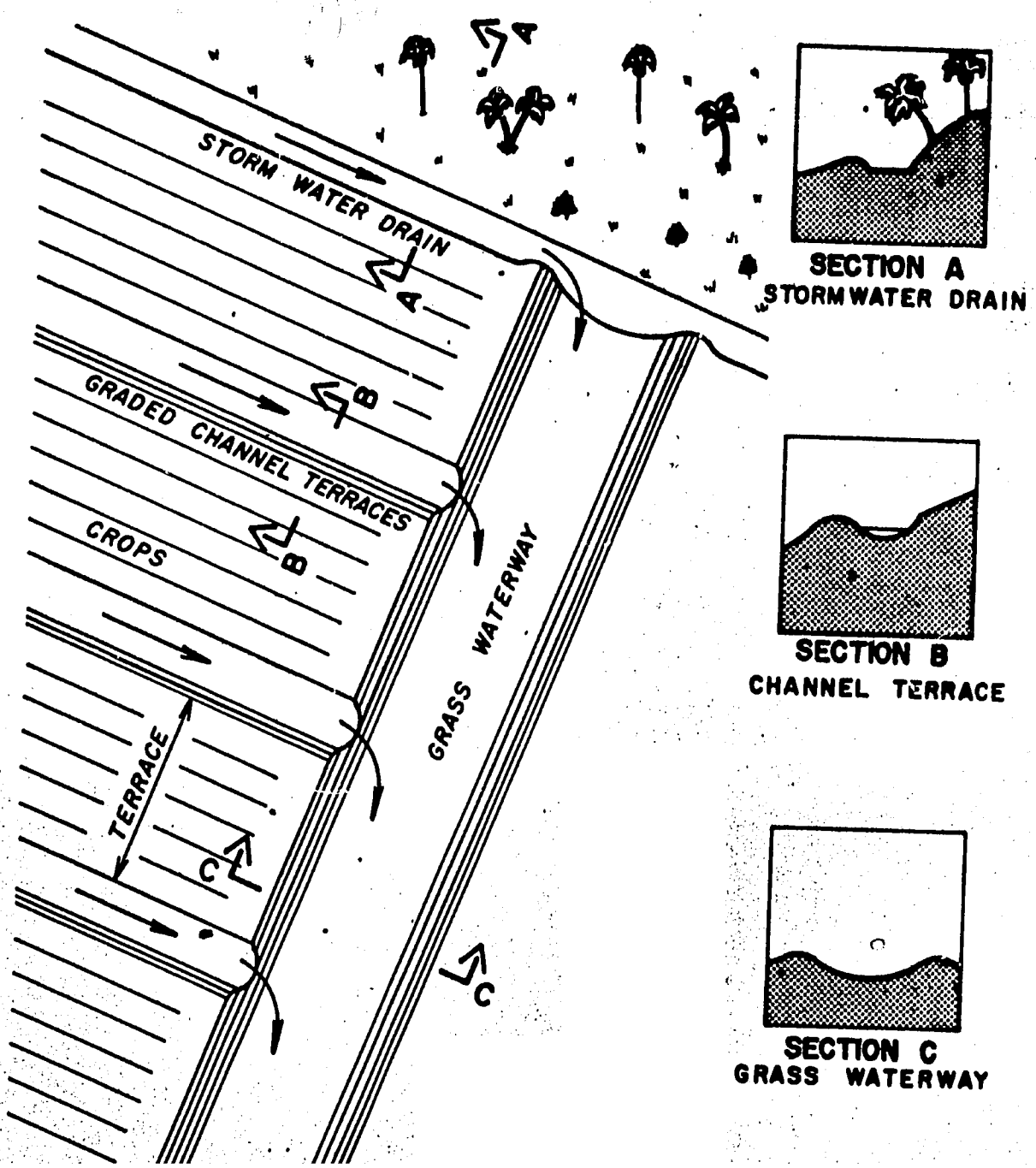
VG = Very Good
G = Good
F = Fair
P = Poor

S = Seed
VP = Vegetative Prepogation
I = Imported
N = Native

TABLE D-5

CLASSIFICATION OF DEGREE OF RETARDANCE FOR VARIOUS KINDS OF TROPICAL GRASSES

Retardance	Common Name	Condition & Height	Remarks
A. Very High	Para	Excellent Stands, Uncut	
	Pangola	Excellent Stands, Uncut	
	Bermuda	Excellent Stands, Uncut	
	Rhodes	Excellent Stands, Uncut	
	KiKuyu	Excellent Stands, Uncut	
	Guinea	Excellent Stands, Uncut	
	Setaria	Excellent Stands, Uncut	
B. High	Para	Good Stands, Grazed	Height 0.3-0.5 m
	Pangola	Good Stands, Grazed	
	Rhodes	Good Stands, Grazed	
	KiKuyu	Good Stands, Grazed	
	Guinea	Good Stands, Grazed	
	Setaria	Good Stands, Grazed	
	Napier	Good Stands, Uncut	
	Buffel	Good Stands, Uncut	
	Green Panic	Good Stands, Uncut	
	African Star	Good Stands, Uncut	
	Alabang X	Good Stands, Uncut	
C. Moderate	Grasses in A&B Above	Good Stands Cut to 10 to 15 cm	
	Grasses in A&B Above	Poor Stands, Uncut	
	Bahia	Good Stands, Uncut	Areas that are too wet will die
	Buffel	Good Stands, Uncut	
D. Low	Grasses in A,B,&C Above	Good Stands Cut to 5 to 15 cm	
	Grass & Legume Mixtures	Good Stands Cut to 5 to 15 cm	
E. Very Low	Any Grasses Burned Stubble	Cut to 2.5-3.5 cm	



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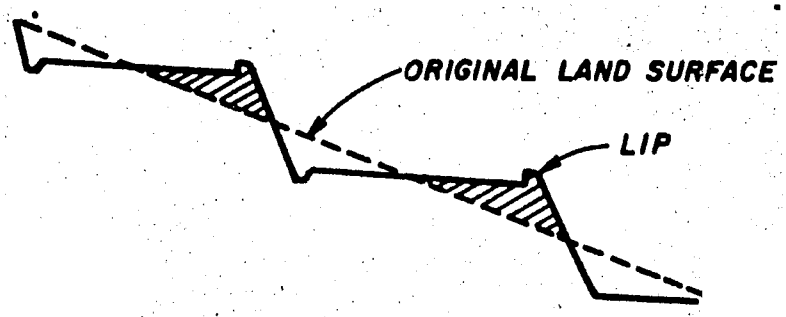
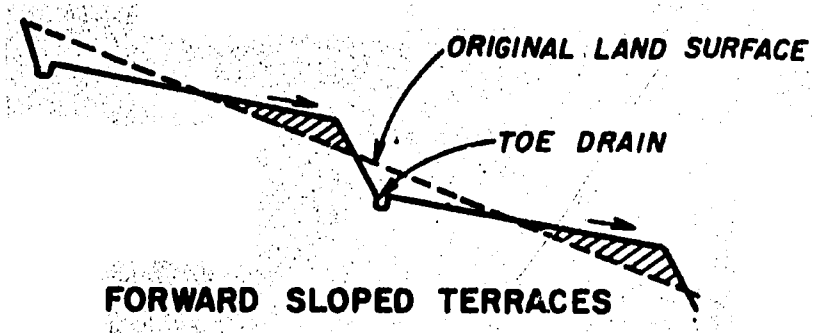
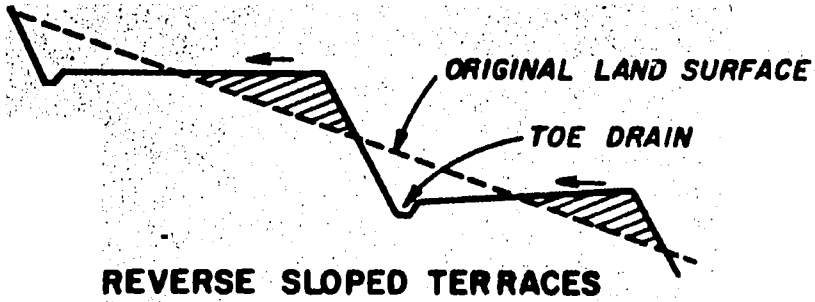
BASIC COMPONENTS OF MECHANICAL PROTECTION



HORIZONTAL TERRACES



FORWARD SLOPED TERRACES



REVERSE SLOPED TERRACES

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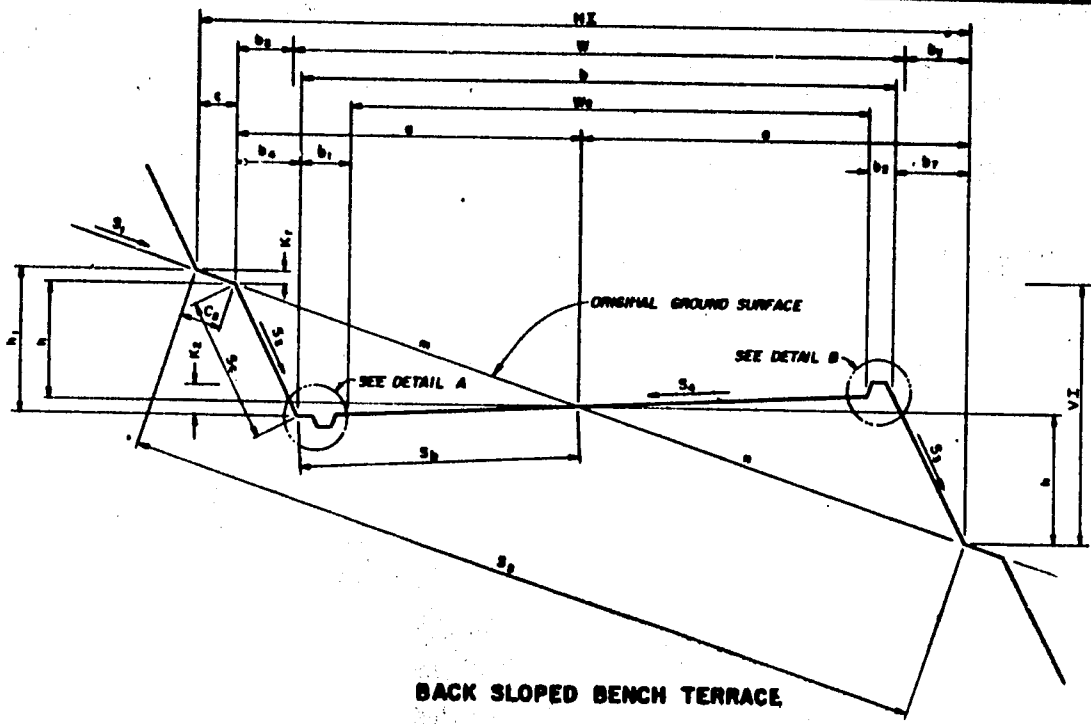
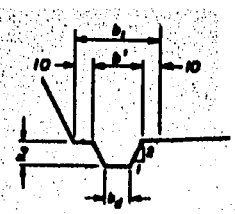
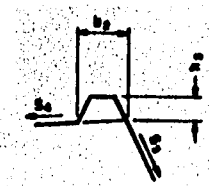
TYPES OF BENCH TERRACES



BACK SLOPED BENCH TERRACE



DETAIL A
TERRACE CHANNEL



DETAIL B
TERRACE LIP

TERRACE CHANNEL DIMENSIONS (cm)

h_4	b_d	b'	b_1	b_2
15	15	30	50	20
20	15	35	55	20
25	15	40	60	20

DEFINITIONS

S_1 = ORIGINAL GROUND SLOPE
S_0 = CUT SLOPE
S_3 = RISER SLOPE
S_4 = TERRACE BACK SLOPE
VI = VERTICAL INTERVAL
HI = HORIZONTAL INTERVAL
W_0 = EFFECTIVE CROP WIDTH
c = WIDTH OF SAFETY STRIP
$h + \frac{1}{2} b_2$ = HEIGHT OF RISER
A_c = AREA OF CUT

EQUATIONS

ASSUME VI GIVEN

$$HI = \frac{100\,VI}{S_1}$$

$$h = \frac{\frac{1}{2}[S_1\,(HI - c)]}{100}$$

$$b_2 = \frac{100\,(h)}{S_0}$$

$$K_1 = \frac{S_1\,c}{100}$$

$$K_2 = \frac{W\,S_4}{100}$$

$$h_1 = h + K_2/4 + K_1$$

$$W = HI - (b_4 + b_7) - c$$

WHERE $S_0 = S_3$ $b_2 = b_7$

$$b_4 = \frac{100}{S_0}(h + \tfrac{1}{2} K_2) \;\&\; b_7 = \frac{100}{S_0}(h + \tfrac{1}{2} K_2)$$

$$b = HI - c - b_4 - b_7$$

WHERE $b_4 = b_7$ & $S_0 = S_3$

$$b = HI - c - 2b_4$$

$$W_0 = b - (b_1 + b_2)$$

$$a = b_d + b_4 = W/2 + b_2$$

$$a' = W/2 + b_7 = b_d + b_7$$

$$HI = a + a' + c$$

$$S_0 = \sqrt{HI^2 + VI^2} \text{ OR } S_0 = m + n + c_0$$

$$C_0 = \sqrt{C^2 + K_1^2}$$

$$S_0 = \sqrt{(a - b_4)^2 + (K_2/4)^2}$$

$$S_c = \sqrt{b_4^2 + (h + K_2/4)^2}$$

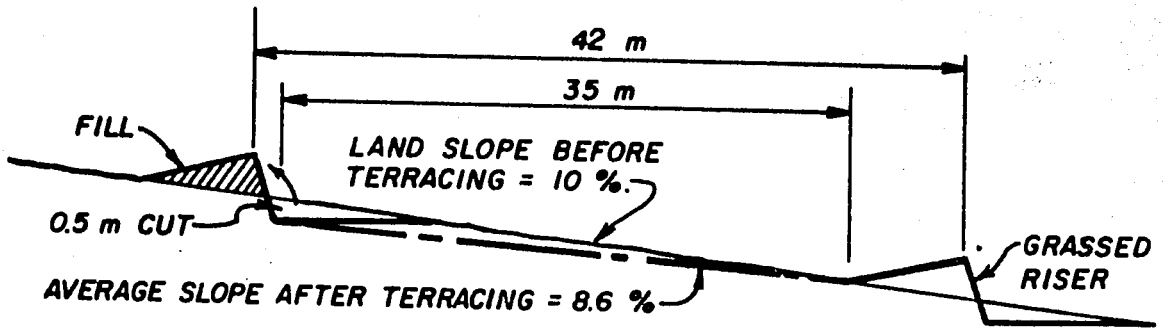
$$m = \sqrt{a^2 + b^2}$$

$$P = \tfrac{1}{2}(m + S_0 + S_c)$$

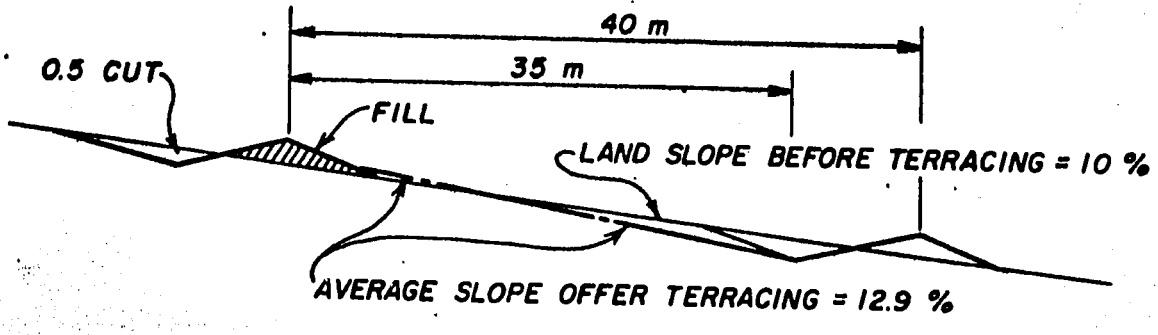
$$A_c = \sqrt{P(P - m)(P - S_0)(P - S_c)}$$

EROSION CONTROL STUDY PROJECT

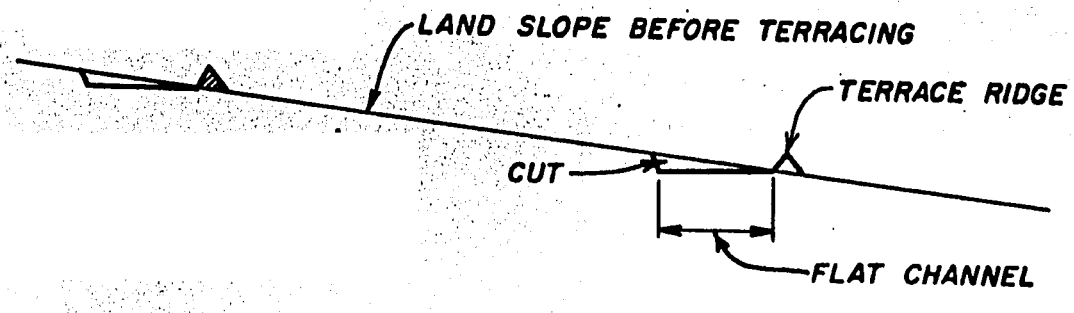
DEFINITIONS, DIMENSIONS AND PROPERTIES OF BENCH TERRACES



GRASS BACK CONSERVATION TERRACE DOWNHILL BORROW
(AVERAGE SLOPE DECREASED)



BROAD BASE CONSERVATION TERRACE UPHILL BORROW
(AVERAGE SLOPE INCREASED)



FLAT CHANNEL MOISTURE CONSERVATION TERRACE

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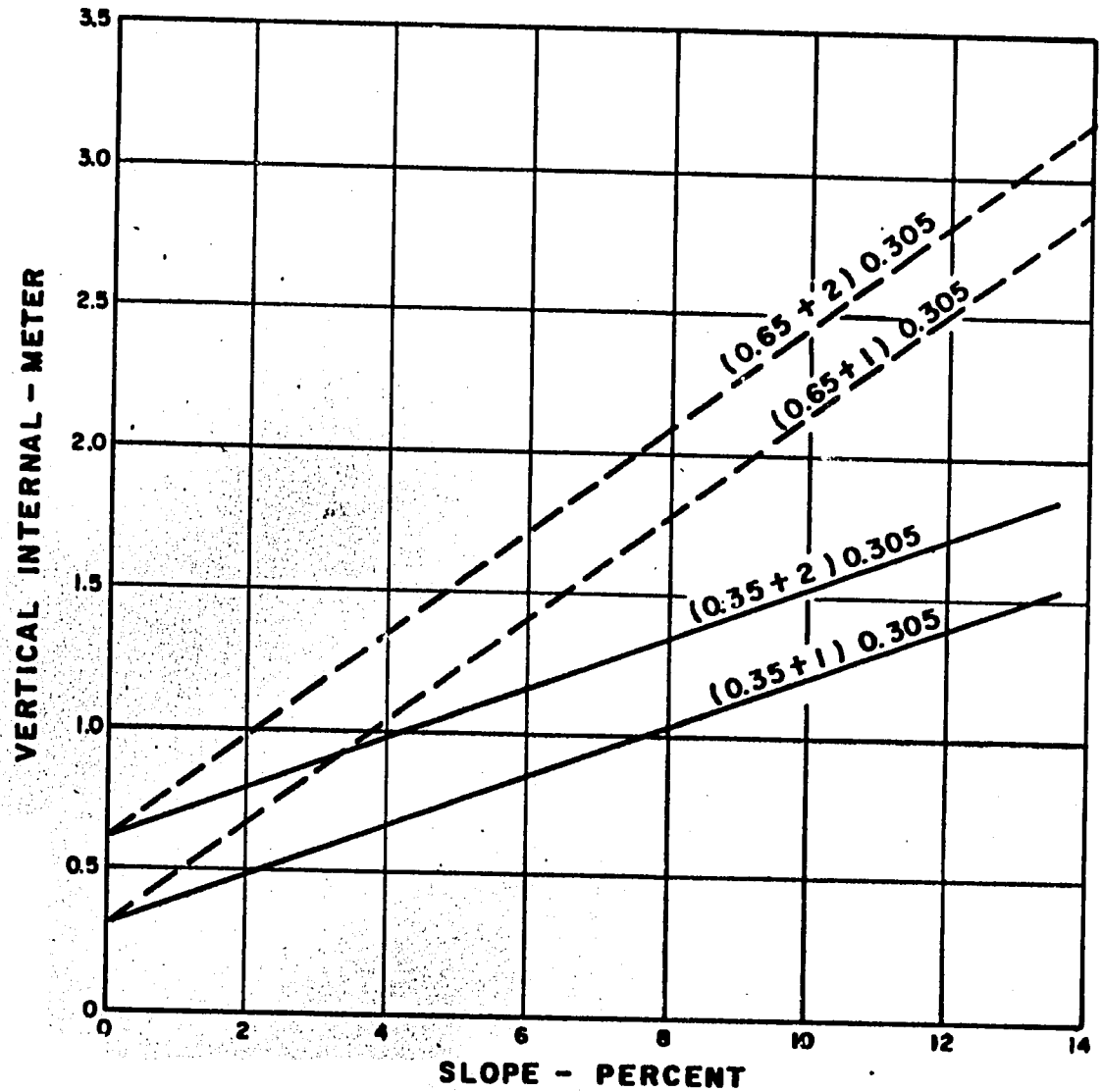
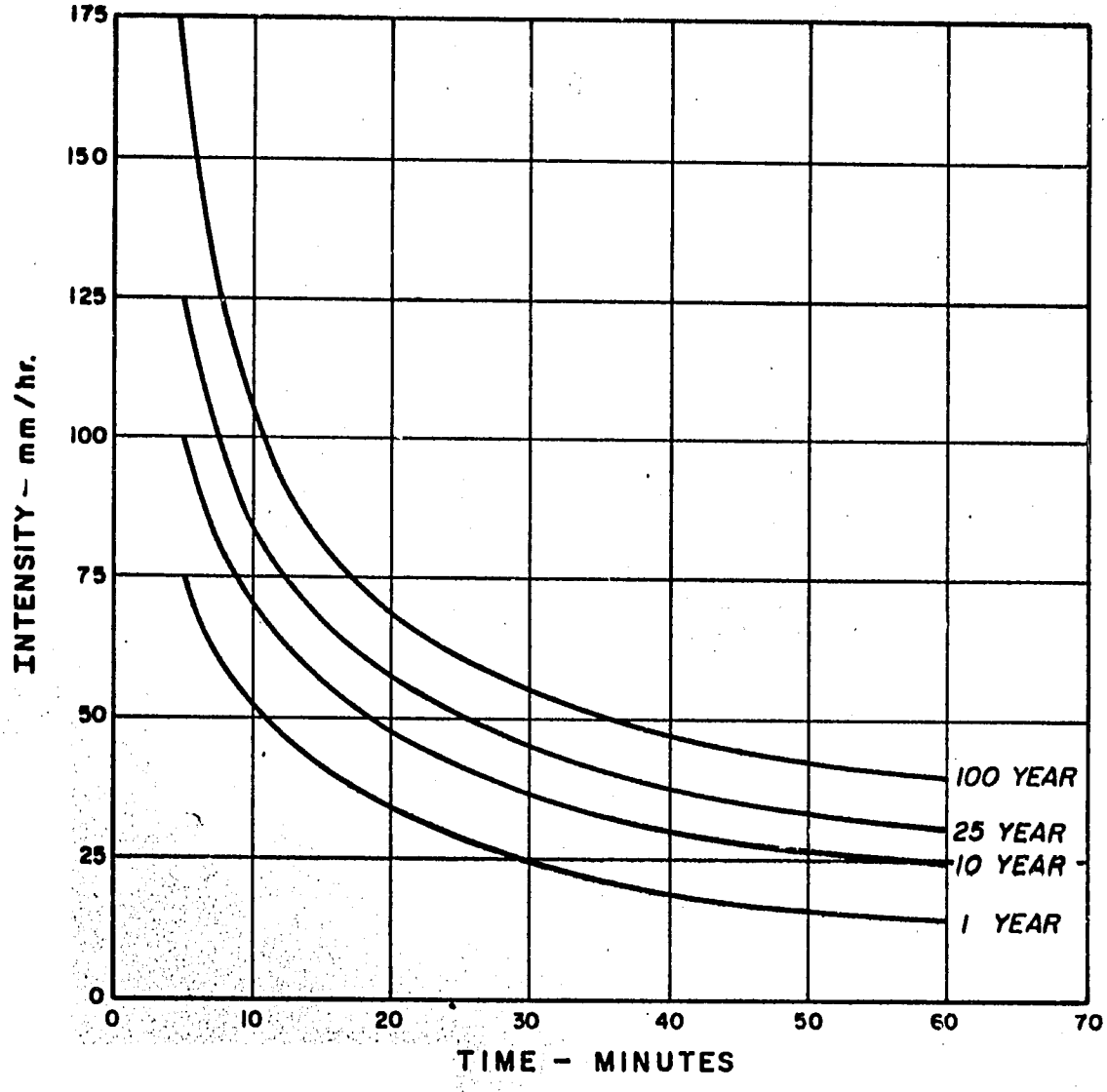
CONSERVATION TERRACES



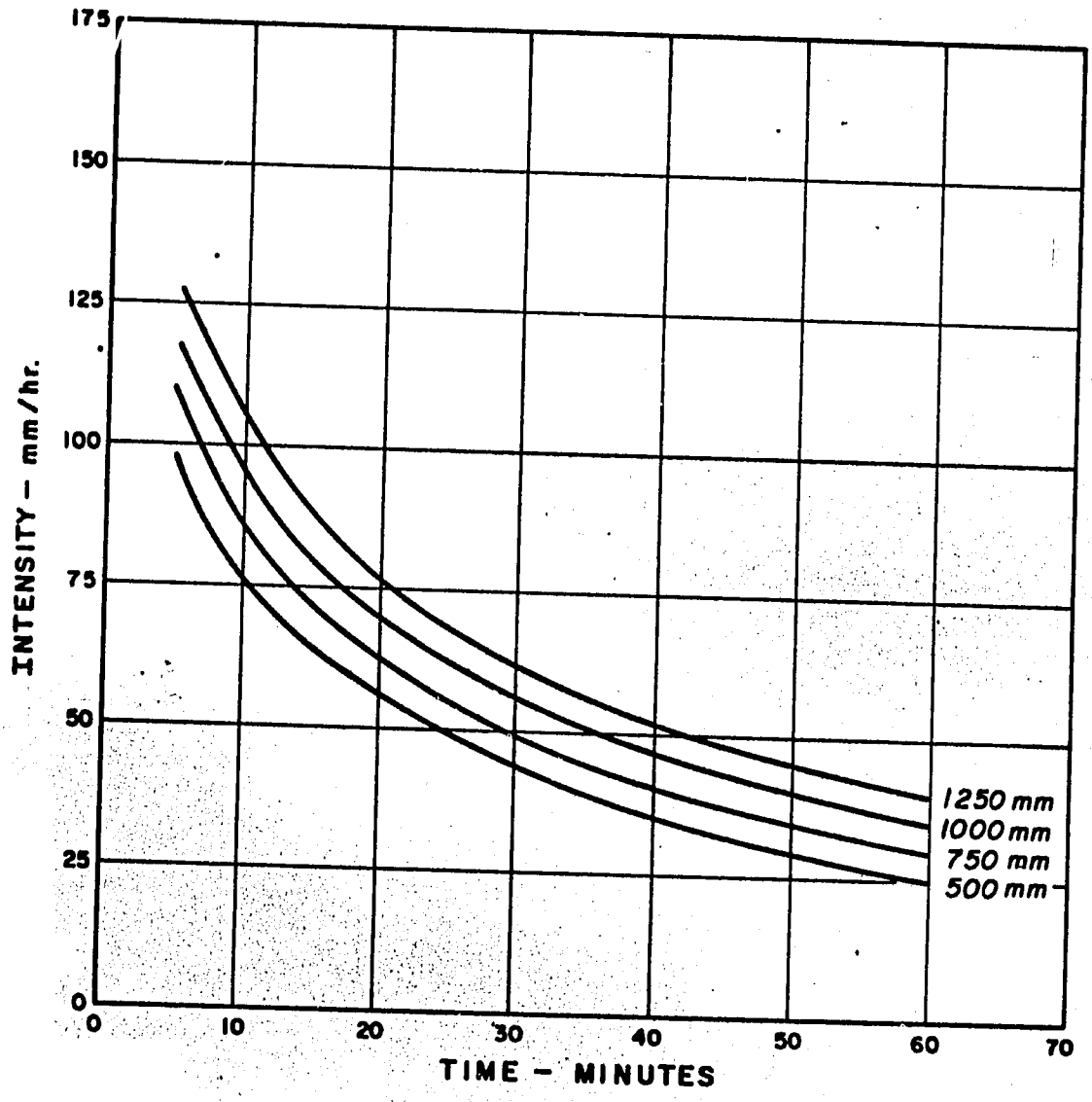
EROSION CONTROL STUDY PROJECT

COMPARISON OF VERTICAL INTERVAL EQUATIONS CONSERVATION TERRACES



EROSION CONTROL STUDY PROJECT

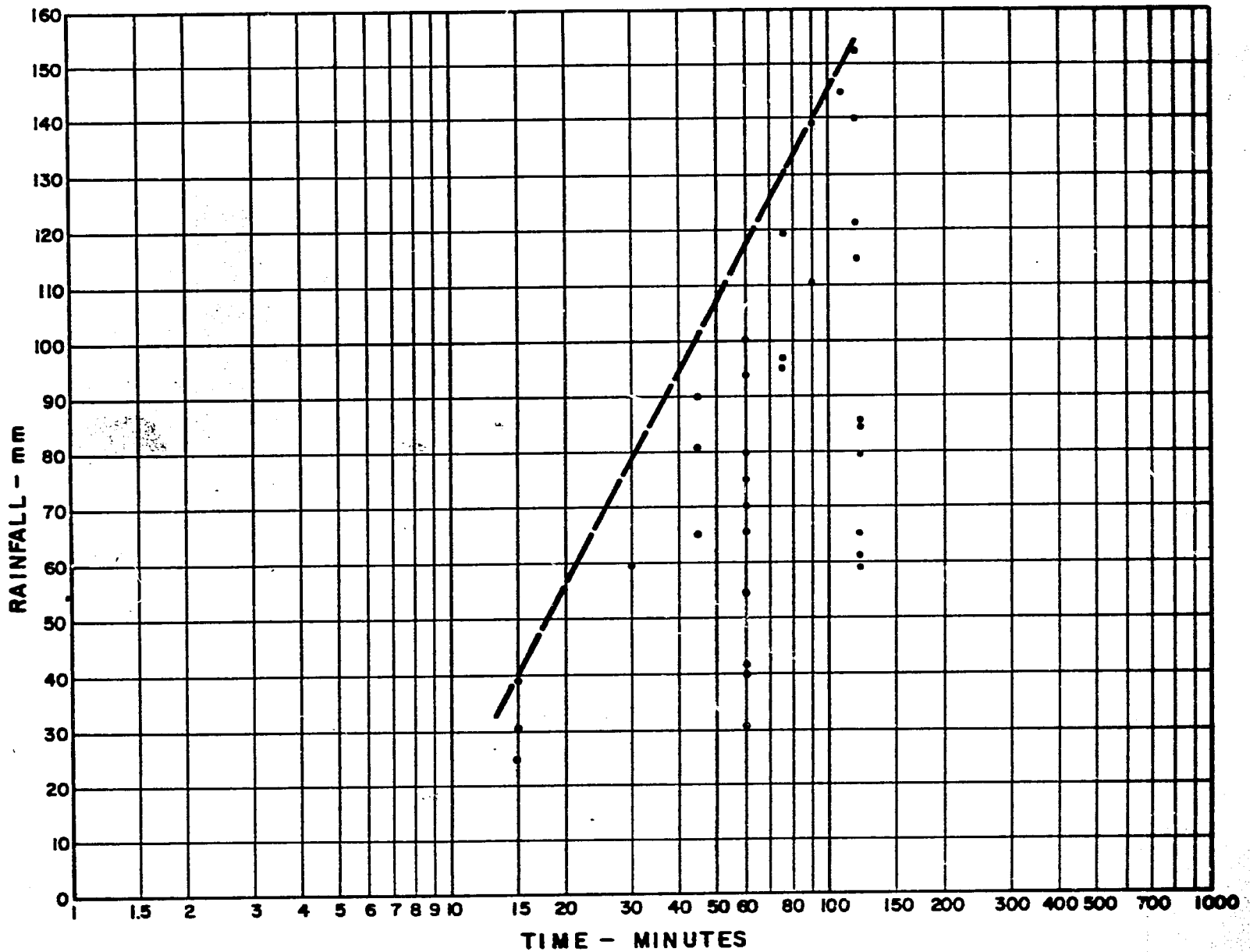
EXAMPLE OF RAINFALL PROBABILITIES VARIOUS RETURN PERIODS



NOTE: INTENSITY - DURATION RELATIONSHIP FOR 10 YEAR RETURN PERIOD.

EROSION CONTROL STUDY PROJECT

EXAMPLE OF VARIATION OF INTENSITY - DURATION WITH MEAN ANNUAL RAINFALL

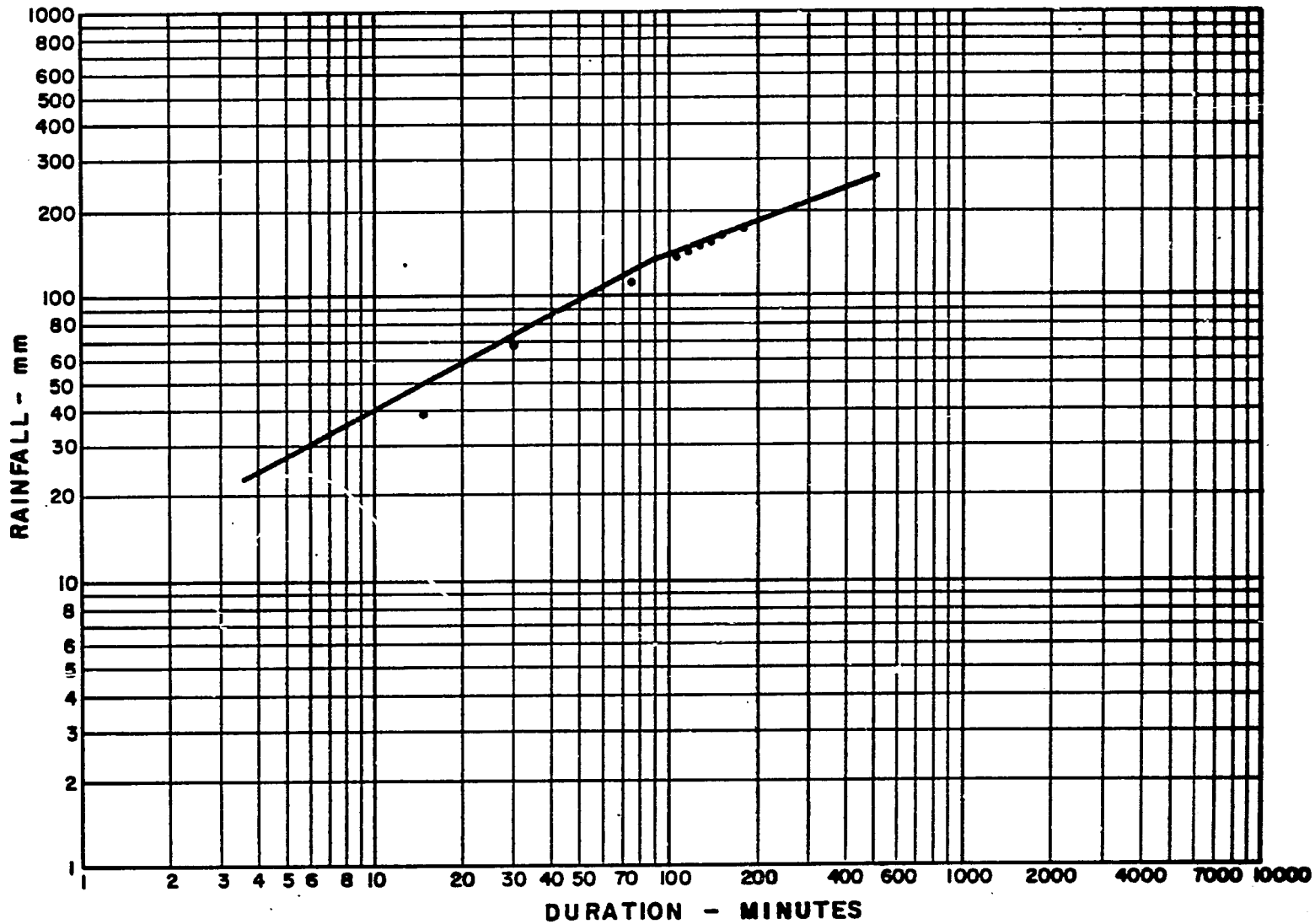


EROSION CONTROL STUDY PROJECT

ENVELOPE OF INTENSITY-DURATION DATA

KARANGSAMBUNG AREA

FIGURE D-8

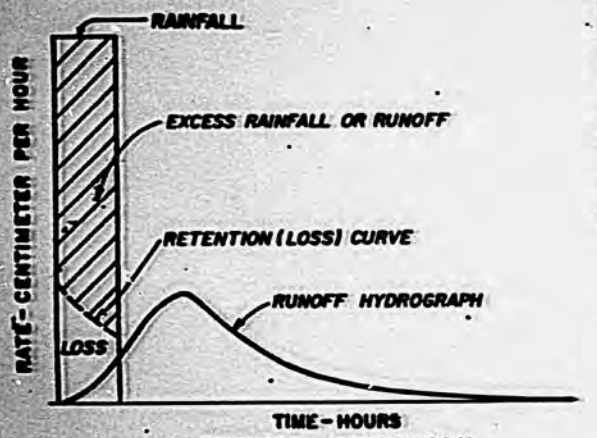


EROSION CONTROL STUDY PROJECT

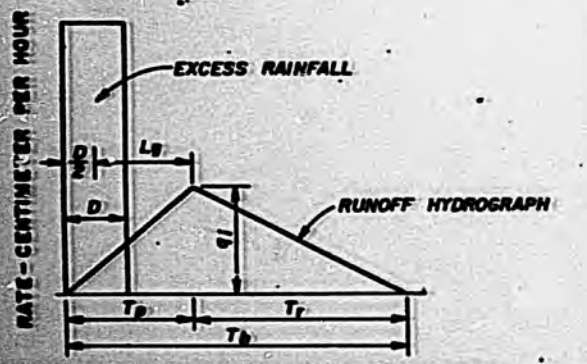
ENVELOPE OF MAXIMUM RAINFALLS

WATUBELAH

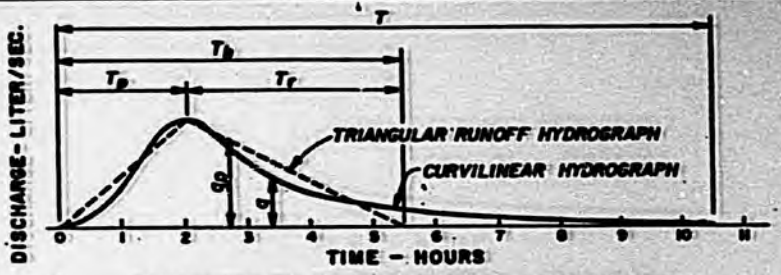
FIGURE D-8



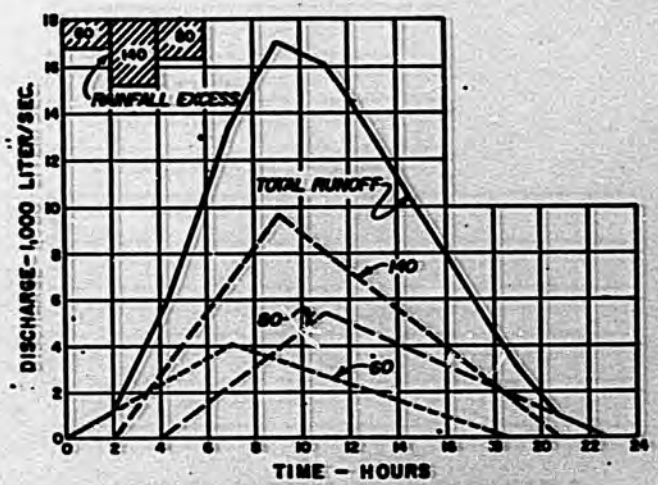
TYPICAL UNITGRAPH



SCHEMATIC REPRESENTATION OF UNITGRAPH



CONSTRUCTION OF CURVILINEAR HYDROGRAPH FROM TRIANGULAR



COMPLEX HYDROGRAPH WITH VARIABLE RAINFALL INCREMENTS

RATIO FOR CURVILINEAR HYDROGRAPH CONSTRUCTION

TIME RATIO, T/T_p	DISCH. RATIO, q/q_p	TIME RATIO, T/T_p	DISCH. RATIO, q/q_p
0	0	1.1	[illegible]
0.1	0.015	1.2	[illegible]
0.2	0.07	1.3	[illegible]
0.3	0.16	2.0	[illegible]
0.4	0.28	2.2	[illegible]
0.5	0.43	2.4	[illegible]
0.6	0.60	2.6	[illegible]
0.7	0.77	3.0	[illegible]
0.8	0.86	3.5	[illegible]
0.9	0.97	3.5	[illegible]
1.0	1.00	4.0	[illegible]
1.1	0.98	4.5	[illegible]
1.2	0.92	5.0	[illegible]
1.3	0.84		
1.4	0.75	INFINITY	0

EQUATIONS

$$Q = \frac{q_i t_p}{2} + \frac{q_i t_r}{2}$$

$$q_i = \frac{2Q}{t_p + t_r} = \frac{2}{(1+H)} \frac{Q}{t_p}$$

$T_r = Ht_p$ WHERE $H = 1.67$ FOR UNGAGED WATERSHEDS.

CONVERT TO L/s/ha.

$$q_p = \frac{2(27.78)}{1+1.67} \frac{AQ}{t_p} = \frac{20.8\,AQ}{t_p}$$

$L_g = 0.6\,T_c$ FOR UNGAGED WATERSHEDS.

$$T_p = D/2 + L_g = D/2 + 0.6\,T_c$$

$$T_c = \left[0.87 \frac{L^3}{E}\right]^{0.385} \text{ IN HOURS}$$

DEFINITIONS

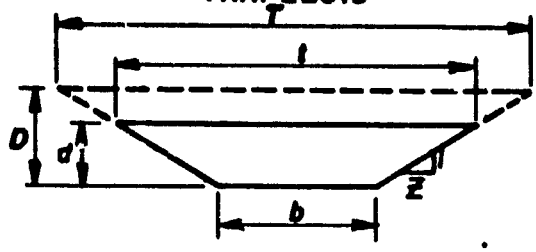
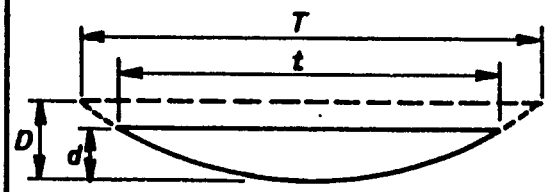
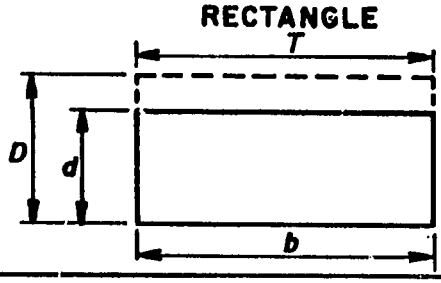
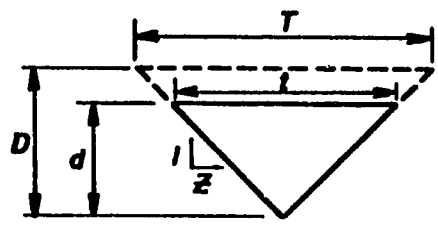
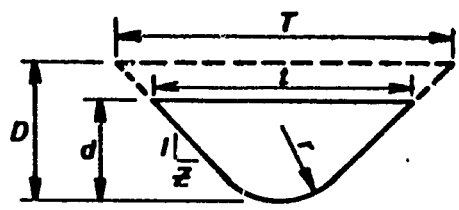
- Q = TOTAL RUNOFF, cm.
- q_i = PEAK RUNOFF RATE, cm/ha.
- q_p = PEAK RATE IN L/s, TRIANGULAR HYDROGRAPH.
- q = PEAK RATE IN L/s, CURVILINEAR HYDROGRAPH.
- T_p = TIME IN HOUR FROM START OF RISER TO PEAK RATE.
- T_r = TIME IN HOURS FROM PEAK RATE TO END OF TRIANGLE.
- A = AREA IN HECTARE.
- L_g = LAG, TIME FROM CENTER OF EXCESS RAINFALL TO PEAK, HOURS.
- T_c = TIME OF CONCENTRATION; TRAVEL TIME FROM HYDRAULICALLY MOST DISTANT POINT TO POINT OF INTEREST.
- T_b = TIME BASE OF TRIANGULAR HYDROGRAPH.
- T = TIME BASE OF CURVILINEAR HYDROGRAPH.
- L = LENGTH OF LONGEST WATER COURSE IN METERS.
- E = DIFFERENCE IN ELEVATION BETWEEN WATERSHED DIVIDE AND POINT OF INTEREST IN METERS.

NOTE

METHOD APPLICABLE FOR WATERSHEDS UP TO 2600 HA.

EROSION CONTROL STUDY PROJECT

TRIANGULAR HYDROGRAPH ANALYSIS

TRAPEZOID 	AREA (A)	$bd + Zd^2$
	WETTED PERIMETER (P)	$b + 2d\sqrt{1+Z^2}$
	HYDRAULIC RADIUS (R)	$\frac{bd+Zd^2}{b+2d\sqrt{1+Z^2}}$
	TOP (t) WIDTH (T)	$t = b + 2dZ$ $T = b + 2DZ$
PARABOLA 	AREA	$\frac{2}{3}\,td$
	WETTED (*) PERIMETER	$t + \frac{8d^2}{3t}$ (Approx.)
	HYDRAULIC(*) RADIUS	$\frac{t\,d}{1.5t+4d}\left(\frac{2d}{3}\right)$
	TOP WIDTH	$t = \frac{3a}{2d}$ $T = t\,\frac{D}{d}$
RECTANGLE 	AREA	bd
	WETTED PERIMETER	$b + 2d$
	HYDRAULIC RADIUS	$\frac{by}{b+2d}$
	TOP WIDTH	b
TRIANGLE 	AREA	Zd^2
	WETTED PERIMETER	$2d\sqrt{1+Z^2}$
	HYDRAULIC RADIUS	$\frac{Zd}{2\sqrt{1+Z^2}}$
	TOP WIDTH	$2Zd$ $T = 2ZD$
ROUND-BOTTOMED TRIANGLE 	AREA	$\frac{t^2}{4Z} - \frac{r^2}{Z}(1 - Z\cot^{-1}Z)$
	WETTED PERIMETER	$\frac{t}{Z}\sqrt{1+Z^2} - \frac{2r}{Z}(1 - Z\cot^{-1}Z)$
	HYDRAULIC RADIUS	A/P
	TOP WIDTH	$2\left[Z(d-r) + r\sqrt{1+Z^2}\right]$

NOTES:

* EXACT EXPRESS $P = (T/2)\left[\sqrt{1+X^2} + \frac{1}{X}\ln\left(X + \sqrt{1+X^2}\right)\right]$

WHERE $X = 4d/T$

APPROX. SOLUTION VALID

WHERE $0 < 4d/T \leq 1$

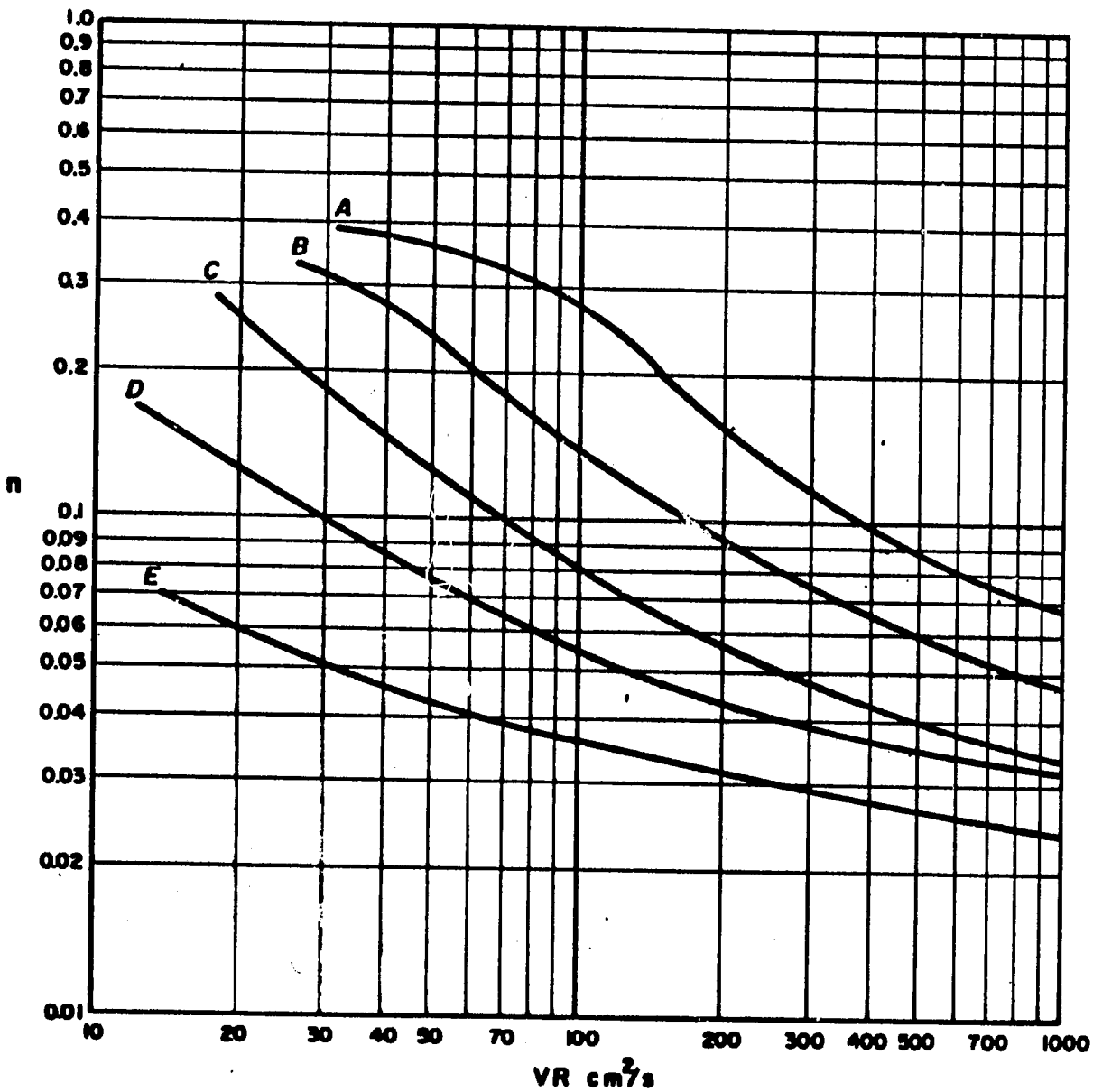
FREEBOARD (Fb) = D − d OR D = d + Fb

$R = A/P$

EROSION CONTROL STUDY PROJECT

GEOMETRIC ELEMENTS OF CHANNEL SECTIONS

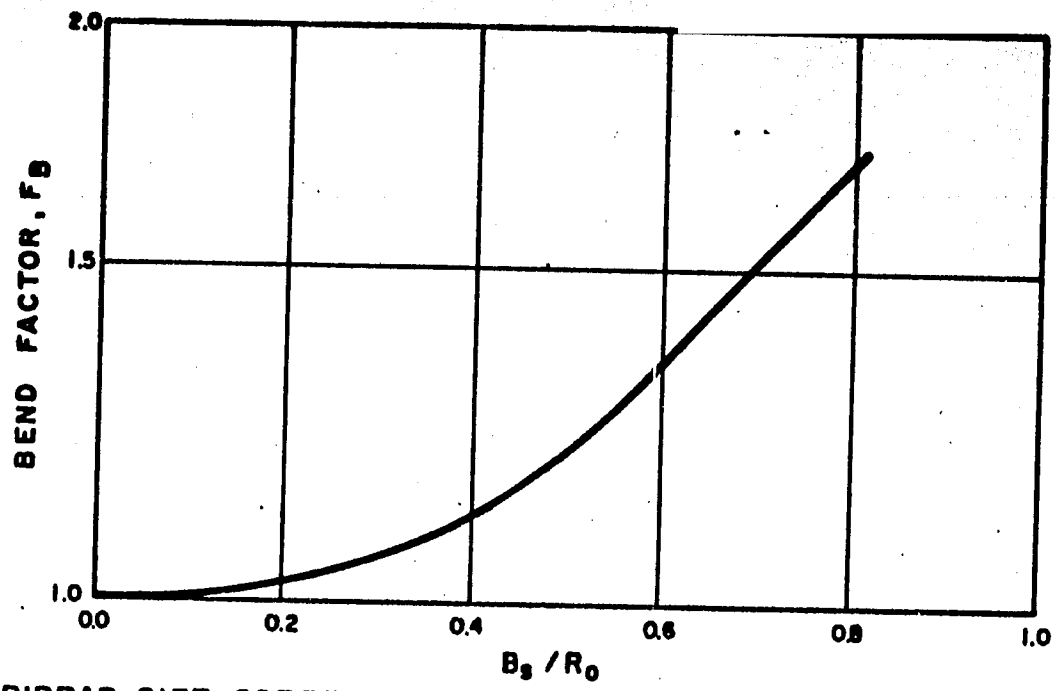
RETARDANCE CURVE		AVERAGE LENGTH OF GRASS GOOD STAND	FAIR STAND
A	VERY HIGH	>30	
B	HIGH	11-24	>30
C	MODERATE	6-10	11-24
D	LOW	2-6	2-10
E	VERY LOW	<2	<2



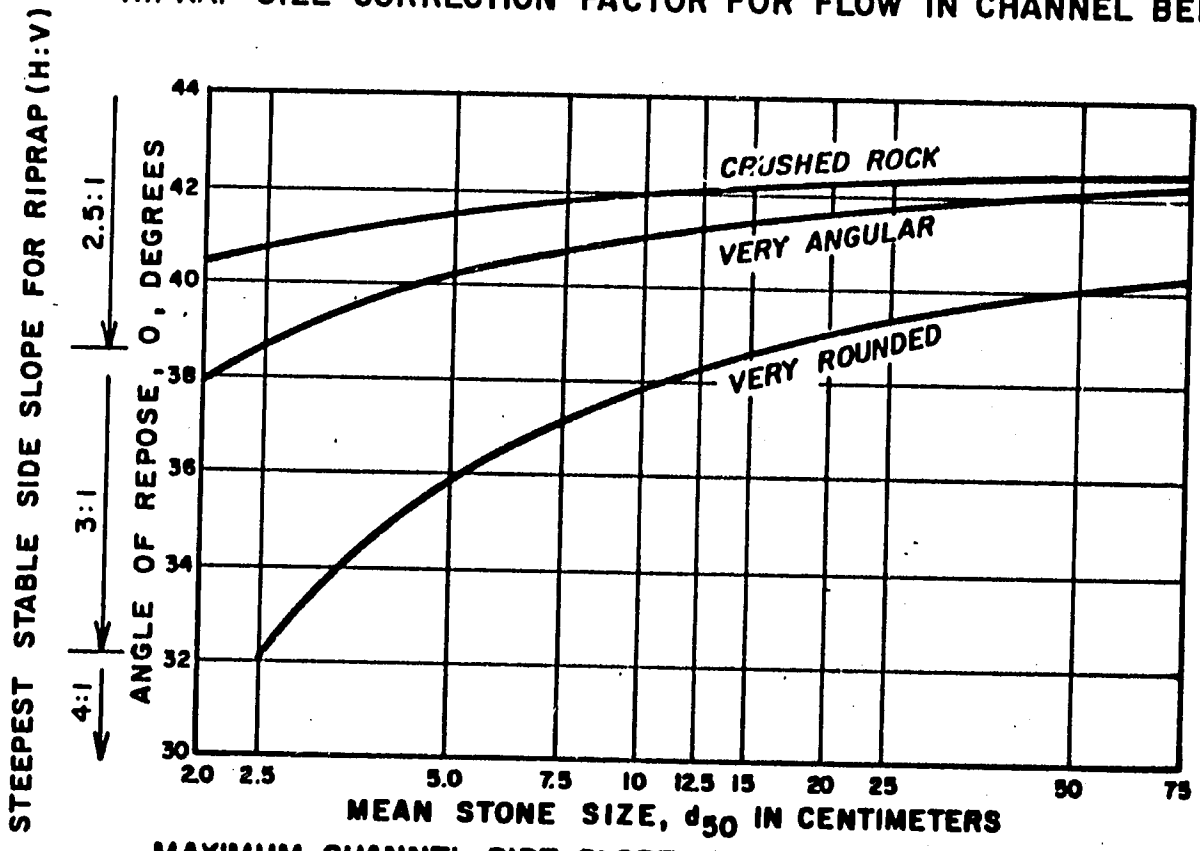
SOURCE: U.S. SOIL CONSERVATION SERVICE.

EROSION CONTROL STUDY PROJECT

RETARDANCE CURVES



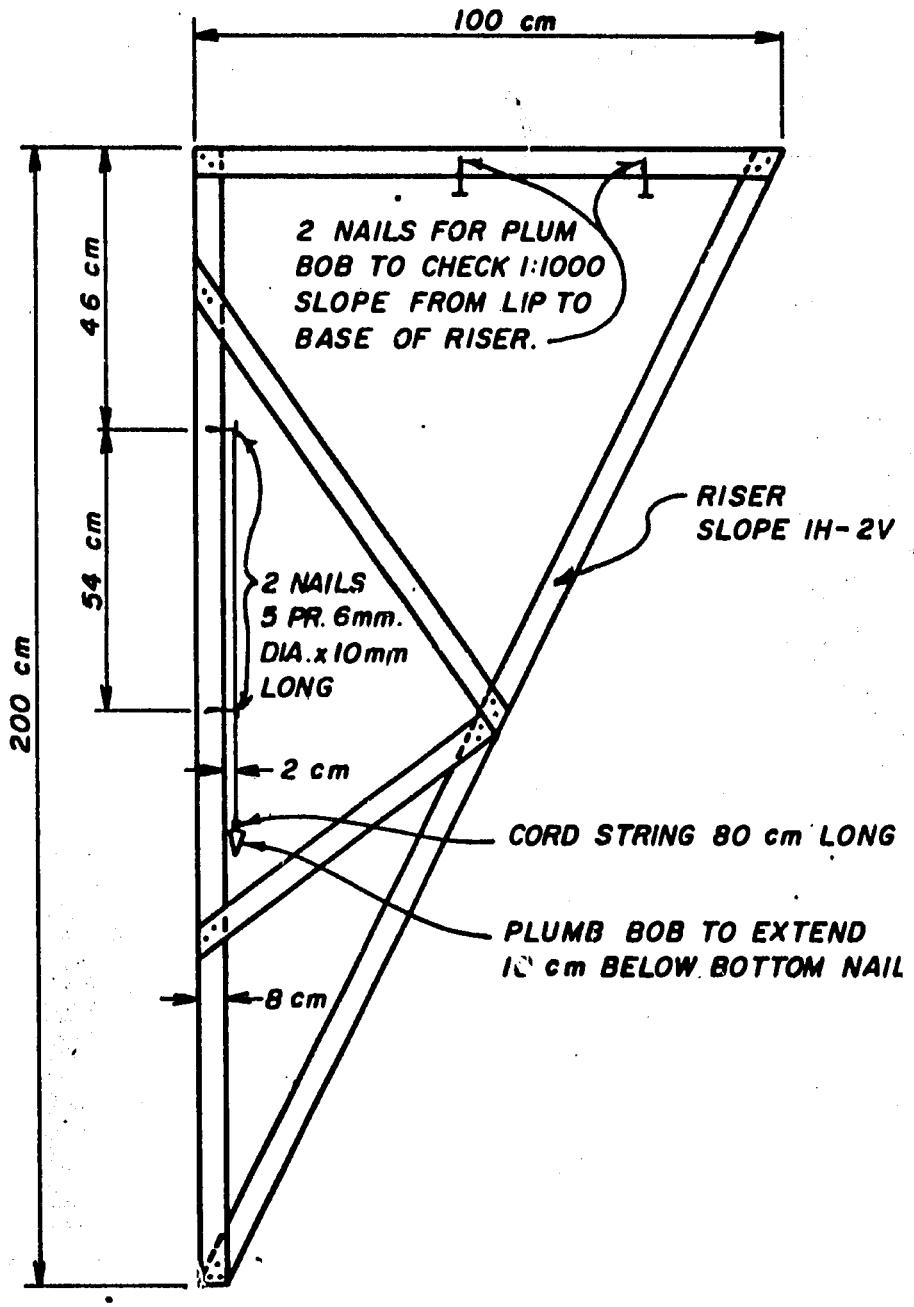
RIPRAP SIZE CORRECTION FACTOR FOR FLOW IN CHANNEL BENDS



MAXIMUM CHANNEL SIDE SLOPE WITH RESPECT TO RIPRAP SIZE

EROSION CONTROL STUDY PROJECT

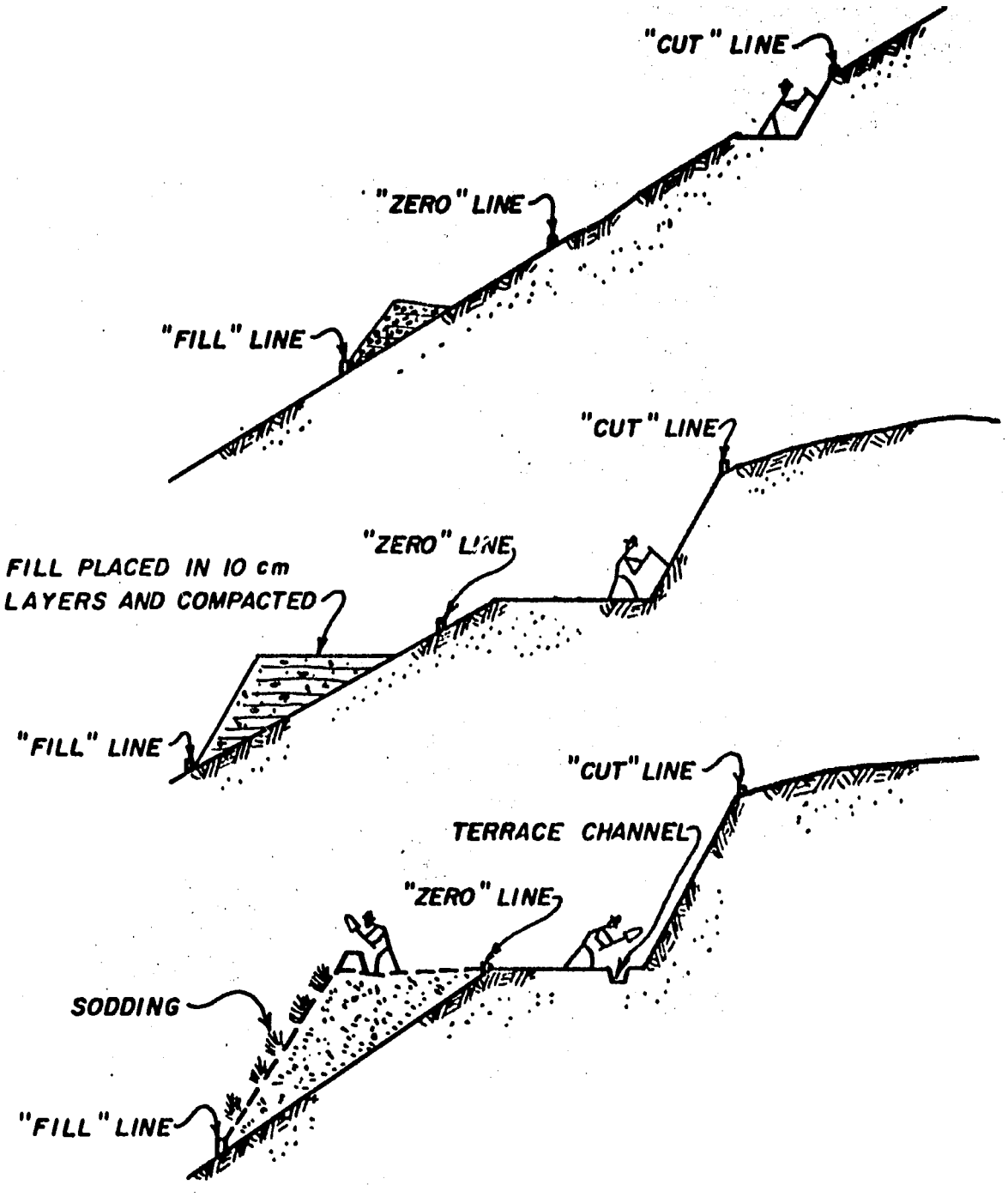
RIPRAP SIZES FOR CHANNEL BENDS AND SIDE SLOPES



ALL WOOD MATERIAL 2½ OR 3 cm THICK BY 8 cm WIDE

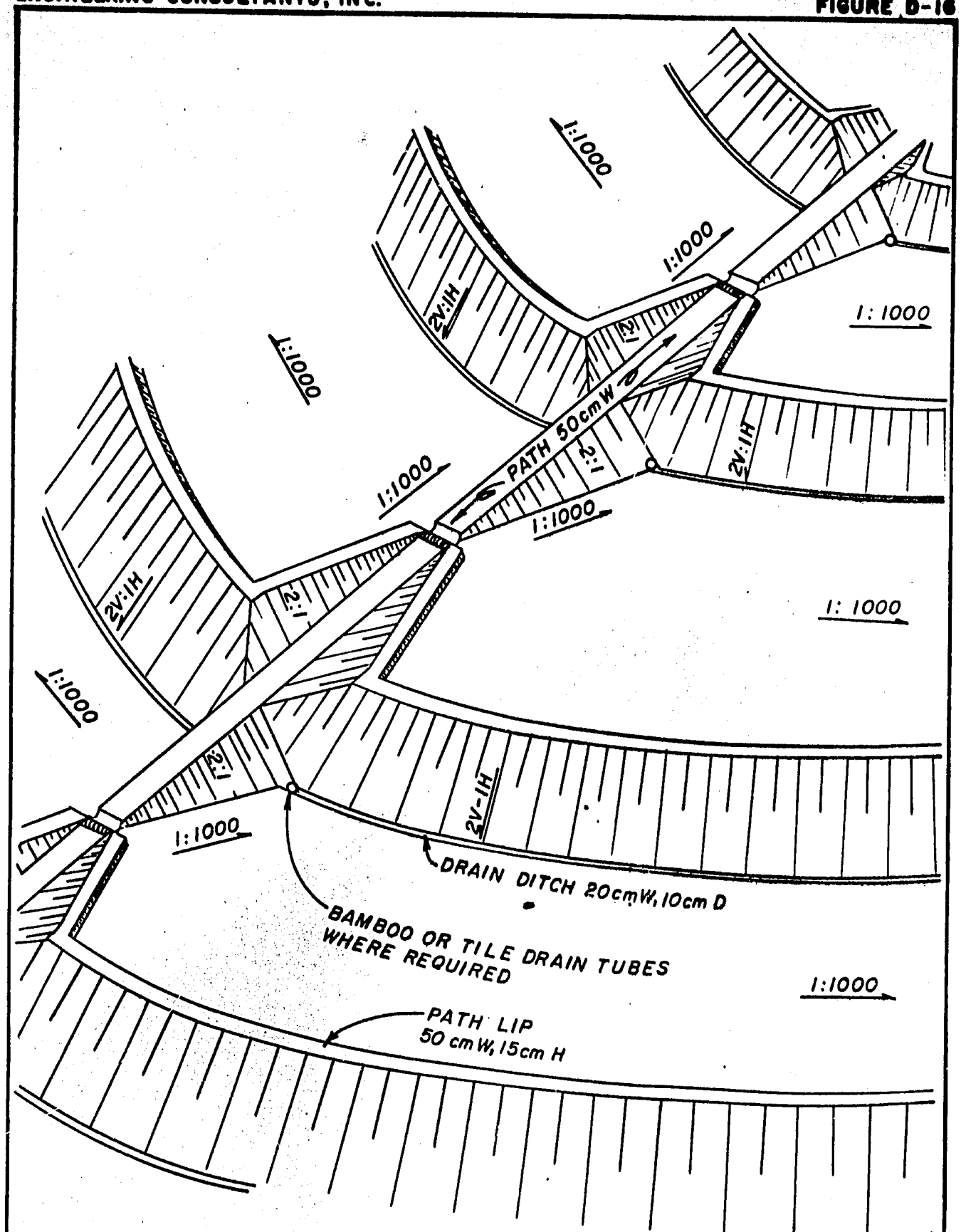
EROSION CONTROL STUDY PROJECT

SIMPLE WOOD FRAME TO MEASURE RISER SLOPE



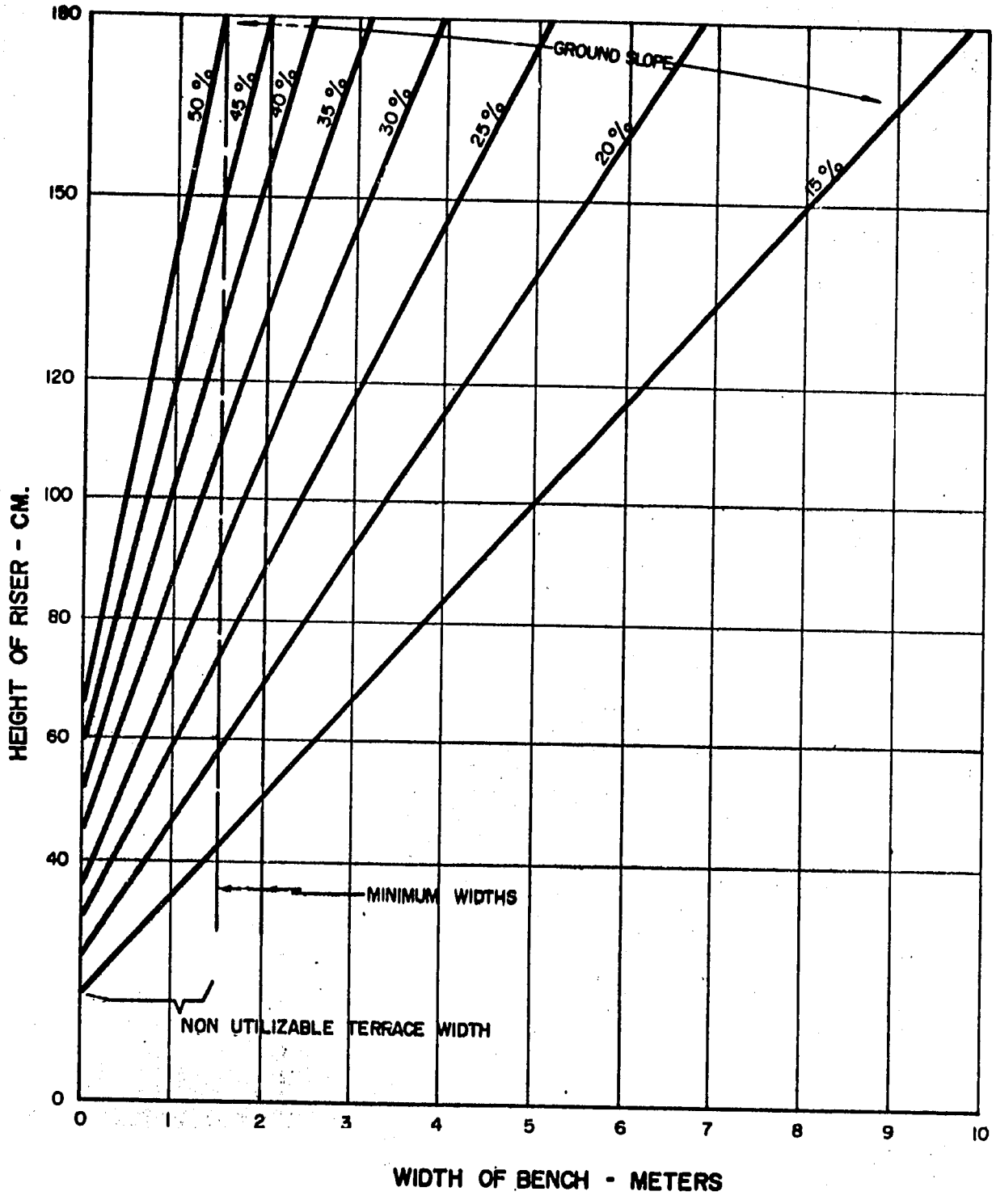
EROSION CONTROL STUDY PROJECT

SEQUENCE OF TERRACE CONSTRUCTION



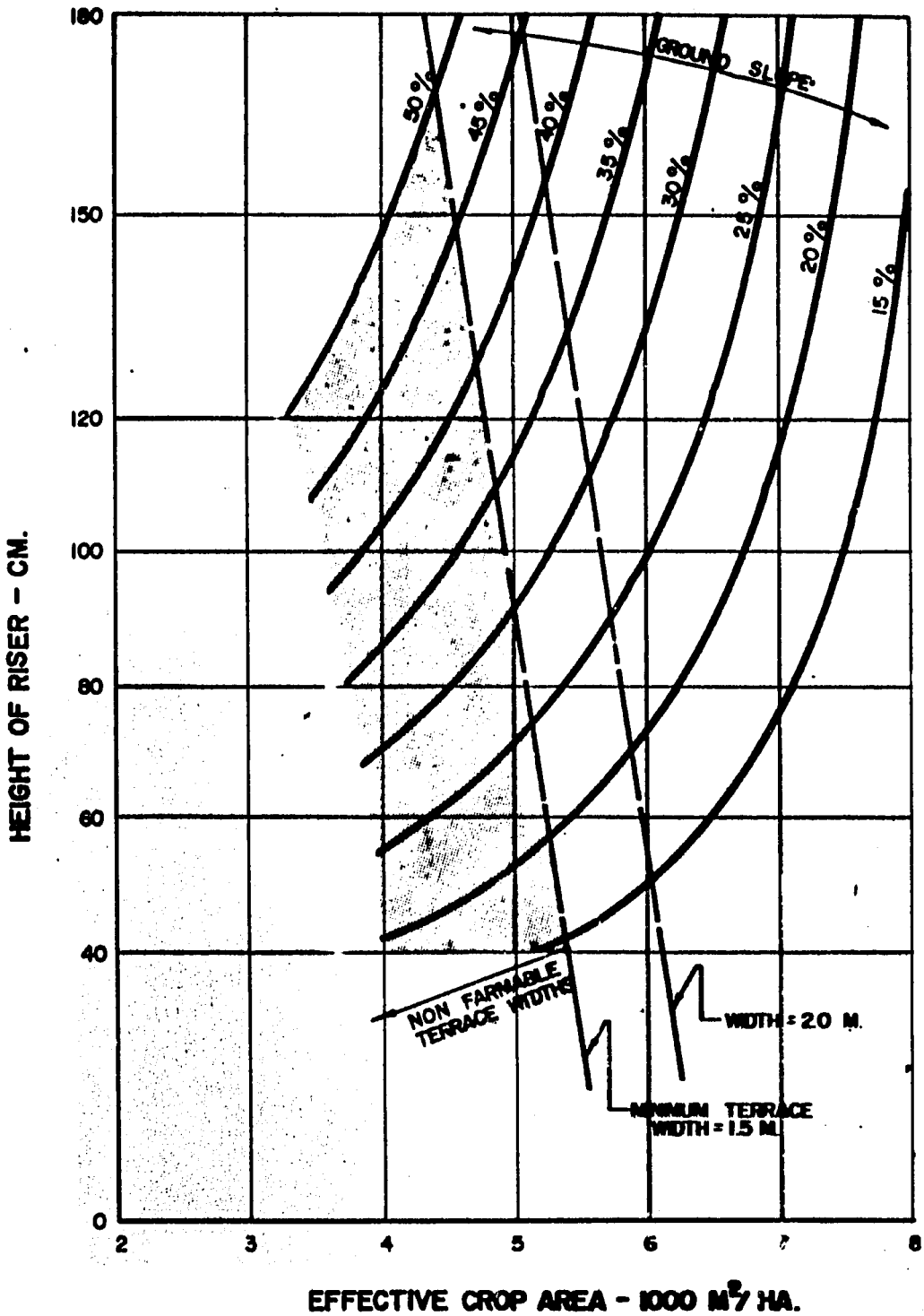
EROSION CONTROL STUDY PROJECT

ACCESS TO BENCH TERRACE SYSTEM



EROSION CONTROL STUDY PROJECT

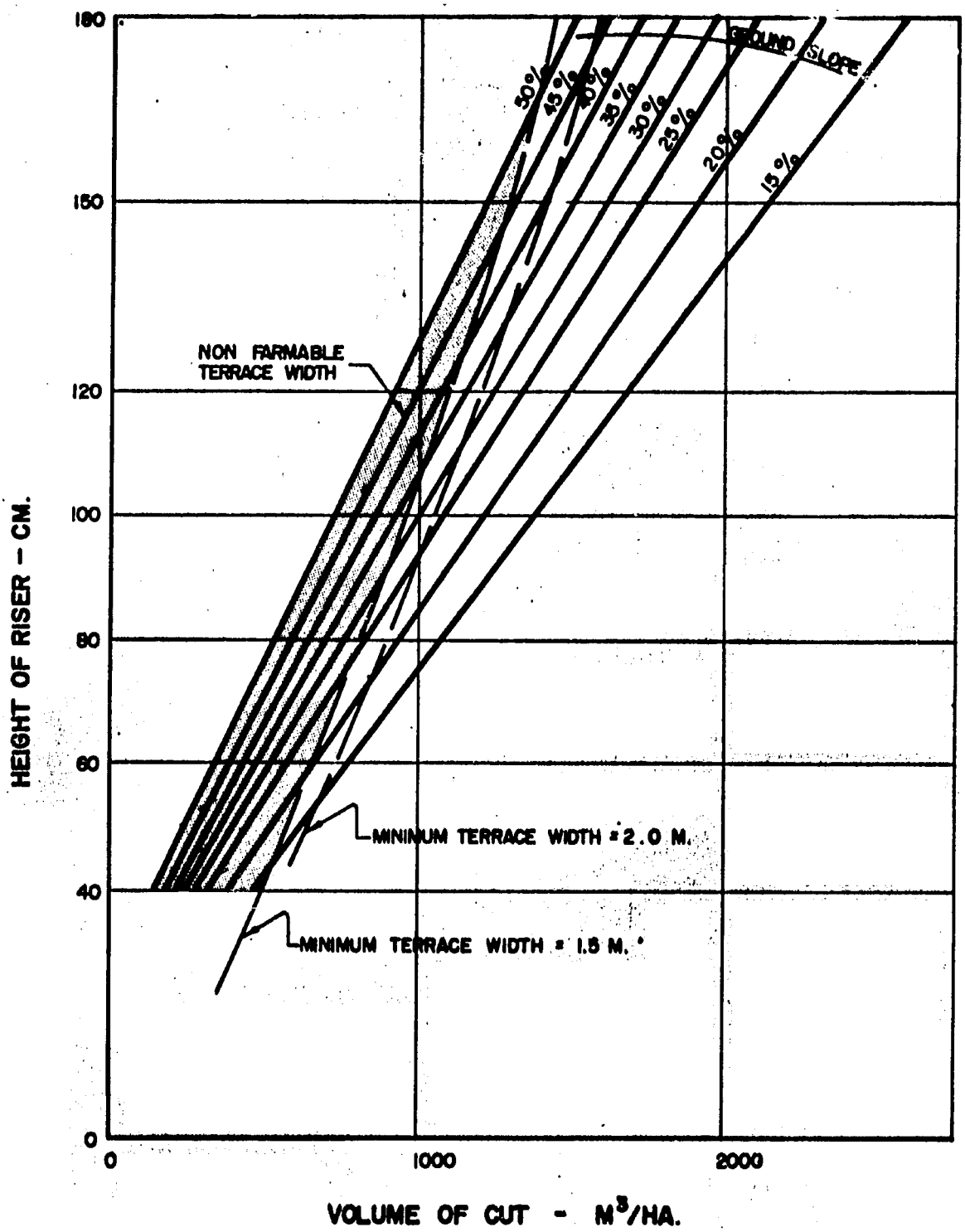
EFFECTIVE CROP WIDTH
REVERSE SLOPE BENCH TERRACES



EROSION CONTROL STUDY PROJECT

EFFECTIVE CROP AREA

REVERSE SLOPE BENCH TERRACES



EROSION CONTROL STUDY PROJECT

VOLUME OF EXCAVATION

REVERSE SLOPE BENCH TERRACES

ANNEX D-1

PLANNING PARALLEL TERRACE SYSTEM ON A MAP

ANNEX D-1

PLANNING PARALLEL TERRACE SYSTEM ON A MAP

A topographic map with an 1-meter contour interval or a contour interval equal to the vertical interval between terraces, if less than 1 meter, will be quite helpful in laying out parallel terraces. If a topographic map is not available, constant grade terraces may be staked and a map showing their location and elevation should be made. This map can then be used to plan the layout of the parallel terraces.

The advantage of using a topographic map or a map of constant grade terraces is that all the terraces on the field can be seen at a glance, and adjustments in terrace location can be made much faster than would be possible by restaking the terraces in the field. Also, several tentative systems may be laid out on the map for comparison much faster than it could be done in the field.

The following procedure is suggested:

1. Plan the best possible layout on the map. The slope in different parts of the field, or unit, should be determined and the terrace spacing selected. The fact that the slope of the entire area can be seen on the map will make it relatively easy to determine which terrace, or section of a terrace, would be the best key terrace for that part of the area. Select these key terraces, or sections of terraces, and lay out the others as nearly parallel to them as possible, keeping the limits of grade and depth of cut.

The layout of a terrace plan on a topographic map is illustrated in Figure D-1-1. The average land slope in the upper part of the field is approximately 30 percent, and a horizontal interval of 4.0 m is selected. The land slope in the lower part of the field averages 40 percent, so a horizontal interval of 4.5 m is selected, which increases the vertical interval from 120 cm to 180 cm in order to maintain the width.

It would appear that the seven upper terraces can be made parallel. The upper half of terrace 7 should be the key. The grades in the upper half of terraces 1 to 6 will be greater than the grade in the key terrace, but will not exceed the permissible grade. If the upper end of either terrace 1 or 2 had been selected as the key, the grade in the upper end of terrace 7 would have been too flat, or the direction of the grade reversed.

The lower half of terrace 4 should be the key for this section. The slight increase in grade for terrace 1, and a slight decrease in grade for terrace 7 will be required to make them parallel to terrace 4. It appears impractical to make terrace 8 parallel to terrace 7.

Whenever it is necessary to vary the spacing between terraces, it should be increase or decreased in intervals equal to, or in multiples of the width of the equipment or row spacing that is to be used in farming. In Figure D-1-1, the spacing between terraces 7 and 8 is increased from 4.0 m at the lower end to 4.5 m. The resulting point row area is 3 m wide. The change from one spacing to the other should be made in as short a distance as possible so that the point row area will be roughly rectangular in shape rather than a long, tapered triangle.

Terraces 9-11 can be made parallel to terrace 8.

In planning the terrace layout on the map, care must be exercised in that neither the variation in grade nor the depth of cut will be excessive. It is possible to estimate the approximate grade and depth of cut from the map. For example, in Figure D-1-1, the steepest grade appears to be in terrace 4. The elevations at the upper end of the terrace is 93.6 m, and the elevation 30 m from this point is 92.0, a drop of 1.6 m. This grade of 5.3 percent is not excessive in this section of the terrace.

The maximum variation in cut appears to be on terrace 1 Assume that a normal cut of 1 m is made at the point where t terrace crosses the 80 m contour line, the elevation of the chann along the terrace at this point would be 79 m. The figures alo the terrace represent the elevation of the channel, assuming that 3 percent grade is used in the terrace. The least cut will be ma at A, where the elevation of the ground surface is 78.5 m. Th channel elevation is 78.4 m. A cut of 0.1 m will be required. Th greatest cut will be at B. The elevation of the ground surfac is 79.5 m. The elevation of the channel is 77.8 m. The cut wil be 1.8 m.

2. Transfer the location of one terrace from the map to the field After the parallel terraces have been planned on the map, one o these must be staked in the same relative position in the field Reference points must be established in the field and on the map s that this can be done. This terrace must be staked with smooth uniform curves that will be convenient to farm. It is used as guide in staking the other terraces. Stakes on parallel terrace with an appreciable variation in depth of cut are usually set as 5 to 15 m intervals.

3. Use the step-offset method for staking the curves. This is a simple method to assure that smooth, uniform curves are staked out. Refer to Figure D-1-2 while studying this procedure. Assume that a uniform curve is to be laid out to connect two straight sections of terrace. Step 15 m from PC, the point where the curves begins, in line with the straight section of the terrace. Step sideways a distance equal to one-half the estimated offset and set stake 1. Step out 15 m in line with the two previous stakes set at PC and stake 1. Step sideways a distance equal to the estimated offset and set stake 2. Repeat this process until PT, the point where the curve ends, is reached using the full offset for each stake. If the curve does not join the straight section at PT with the first estimated offset, another offset distance must be selected and the curve restaked. With a little experience, it will prove easy to closely select the correct offset on the first trial.

This same procedure can be used to stake out a series of curves not connected to straight sections to assure that there will be no abrupt change in curvature along the terrace.

A curve with a 7.5 m offset in 15 m will be about as sharp as can be farmed with modern machinery. This curve will have a radius of about 30 m. To determine the approximate radius, divide 230 by the offset distance.

$$\text{Radius (m.)} = \frac{230}{7.5}(0.305) = 9.35$$

Keep in mind, when selecting the radius of curvature or the offset distance, that terraces staked out or crop rows planted on the inside of the curve will have a smaller radius, and will be more difficult for machinery operation.

4. Stake terraces so that they are parallel. After a key terrace has been staked, adjacent terraces can be staked parallel to it at the desired spacing. This can be accomplished by two men using a tape or line of the desired length. One man walks along the already staked terrace line, holding one end of the line, and checks to determine if the line is perpendicular to his terrace. The second man holds the other end of the line and moves to the first stake on the adjacent terrace, point 1 in Figure D-1-2. The man on the key terrace must be sure that the distance between the terraces is measured perpendicular to the key terrace. A positive check to determine if this is the case is made by having the second man hold his end of the line at the stake just set. The man on the key terrace moves forward and back along the terrace, if the measured distance is perpendicular, he will swing away from his terrace in the direction of the second terrace on each side of his mesuring position.

The second man steps 15 m, keeping a taut line, and the other man walks along the key terrace, keeping it perpendicular to him. The man on the key terrace will go less than 15 m in staking a terrace on an outside curve, and more than 15 m in staking a terrace on an inside curve. The man on the second terrace sets the stake, making sure that the line is taut, and the man on the key terrace checks to determine if the measurement is perpendicular to his terrace. This process is repeated for the remaining stakes.

Lay out all terraces with the spacings as indicated on the map.

Field Survey

The layout of a parallel terrace system in the field is more or less a "cut and try" procedure. It is usually necessary to adjust the location of the terrace lines several times to obtain the best system. The amount of adjustment often depends upon the experience of the layout men and the topography of the field (Figure D-1-3).

1. Stake out the top terrace. In staking the top terrace, follow the procedures given for nonparallel terraces. The location of the top terrace will probably be changed somewhat later if it is not selected as the key terrace.

2. Space the remaining terraces. Determine the average slope of the area that will drain into each of the remaining terraces. Select the spacing for each terrace. Mark the location of each with a single stake. These stakes should be set where the land slope is about average and near the center of the field, if possible.

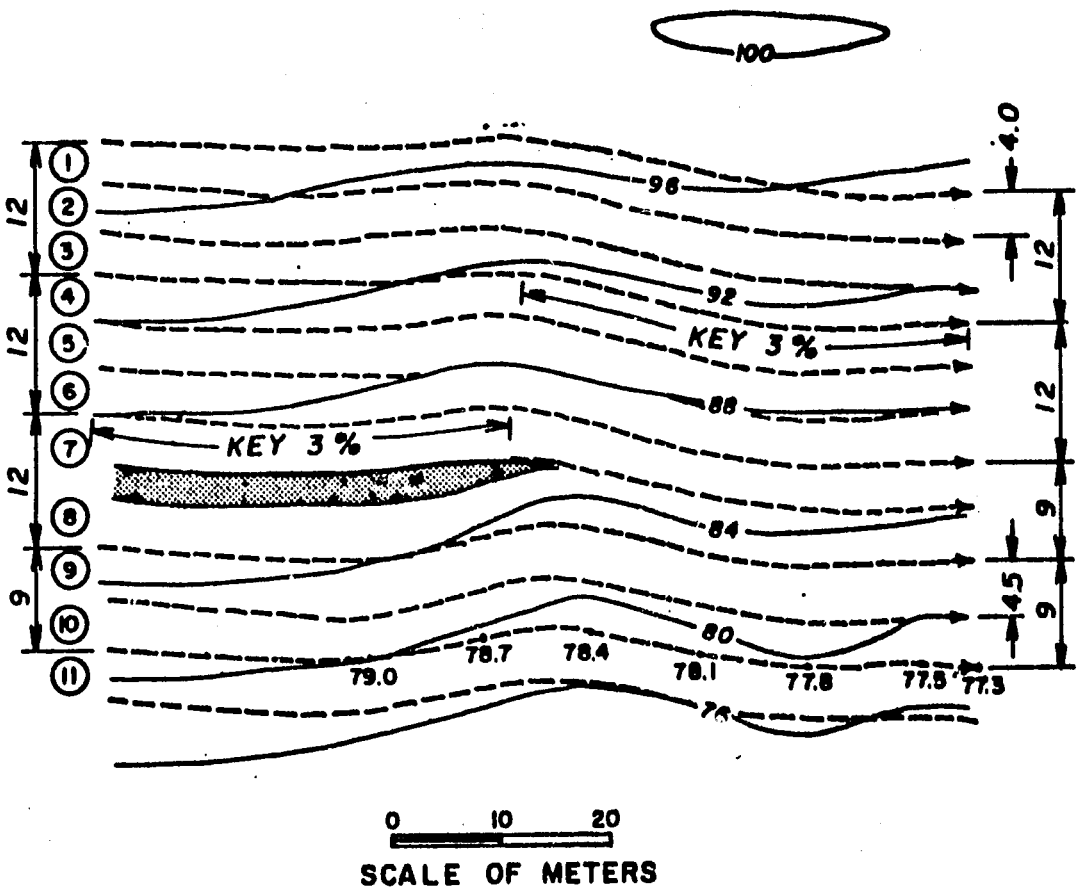
3. Select the key terrace. This terrace, or section of terrace, should be so located that several terraces can be made parallel to it. The location of the outlet and the topography of the field must be considered in selecting the key terrace. The following points will be helpful in selecting the key. The grade in a parallel

terrace below the key terrace will be greater than that in the key if the slope of the land increases as the outlet end of the terrace is approached (Figure D-1-4). The grade in a parallel terrace below the key terrace will be less than that in the key if the slope of the land is less toward the outlet end of the terrace. If the variation in land slope is great enough, it may result in the terrace grading in the opposite direction (Figure D-1-4). On long, irregular slopes it may be necessary to divide the terraces into groups and to select a key for each group.

4. Stake out the key terrace. Set stakes at 5 to 15 cm intervals using a desirable grade for the soil type.

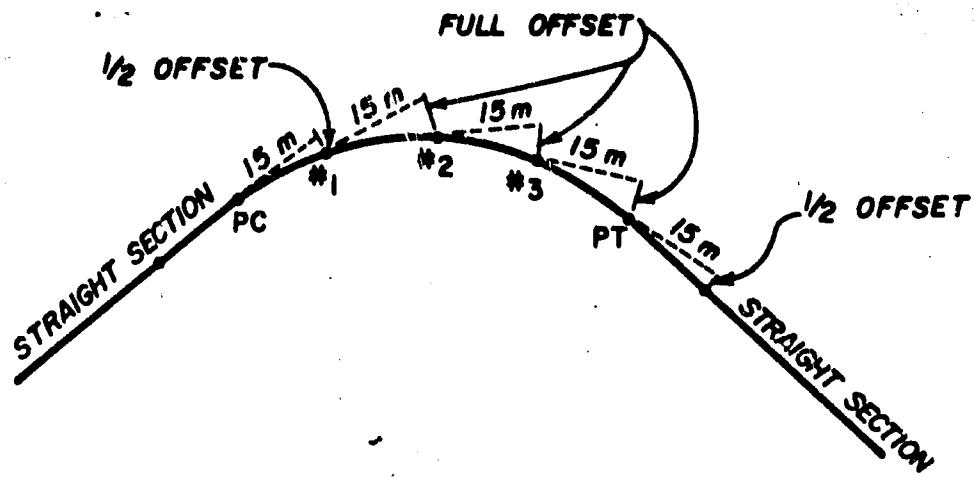
5. Adjust the key terrace. Adjust the stakes on the key terrace slightly, where necessary to reduce the curvature of sharp or irregular curves (Figure D-1-5).

6. Stake other terraces parallel to the key terraces. Use the same procedure as previously discussed in this Annex.

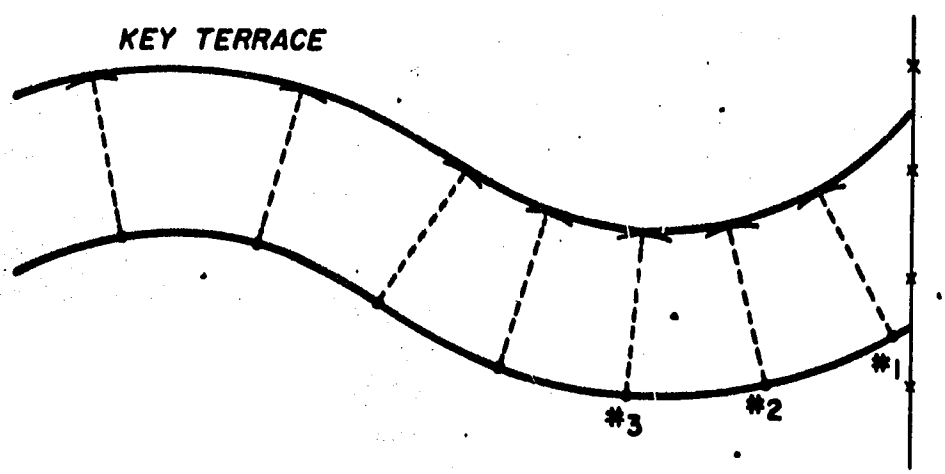


EROSION CONTROL STUDY PROJECT

MAP OF A PARALLEL TERRACE SYSTEM



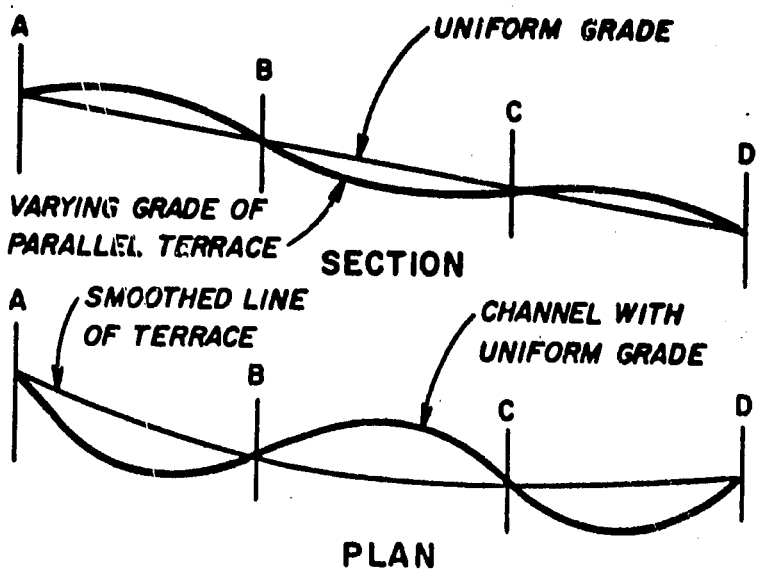
LAYING OUT A UNIFORM CURVE BY THE STEP-OFFSET METHOD



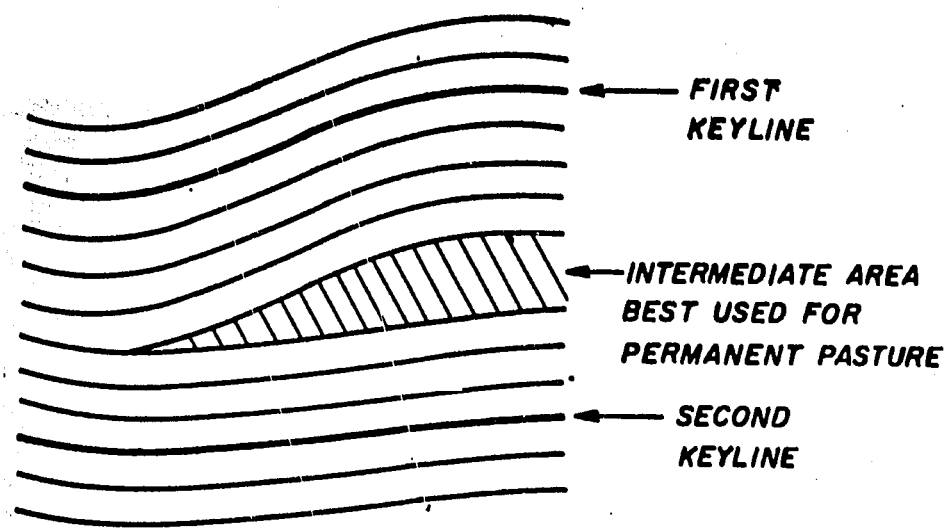
STAKING A TERRACE PARALLEL TO A KEY TERRACE

EROSION CONTROL STUDY PROJECT

FIELD LAYOUT OF PARALLEL TERRACES



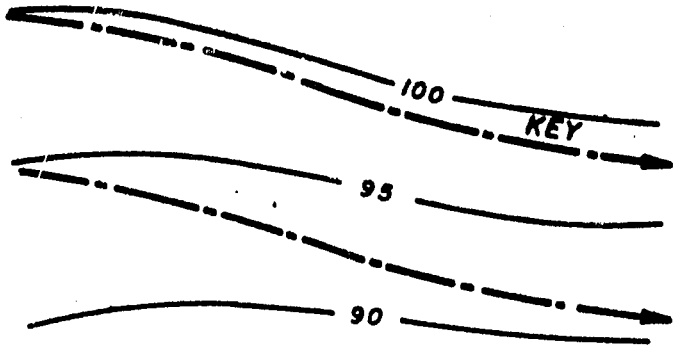
PARALLEL TERRACES REQUIRE SOME DEVIATION FROM GRADIENT



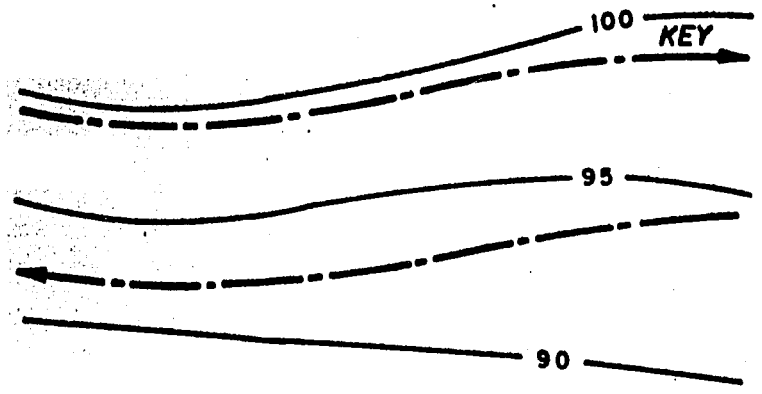
THE 'KEYLINE' METHOD OF LAYING OUT
PARALLEL TERRACES

EROSION CONTROL STUDY PROJECT

PARALLEL TERRACE LAYOUT



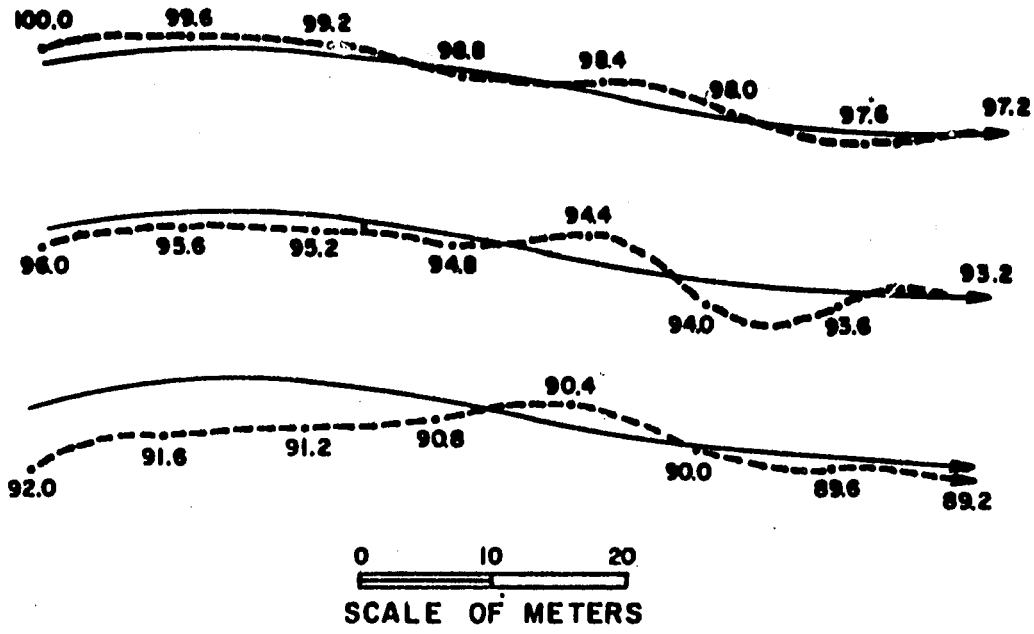
(a) GRADE IN PARALLEL TERRACE BELOW THE KEY TERRACE INCREASES



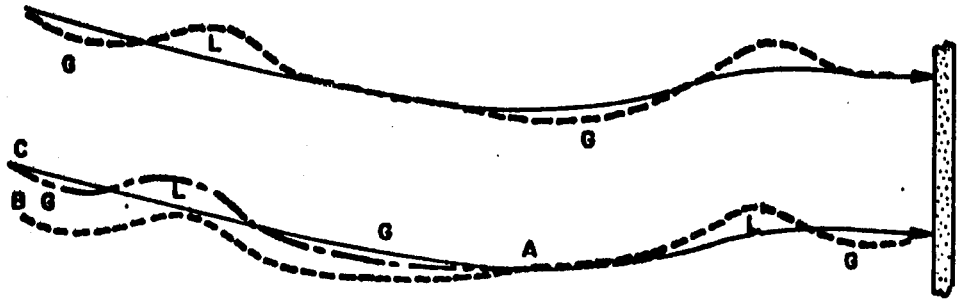
(b) GRADE IN PARALLEL TERRACE BELOW THE KEY TERRACE DECREASES
(IN THIS CASE, THE GRADE IS REVERSED)

EROSION CONTROL STUDY PROJECT

EFFECT OF TOPOGRAPHY ON TERRACE GRADES



MAP OF CONSTANT GRADE AND PARALLEL TERRACES FOR STUDY.



TERRACE LOCATION USING A CONSTANT GRADE AND UNIFORM CUT.
TERRACE LOCATION USING AN INCREASED GRADE AND UNIFORM CUT.
FINAL TERRACE LOCATION RESULTING FROM VARYING THE GRADE AND DEPTH OF CUT.

IMPROVING TERRACE ALIGNMENT AND CURVATURE BY VARYING THE DEPTH OF CUT AND THE GRADE.

EROSION CONTROL STUDY PROJECT

AIDS TO IMPROVE TERRACE LAYOUT

ANNEX D-2

COMPUTING TERRACE GRADES AND DEPTH-OF-CUT

ANNEX D-2

COMPUTING TERRACE GRADES AND DEPTH OF CUT

The following procedure applies to broad-base graded terrace with a grassed outlet. The same general procedure, with some modifications, would apply to other types of terraces.

1. Run profile levels along the terrace stake line. As soon as a terrace has been staked out, take a rod reading on the ground beside each stake and in the outlet in line with the terrace. Record these rod readings as "ground rod". (See Survey Notes, Table D-2-1, column 2.) Observe that these notes are of somewhat different form that conventional level notes and that the actual elevation of the ground surface is not computed. Note that when the level is moved, a reading is taken on a common stake from each level set-up (stake 8 in Table D-2-1). Record any field conditions which will influence the planning of the terrace, such as the gullies in the field near stakes 9 and 15.

2. Plot a profile of the ground surface along each terrace. To determine the grade in each section of the terrace that will result in the least amount of work in construction, the survey notes should be plotted and a profile of the ground surface drawn (Figure D-2-1). Note that rod readings are plotted rather than elevations, and that rod readings are numbered down from the top of the profile sheet. If more than one level set-up is made, the profile is plotted as if all readings had been taken from the first one.

In the survey notes (Table D-2-1) observe that the second level set-up was 2 m lower in elevation than the previous one. This can be determined by noting the rod reading on stake 8 from each set-up. In plotting the profile, 2 m is added to each rod reading taken from the second set-up.

This profile represents the elevation of the ground surface along the terrace. Draw a line along the profile at such grade and elevation that the amount of earth above the line will be approximately equal to the amount below the line (line A in Figure D-2-1). Plan so the distance that the earth must be moved will be minimal. If additional earth is needed to fill gullies in the field, such as in the vicinity of stakes 9 and 15, then the line should be drawn with additional earth above it in the vicinity of the gullies. Where the profile is above this line, a greater depth of cut will be required than where it is below. The grade of this line must fall within the allowable limits for the different sections of the terrace.

3. Compute the depth of cut required at each stake. At a certain depth of cut the earth taken from the channel will be equal to the earth required on the ridge. This depth of cut will vary with the shape of the terrace cross-section, the height of the terrace ridge, and the land slope. The depth of cut for a V-shaped channel with the cutslope equal in length to the backslope can be computed by the equation:

$$\text{Depth of Cut} = 1/2(h + SW/100)$$

Where: h = Height of the terrace, in meters.
S = Land slope, percent slope.
W = Length of the front slope, in meters.

Let us assume that the depth of cut required in this example is 0.8 m for the upper 240 meters of the terrace, 0.9 m from 240 to 280 m, and 1.0 m for the remainder.

Draw a line on the profile below line A at a distance equal to the depth of cut required. This is designated "grade line" in Figure D-2-1.

The grade line represents the location of the bottom of the completed terrace channel. The "grade rod" gives the rod readings that would have been obtained had it been possible to place the rod at the elevation of the bottom of the completed terrace. The values may be taken directly from the profile; however, it is usually easier to compute them by taking the grade rod reading at the upper end of the terrace and adding the proper grade for each succeeding stake. Record these values to the nearest centimeter in column 3 of your survey notes, as shown in Table D-2-1.

Compute the depth of cut at each stake by subtracting the ground rod from the grade rod and record in column 4.

The grade rod reading at the outlet should be approximately the same as the rod reading taken there. The terrace can be cut into the outlet either upslope or downslope from the point at which the rod reading was taken, if necessary, to obtain the proper grade between the end of the terrace and the outlet.

Columns 5, 6, and 7 of Table D-2-1 give the desired cut and the excess or deficiency. It is noted that there is an excess of earth between stakes 11 and 13. This excess was planned and will be used to fill the gullies in the field near stakes 9 and 15.

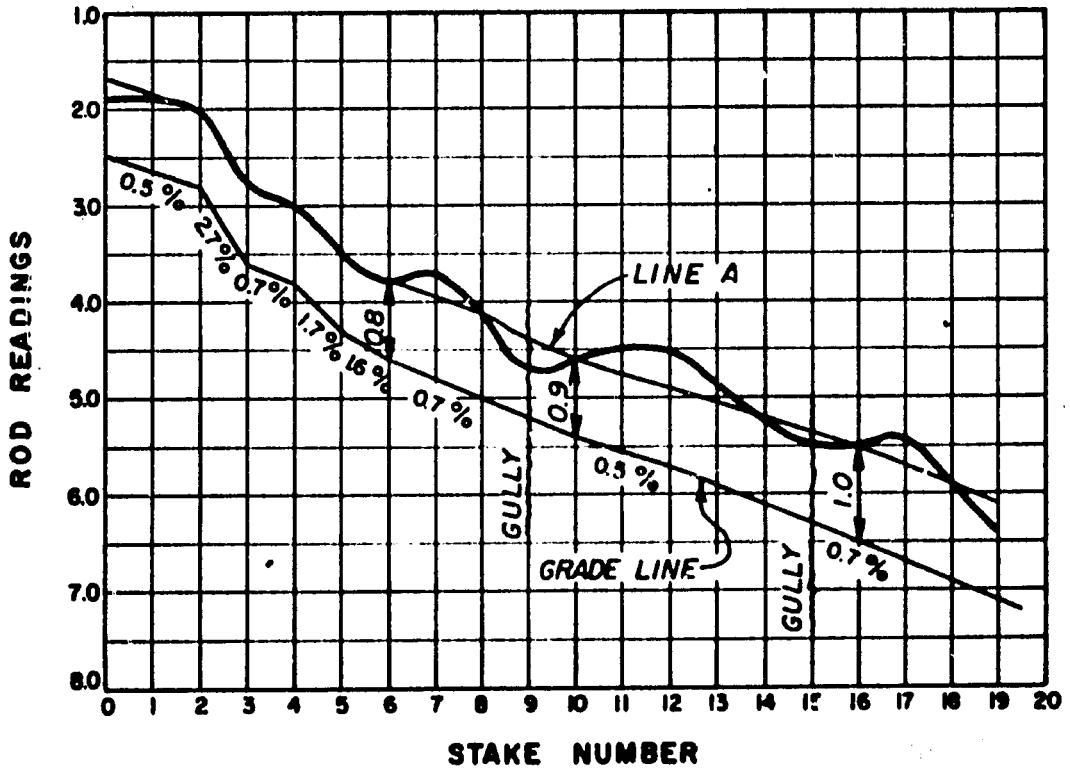
4. Mark the stakes for constrution. The depth of cut to be made at each stake should be marked on that stake for use during construction.

TABLE D-2-1

Survey Notes for a Terrace

Stake*	Ground Rod	Grade Rod	Cut (m)	Desirable Cut	Excess Cut	Deficient Cut
0	1.90	2.50	0.60	0.60		
1	1.90	2.70	0.80	0.80		
2	2.00	2.80	0.80	0.80		
3	2.80	3.60	0.80	0.80		
4	3.00	3.80	0.80	0.80		
5	3.50	4.30	0.80	0.80		
6	3.80	4.60	0.80	0.80		
7	3.70	4.80	1.10	0.80	0.30	
8	4.10	5.00	0.90	0.80	0.10	
TP						
8	2.10	3.00	0.90	0.80		
9 gully	2.70	3.20	0.50	0.90		0.40
10	2.60	3.40	0.80	0.90		0.10
11	2.50	3.60	1.10	0.90	0.20	
12	2.50	3.70	1.20	0.90	0.30	
13	2.90	3.90	1.00	0.90	0.10	
14	3.20	4.10	0.90	0.90		
15 gully	3.50	4.30	0.80	0.90		0.10
16	3.50	4.50	1.00	1.00		
17	3.40	4.70	1.30	1.00	0.30	
18	3.90	4.90	1.00	1.00		
19	4.40	5.10	0.70	1.00		0.30
19+25 - Outlet	5.20	5.20	0	0		

*Stakes are set at 30 m intervals.



EROSION CONTROL STUDY PROJECT

PROFILE OF GROUND SURFACE AND PROPOSED GRADE LINE FOR A TERRACE

ANNEX D-3

STAKING TERRACES

ANNEX-D-3
STAKING TERRACES

A surveyors level should be used for staking out of terraces. It need not have great precision, but should be built for robustness. Long-shots should not be taken, particularly when there is heat haze. A level is not absolutely necessary. Other instruments which can be used are the hand level, Abney hand level, clinometer or Mason's bubble level. The hand levels, etc., have their accuracy improved if they are supported by either a supporting pole or two-legged A-frame (see Figure D-3-1).

Ordinarily, stakes are set on grade at intervals of 25 meters on flatter terrain, and 15 meters on steeper slopes. If local hand methods are used it would be better to located the stakes at 5 meter increments. Extra stakes should be used at local obstructions, especially depressions. If the rod-man is unskilled, care is required to make sure that the rod is in a suitable place, not in a hollow or on a stone. Figure D-3-2 shows the basics of using locally available equipment.

Staking should be done just prior to construction because stakes left in the field are liable to be blown down, knocked over by cattle or people, used for firewood, etc. Also, it is surprisingly easy to join up stakes in adjacent lines. For this reason, color coding can be used.

There are two ways of surveying and staking out terraces, depending on the tools to be used for cutting terraces and the kind of terraces. For both methods, staking should start from the first terrace, i.e., the top of the field, or subwatershed unit. This is not an absolute rule, as there are reasons for starting at the bottom of a slope, particularly if designs were made on a map. Staking for field design normally starts at the top of the ridge, although it would be possible to start staking the up-and-down guideline from the bottom, with adjustments made on reaching the top. The main reason for starting at the top is that, in general, the topmost terrace will be the longest terraces, and they will become progressively shorter as you move downhill.

The centerline method is the most common method used where draught animals or manual labor are used. This is to survey and stake out the outer lines of the terraces according to the vertical interval. After completing the staking of all centerlines, a line of stakes is added in the middle of every two centerlines (cut and fill being equal) by eye judgement, to indicate that it is the bottom line of the upper terrace and, also, the top line of the succeeding lower terrace. The centerline should be retained and marked as a guide for the non-cut and non-fill line during the entire period of construction. The area above this line is the cutting area, while the area below is the filling area (Figure D-3-3).

The two-line method does not stake out centerlines. Instead, it is to survey and stake both the upper line and the bottom line of a terrace, with proper distances to form the planned width of terrace. A specification table should be consulted to find out the width of the terrace for the given slope. The method is very useful in staking terraces that have been planned and designed on maps.

Before staking, an up-and-down guideline should first be set on a representative slope or, preferably, on the drainge divide between two drainage outlets. Then stakes are set along this line for the top and bottom lines of each descending terrace. The top and bottom lines are then surveyed in, and staked according to the design or bench width to be used. This method is particularly adapted to machine construction.

An example of downhill staking a level bench terrace on a 25% slope along the guideline with a safety strip is provided as follows:

Step 1

The level man places his levelling instrument on top of the 150 cm high support (either the support pole or A-frame) at the point where it is decided that the zero point for cut and fill is located, and stake S-2 is dirven at this point (see Figure D-3-3). The rod man, with his 250 cm scaled rod ("0" mark at the top and

"250" cm mark at the bottom) walks up the slope, but always along the guideline, and then adjusts the rod up or downhill according to the instruction of the level man, until this level man sights the 150 cm mark on the rod. Stake S-1 is driven at this point. The 150 cm mark indicates that the point on the ground is 50 cm above the point of zero cut and fill, since the total pole length of 250 cm less the 150 cm reading is 100 cm, which is the distance from the line-of-sight down to the ground. The point S-1 is the top of the cut section, (Figure D-3-3).

In order that the level man can easily sight the desired mark on the rod, the rod man should hold the rod as illustrated in Figure D-3-2.

Step 2

After stake S-1 is set, the rod man moves downhill along the guideline to a position downslope from the level man. The level man remains at his position at stake S-2. The rod man will move downhill until the level man reads the 100 cm mark on the scaled rod, as shown in Figure D-3-3. Stake S-3 is driven at this point. Stake S-3 locates the bottom line of the fill section for the first terrace.

Step 3

After stake S-3 is driven, the rod man moves downhill roughly 30 cm or so until the level man reads 92.5 cm on the rod. Stake S-4 is driven here, and marks the location of the start of the cut section for the second terrace. The distance between stakes S-3 and S-4 is the safety strip.

Step 4

The rod man again moves downhill along the guideline until the level man reads 42.5 cm on the rod. Stake S-5 is driven at this point. Stake S-5 is the point of zero cut and fill on the second terrace.

We now have the first five stakes driven, and terrace no. 1 is completely staked. The level man now moves to stake S-5. Steps 2, 3 and 4 are now repeated as each succeeding terrace is located down the slope, until all the proposed terraces are staked (see Figure D-3-4).

The following items must be remembered when staking terrace points:

1. The movements of the level man and rod man are always along the centerline.

2. The scaled rod is held by the rod man in such a position that the "0" mark is up and the "250" cm mark is on the ground.

3. Staking starts from the highest point on the centerline, and movement and staking are down the slope.

4. A safety strip of 30 cm, measured along the centerline, is left between the terraces for stabilization of the risers.

5. The levelling instrument support is 150 cm in height, and the scaled level rod is 250 cm in height. The length of the level rod may have to be lengthed on steeper slopes.

It is also possible to survey and stake the terraces from the bottom in an uphill direction. This is illustrated in Figure D-3-3A. This is not a recommended practice because of the difficulty in positioning the highest, or top terrace, near the ridge line. Where the terraces will not be constructed up the entire slope, and the bottom terrace becomes the key or guide terrace, then surveying would proceed uphill.

After staking the cut, zero, and fill points on the guideline have been completed, it is then necessary to stake each terrace from the guideline to the outlet structure, i.e., the low point at which the water drains off from the terrace into a waterway. For this example, it will be assumed that the terrace will have a 1% slope from the guideline to

the waterway, i.e., a drop of 1.0 m in each 100 m of traverse. This slope reduces to 5 cm in each 5.0 m of traverse.

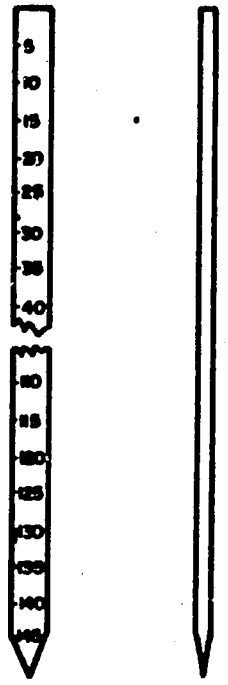
The level man moves back to stake S-1 and sets up at this point, which is a cut point. The level instrument is set on the support pole or A-frame. The level man then sights along the contour, which is essentially across the guideline (not up or downhill). The rod man moves laterally along the contour for a distance of 5 meters (this can be accomplished by using a piece of string or rope 5 meter long). The rod man moves the rod up or downhill until the level man reads 100 cm on the rod. This point is then the same elevation as the stake S-1. The rod man should then move the rod downhill until the level man reads 95 cm on the rod. This means that this point is now 5 cm lower than the ground at stake S-1. A stake is driven at this point and labeled S-1-1. The rod man continues to move across the slope in 5-meter increments. The level man will continue to subtract 5 cm from the previous stake (location) until the waterway is reached (see Figure D-3-5).

In cases where the level man can no longer read the level rod, he must move his level and support to the last stake on the grade, and reset his equipment. The next stake he reads will again be 95 cm, and located 5 meters from instrument set-up point. After one side of the guideline is completed, the same method of staking continues on the other side of the guideline up to the waterway located on this side of the guideline (see Figure D-3-5). The line connecting at these stakes is known as the "cut" line of this terrace.

After the cut line of the highest terrace is completed, both the level man and the rod man move down to stake S-2, the zero cut and fill point of this terrace, and repeat the same procedure as described above to locate the "zero line" of the terrace. This procedure continues down the slope, in the same manner, for every "cut," "zero," and "fill" lines of all terraces (see Figure D-3-6).

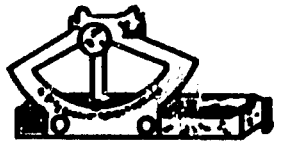
The above is basic methodology necessary to lay out a simple terrace system. The above assumes uniform slopes without irregularities. This seldom occurrs in the field. Normally, terraces will have to cross small depressions, gullies or other obstacles. Modifications will be required to maintain grade and width. In general, this will require excess cut and fill, resulting in the lateral movement of soil, where required. The modifications in planning are covered in another Annex of Appendix D. An example is shown in Figure D-3-7.

Rules will not be given on the relocation of cut and fill stakes, as the number of variations are too great to be satisfied by simple guidelines. The procedures outlined above can be adapted to making any desired modifications. The decision on adjustments of terraces will depend on the requirements of the farmer and judgement and experience of the technician, as well as the added cost.

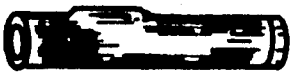


SCALED ROD
(150 cm.)

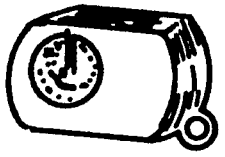
LEVEL INSTRUMENT
SUPPORTING POLE
(150 cm.)



ABNEY HAND LEVEL

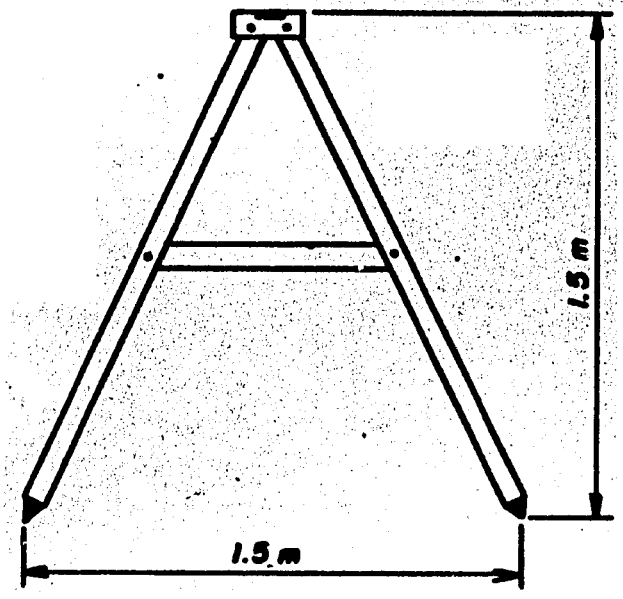


LOCKE HAND LEVEL



CLINOMETER

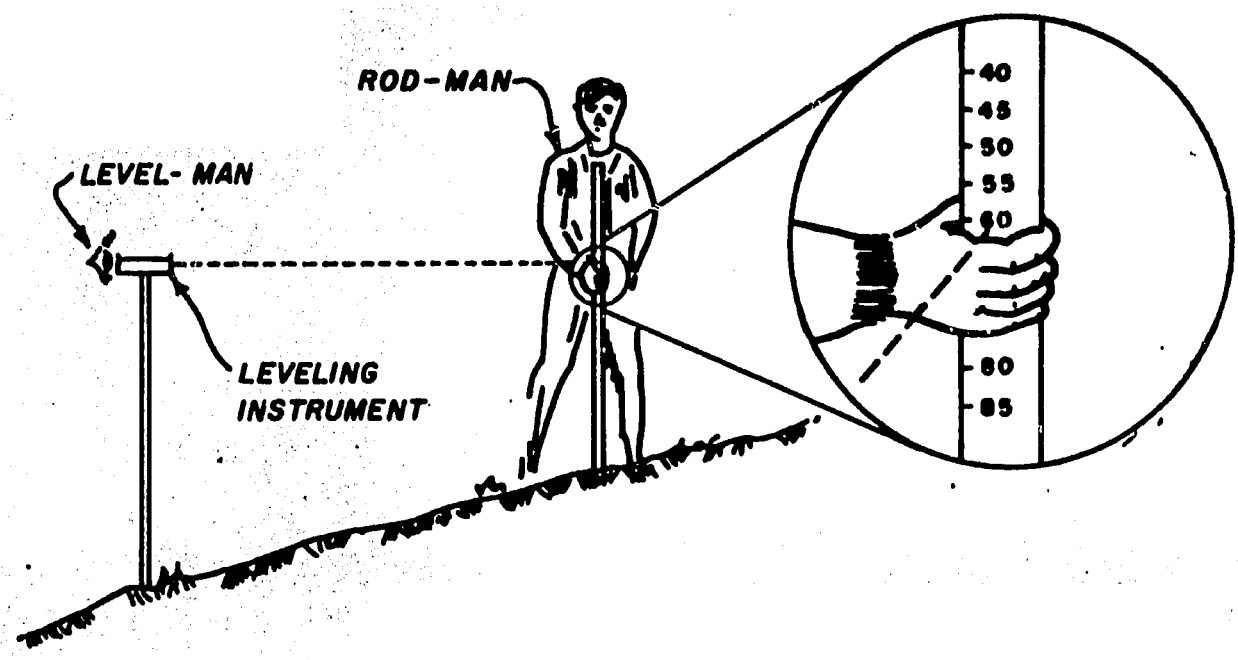
MASON'S
BUBBLE LEVEL



A LOCALLY CONSTRUCTED, TWO-LEGGED A-FRAME FOR SUPPORTING MASONS LEVEL OR HAND LEVEL

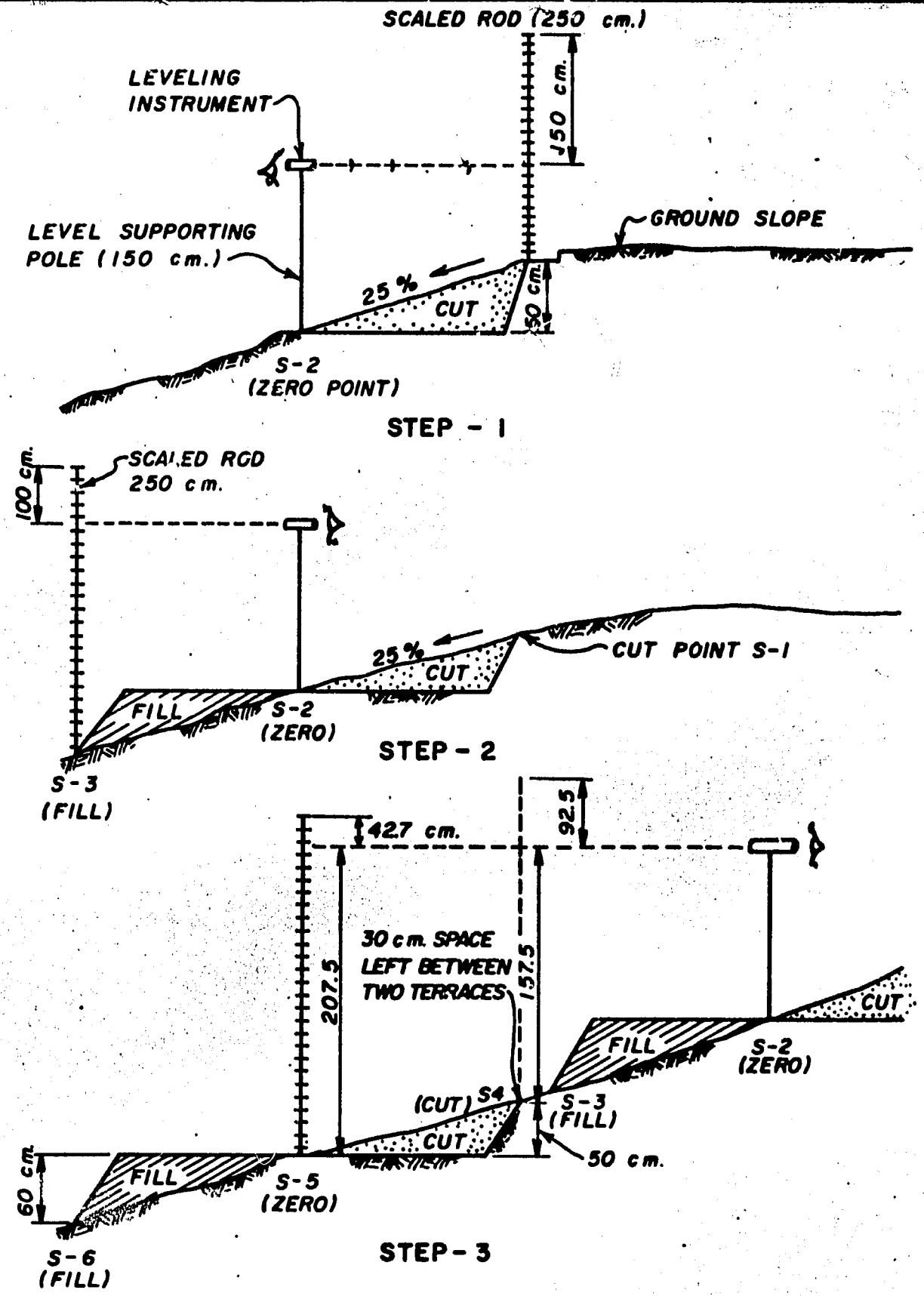
EROSION CONTROL STUDY PROJECT

LEVELING INSTRUMENTS FOR TERRACE CONSTRUCTION



EROSION CONTROL STUDY PROJECT

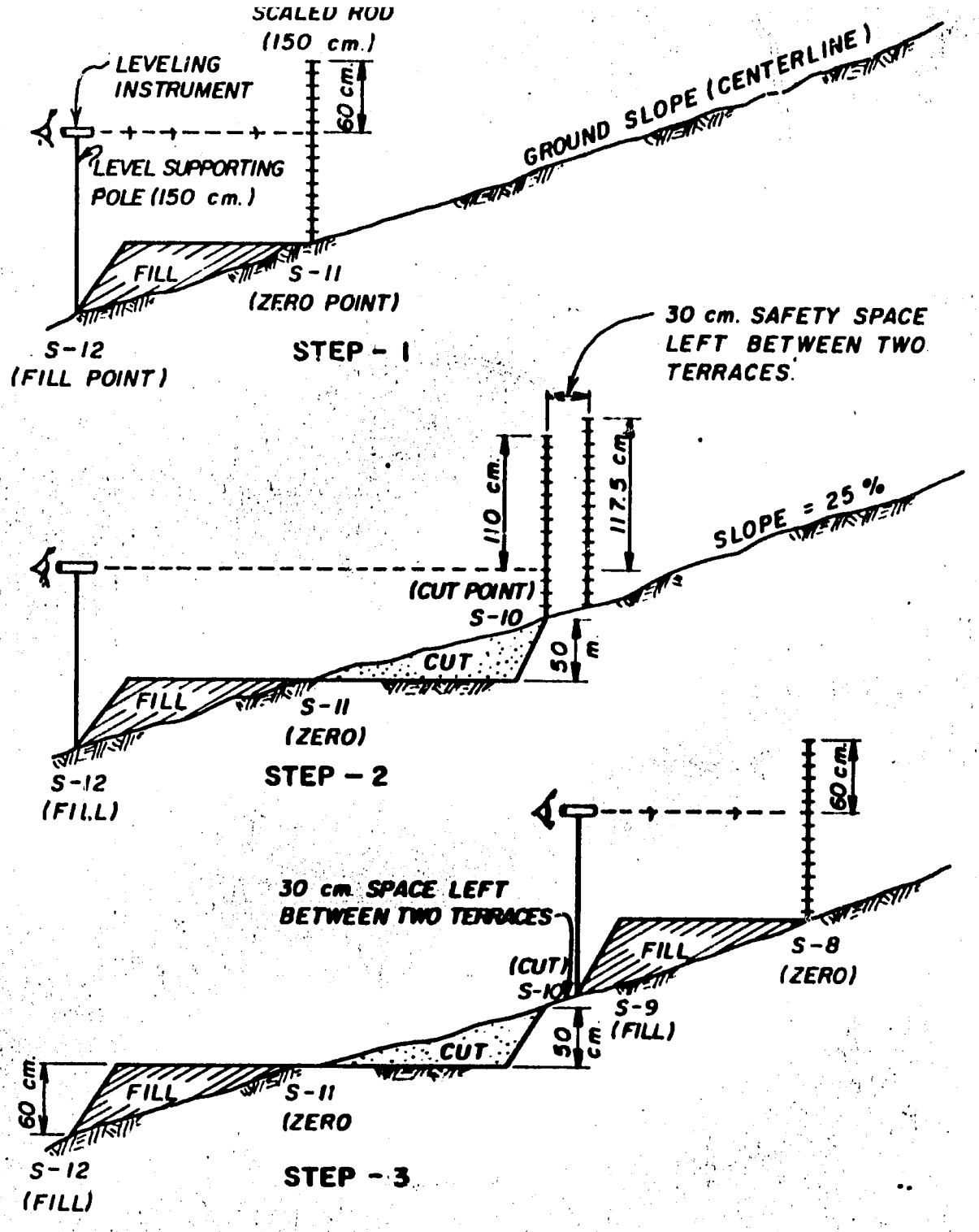
CORRECT WAY OF HOLDING ROD AT 60 CM MARK



NOTE: SURVEY REQUIRES A 2.5 SCALED ROD WITH "0" MARK ON TOP AND 250 cm. ON BOTTOM

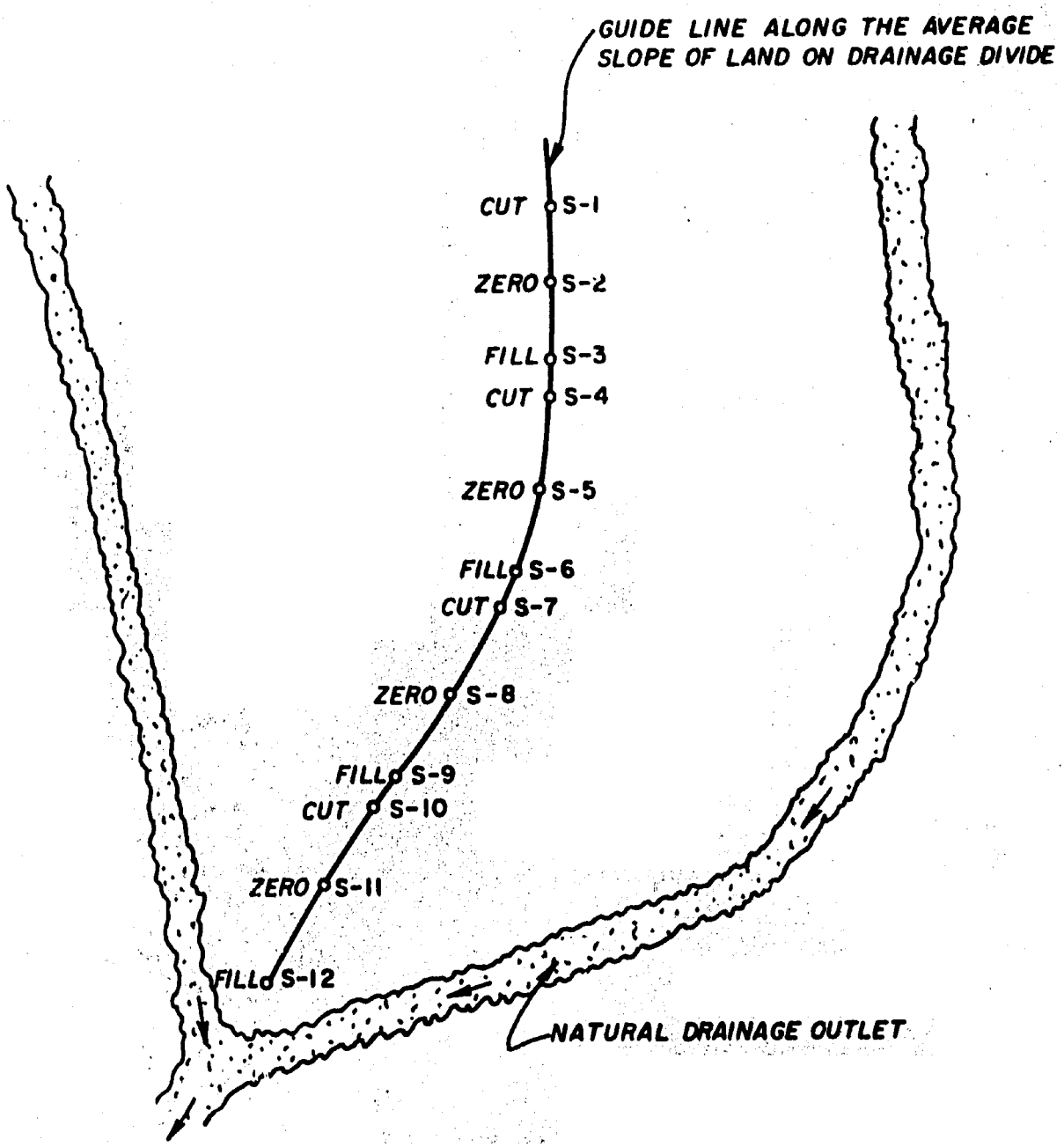
EROSION CONTROL STUDY PROJECT

STAKING OF "FILL", "ZERO," AND "CUT" POINTS ON GUIDELINE ALONG THE AVERAGE GROUND SLOPE WORKING DOWNHILL



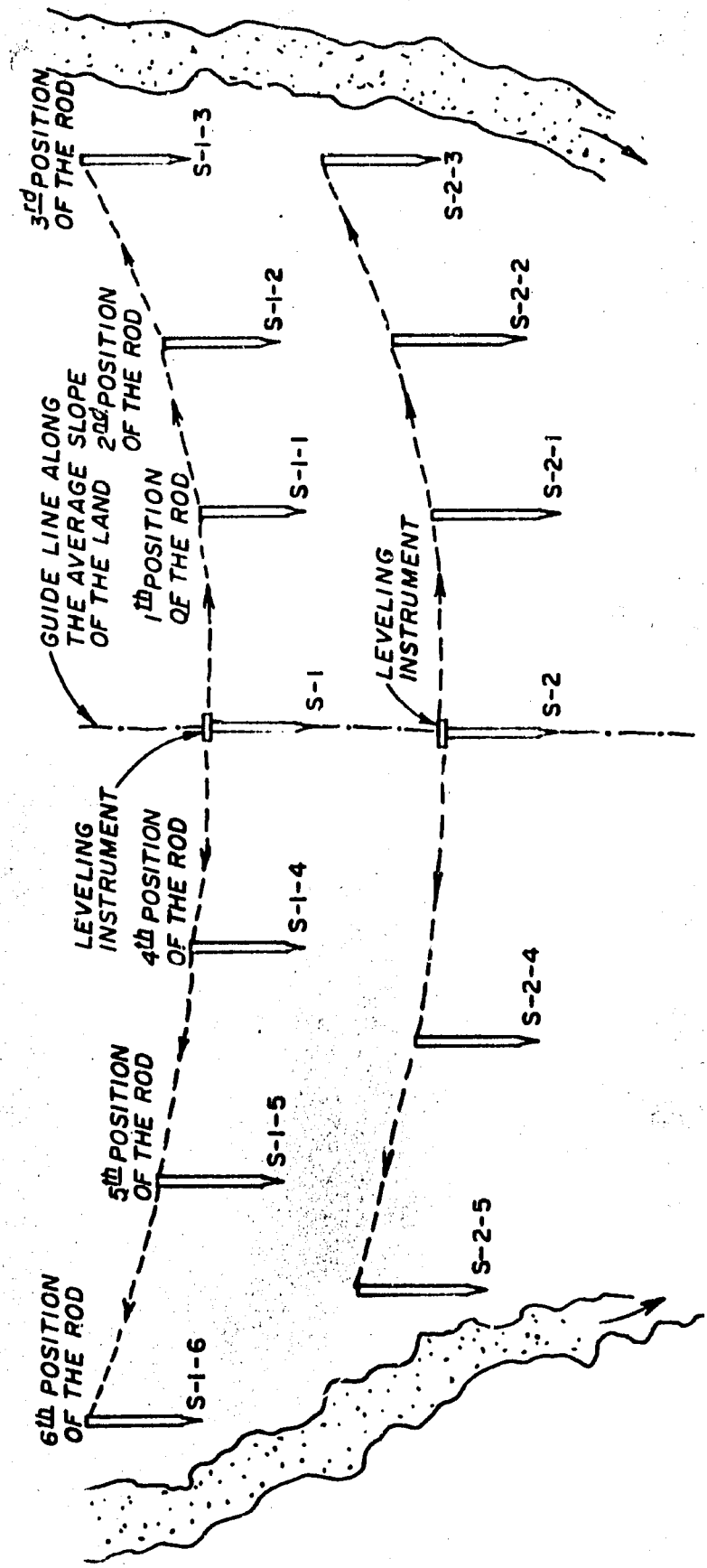
EROSION CONTROL STUDY PROJECT

STAKING OF "FILL", "ZERO," AND "CUT" POINTS ON GUIDELINE ALONG THE AVERAGE GROUND SLOPE WORKING UPHILL



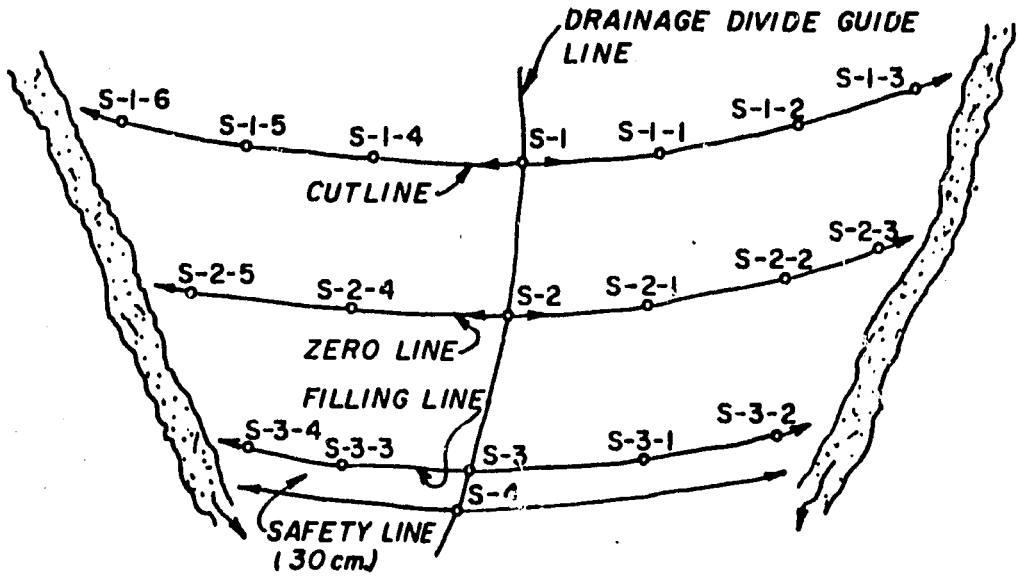
EROSION CONTROL STUDY PROJECT

STAKING OF "CUT", ZERO, AND "FILL" POINTS ON UP-AND-DOWN GUIDE LINE



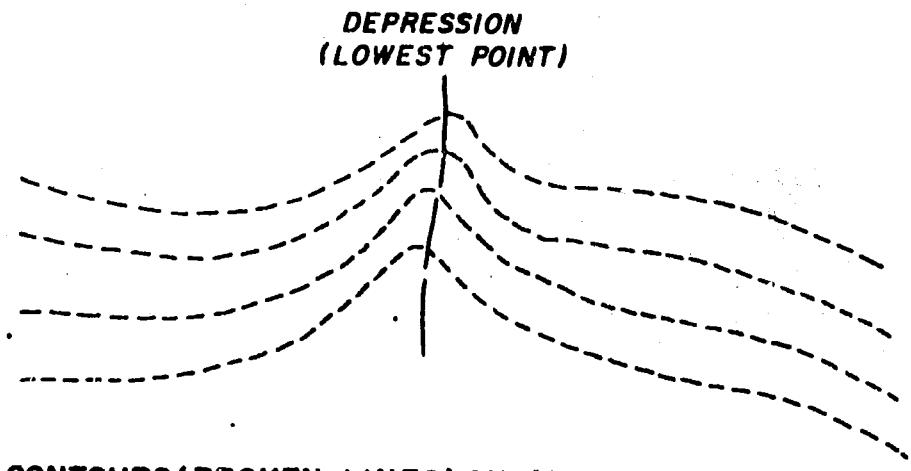
EROSION CONTROL STUDY PROJECT

SCHEMATIC STAKING OF "CUT", ZERO AND "FILL" LINES ALONG CONTOURS ACROSS THE CENTER LINE

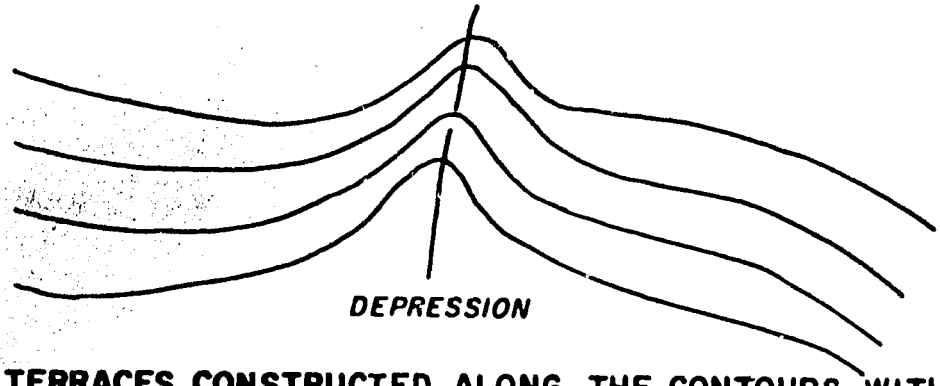


EROSION CONTROL STUDY PROJECT

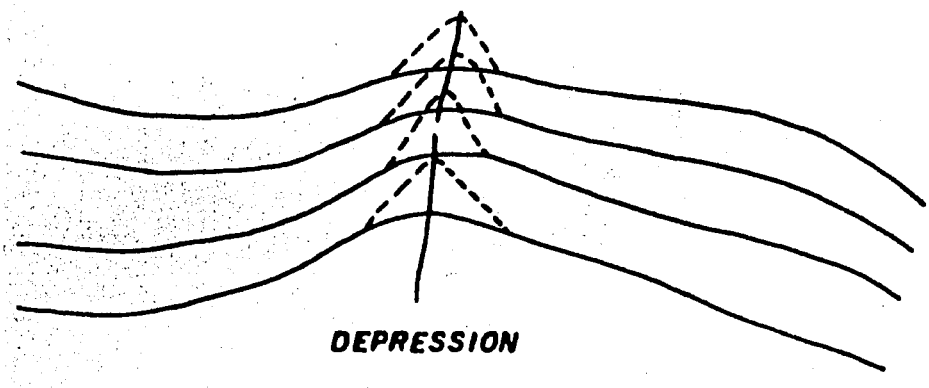
STAKING OF "CUT", "ZERO", AND FILL LINES OF ONE TERRACE COMPLETED



(a) CONTOURS (BROKEN LINES) ON AN UNEVEN TOPOGRAPHY.



(b) TERRACES CONSTRUCTED ALONG THE CONTOURS WITHOUT ADJUSTMENT, WHICH RESULTS IN VERY SHARP CURVES ON TERRACES AT DEPRESSIONS OR GULLIES.



(c) TERRACES CONSTRUCTED ALONG THE CONTOURS, WITH ADJUSTMENTS AT DEPRESSION TO AVOID SHARP CURVES ON TERRACES

EROSION CONTROL STUDY PROJECT

MINOR ADJUSTMENT OF TERRACE LINES ON UNEVEN TOPOGRAPHY

ANNEX D-4

ASAE RECOMMENDATION: ASAE R268.1
"DESIGN, LAYOUT, CONSTRUCTION AND MAINTENANCE
OF TERRACE SYSTEMS"

ASAE Recommendation: ASAE R268.1

DESIGN, LAYOUT, CONSTRUCTION AND MAINTENANCE OF TERRACE SYSTEMS

Developed by ASAE Terrace and Related Slope Modification Systems Committee; approved by Soil and Water Division Steering Committee; adopted December 1962 as tentative recommendation; tentative classification removed and revised December 1963; reconfirmed December 1968, December 1969, December 1970; revised February 1972; reconfirmed for one year December 1976; December 1977.

SECTION 1—PURPOSE AND SCOPE

1.1 This Recommendation is intended as a guide to engineers and technicians in the design, layout, construction and maintenance of terrace systems for erosion control and water conservation.

SECTION 2—TERMINOLOGY

2.1 Terraces are earth embankments, channels or combinations of embankments and channels constructed across the slope at suitable spacings and with acceptable grades for one or more of the following purposes:

2.1.1 To reduce soil erosion

2.1.2 To provide for maximum retention of moisture for crop use

2.1.3 To remove surface runoff water at a non-erosive velocity

2.1.4 To reform land surface

2.1.5 To improve farmability

2.1.6 To reduce sediment content in runoff water

2.1.7 To reduce peak runoff rates to installations downstream

2.2 Terraces alone usually will not provide the desired control of runoff water on sloping land. This control requires a complete water disposal system which may include waterways, underground outlets, diversion channels and structures, plus supplemental practices such as contour farming, strip-cropping, crop rotations, minimum tillage, and good soil management. Properly located fences, field roads, and other related measures must also be considered. Each measure must be planned to interfere as little as possible with farming operations, and be of maximum benefit to conservation of soil and water.

2.3 All types of terrace systems can be classified according to alignment, cross-section, grade and outlet.

2.3.1 **Classification by alignment**

2.3.1.1 **Parallel terraces.** These terraces are designed with straight segments whenever possible and long gentle curves, if curves are necessary. The adjacent parallel terrace ridges are spaced equidistantly throughout their length if possible. On irregular topography it may be necessary to divide terraces into parallel sections with different spacings for each section. Cuts and fills along the terrace channel may be required to establish satisfactory uniform or variable grades.

2.3.1.2 **Nonparallel terraces.** These terraces are designed with the terraces fitted to the contour of the land without regard to paralleling. In practice, adjustment is made to eliminate sharp turns and short point rows by installing additional outlets, using variable grade, and vegetated adjustment or turn areas.

2.3.2 **Classification by cross-section**

2.3.2.1 **Broadbase terrace.** (Fig. 1) This terrace is constructed so that crops can be planted and machinery operated over the entire terrace. Ridge and channel slopes are constructed to fit different machine widths.

2.3.2.2 **Flat-channel terrace or Zingg conservation bench terrace.** (Fig. 2) A level bench is constructed below a sloping runoff contributing area. Flat channel terraces are designed for maximum conservation of water. Channel width will vary depending on the land slope, allowable depth of cut and machine width.

2.3.2.3 **Steep-backslope terrace.** (Fig. 3) This terrace is constructed with a very steep backslope which is usually seeded to a permanent vegetation. The terrace is designed to shape land surfaces for improved farmability. When field slopes are uniform, a balanced cross section can be used. When field slopes are irregular and cuts and fills are necessary along the terrace length, frequent transitions will be required from excess borrow section to excess fill section.

2.3.2.3.1 **Balanced cross section.** This terrace is normally constructed entirely from the lower side. If exposed subsoil is not productive, the top soil may be moved downhill first then moved back over the excavated area.

2.3.2.3.2 **Excess fill section.** Where cuts below the terrace are undesirable, the terrace ridge may be built entirely of soil from excess borrow sections of the terrace or from a planned borrow area. A fill section is desirable when cuts below the terrace would result in increased row grades below the terrace or where terraces are built on shallow soils.

2.3.2.3.3 **Excess borrow section.** Where deep cuts are required in improving terrace alignment, both the backslope and channel may be excavated. Where subsoil will respond to fertilizers, the ridge crossed by the terrace may be planed off during construction to develop acceptable terrace channel grades.

2.3.2.4 **Narrow base terrace.** (Fig. 4) The entire cross section of this terrace is frequently seeded to permanent vegetation.

2.3.2.5 **Bench terrace.** (Fig. 5) This terrace is constructed with a wide level bench. The ridge has steep side slopes which are seeded to a permanent vegetation. The terrace is used mainly to provide more efficient distribution of water under both irrigated and dryland production.

2.3.2.6 **Ridgeless channel terrace.** (Fig. 6) This terrace is constructed on nearly flat to gently sloping land to remove excess surface runoff water at nonerosive velocities. The cut material from the channel is used to smooth the interterrace interval.

2.3.3 **Classification by grade**

2.3.3.1 **Level terraces.** These terraces are constructed where water conservation is the primary objective with erosion control as an accompanying benefit. They are usually used in low-rainfall regions to retain runoff for storage in the soil and may be used in high-rainfall regions on very permeable soils. The ends of the channel may be blocked or left open.

2.3.3.2 **Graded terraces.** These terraces are constructed to reduce field slope lengths and remove runoff with tolerable soil loss as the primary objective. Water conservation may be an accompanying benefit. The grade to the outlet may be uniform or variable.

2.3.4 **Classification by outlet.** Terraces may be classified by outlet such as infiltration in terrace channel only, vegetated waterway, underground outlet, and combinations of these outlets.

SECTION 3—DESIGN CRITERIA

3.1 **Spacing**

3.1.1 Terraces to control water erosion should be spaced by one of the following methods:

3.1.1.1 Where data are available for application of the universal soil loss equation, the horizontal spacing of terraces should not exceed the slope length determined for contour cultivation by using the allowable soil loss, the most intensive use expected for land, and the expected level of management. On gently sloping land, anticipated runoff and the economical terrace cross section size may determine spacing, rather than soil loss between terraces.

3.1.1.2 The equation $VI = XS + Y$ may be used for determining the vertical interval,
where

VI = vertical interval in ft
X = a variable with values from 0.4 to 0.8
Values of X, for different zones, are shown in Fig. 7.
S = the weighted average land slope in ft per 100 ft along the length of the terrace
Y = a variable with values from 1.0 to 4.0

Values of Y are influenced by soil erodibility, cropping systems, and crop management practices. The low value is applicable for very erodible soils with conventional tillage methods, where little to no residue is left on the surface. The high value is applicable to erosion resistant soils where no-plow or mulch tillage methods are used, and which leaves a large amount of residue, minimum 1.5 tons straw equivalent, on the surface.

3.1.1.3 Vertical spacings determined by the above methods may be increased as much as 0.5 ft or 10 percent, whichever is greater, to provide better alignment or location, to miss obstacles, to adjust for farm machinery, or to reach a satisfactory outlet.

3.1.2 Level terraces for water conservation and erosion control should be spaced the same as the terraces in paragraph 3.1.1. Where level terraces are used primarily to impound water, an X value of 0.8 may be used in the spacing equation for all rainfall areas.

3.1.3 Terraces with underground outlets on deep soils are designed to control the runoff from a 24-hour, 10-year frequency rainfall. Runoff is stored in the soil and terrace channel, and discharged through the underground outlet.

3.1.3.1 The spacing is adjusted to provide water storage and an even number of trips for row crop equipment. Care should be taken to use spacings with large multiples of row widths throughout the slope range. For example, 80-120-180-240 ft of horizontal farmed intervals will permit maximum opportunity for changing row widths.

3.1.3.2 Because of the difficulty of farming steep slopes, rapid benching is desirable on slopes greater than 10 percent. The wider the spacing, the greater the amount of earth moving required to bench the land and correspondingly the wider the spacing, the greater will be the length of time required for land to bench.

3.2 Alignment. To make farming operations easier, terraces should be made parallel with long gentle curves where practicable. Smooth curves are extremely important in modern agriculture where the trend is to narrow rows and wide equipment. If terraces traverse natural ridges or natural drainage depressions, alignment and acceptable curvature become more difficult. Improved alignment, to make farming easier and to avoid point rows, is possible in most terrace layouts. Six methods are available to improve alignment, reduce curvature and decrease the area of point rows in a field. These methods may be used singly or in combination to improve terrace layouts.

3.2.1 Use turn strips on long, flat ridges which are of lesser slope than the rest of the field.

3.2.2 Vary grade along the terrace channel within limits specified in paragraph 3.5.

3.2.3 Vary depth of cut along the terrace line.

3.2.4 Shape or smooth land prior to terrace construction.

3.2.5 Vary the amount of excavation or fill along the terrace channel or ridge for steep backslope terraces. With steep backslope terraces much greater leeway is provided for improvement in terrace alignment.

3.2.6 Use channel blocks in level terraces where it is necessary to install segments of the same terrace channel on different elevations.

3.3 Capacity. Graded terraces should have enough discharge capacity to handle the peak rate of runoff expected from a 24-hour, 10-year frequency storm. In computing the capacity use an n value of 0.06 in the Manning formula.* Level terraces and graded terraces with underground outlets that impound runoff water on the field should be designed to hold the runoff volume from a 24-hour, 10-year frequency storm.

3.4 Cross section. The terrace cross section shall be proportioned to fit the ground slope, the crops grown, and the farm machinery used. Additional height should be added to provide for settlement, channel sediment deposits, ridge erosion, the effect of normal tillage operations, and a safety factor. The ridge and channel should each have a minimum width of 3 ft (0.9 m) at the design elevation.

3.5 Channel grade

3.5.1 Minimum grades should be such that ponding in the channel will not cause serious delay in field operations.

3.5.1.1 Soils with slow internal drainage – 0.2 percent

3.5.1.2 Soils with good internal drainage – 0.0 percent

3.5.2 Maximum grades will vary with the type of terrace and the purpose of the terrace. The critical condition will occur when the terraces have been recently cultivated, and there is no vegetal cover. When terraces use an underground outlet, sediment and water will be stored in the channel thus reducing velocities and allowing steeper grades near the outlet.

3.5.3 Maximum velocities should be 2.5 ft per sec (76 cm per sec) for soils with high organic content, 2.0 ft per sec (61 cm per sec) for most soils, and 1.5 ft per sec (46 cm per sec) for extremely erodible soils. Velocities are to be computed by Manning's formula using an n value of 0.03.

3.6 Outlets. All terraces must have adequate outlets. The outlet requirements vary with the different types of terraces.

3.6.1 **Vegetated outlets.** Vegetated outlets may be used for graded or open-end level terraces. The outlet must convey runoff from the terrace and rows to a point where no erosion damage will occur. It should be established in advance of terrace construction, if necessary, to insure vegetative cover.

3.6.2 **Underground outlets.** Underground outlets may be used on closed-end graded or level terraces. The outlet consists of the intake, the underground conduit and the outlet pipe. An orifice plate should be installed in each intake to control the release of runoff water when more than 2 intakes discharge into the same underground conduit. The outlet is designed to remove the volume of storage provided for each terrace in a specified interval of time. The maximum time recommended to drain a terrace is 48 hours. Shorter drain periods are often desirable depending on the inundation tolerance of the crop being grown.

3.6.3 **Soil infiltration.** Level closed-end terraces normally use infiltration into the soil in the channel for an outlet. Soil infiltration should permit draining the terrace channel within 48 hours. The channel should be level along the majority of the length between terrace blocks in order to provide the maximum soil profile storage area. The end blocks on level terraces should be designed so water will flow over the end block before overtopping the terrace ridge.

3.6.4 Combinations of soil infiltration, vegetated, and underground outlets may be used within a terracing system to minimize interference with farming operations and to maximize the conservation of soil and water.

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*The Manning Formula: $V = \frac{1.486\, r^{2/3} s^{1/2}}{n}$

where

V = velocity, feet per second
r = hydraulic radius — the area divided by wetted perimeter, feet
s = slope of channel, feet per foot
n = roughness coefficient

Rate of Discharge: $Q = AV$

where

Q = capacity, cubic feet per second
A = area, square feet
V = velocity, feet per second

SECTION 4—PLANNING AND LAYOUT

4.1 Planning on topographic map. Terrace systems can be planned with the aid of a topographic map. A topographic map with a 5 ft contour interval or a contour interval equal to the vertical interval between terraces if less than 5 ft, can be used satisfactorily. The first step is the selection of terrace outlets, waterways, roadways, and turnrows. Next locate the top terrace and bottom terrace for the field according to the design criteria using the length of slope and average field slope between the top and lower terrace. The terrace interval should be determined according to the terrace spacing formula, row spacing, machine width and length of slope between the top and bottom field terraces. The interval for one or two terraces should be set and a key terrace selected. The selection of a key terrace is dependent upon such physical factors as the location of outlets, the location of ridges, and the uniformity of the slope. Methods used to parallel terraces include: (1) items listed in paragraph 3.2; (2) divide terraces into short segments; (3) use underground outlets to parallel terraces through depressional locations; and (4) any combination of these methods. As the layout continues downhill, the selection of additional key terraces may be necessary with correctional areas provided as needed. Terrace curves should have a radius of 100 ft (30 m) or greater to be farmed with wide, high speed machinery. Grassed turn areas should be planned when sharp terrace curves are necessary. Sharp terrace curves can be reduced by varying the depth of cut in the terrace channels. Several tentative systems may be laid out on the topographic map for comparison. The best plan is selected and staked on the field for construction.

4.2 Field trail method. The same criteria and steps used to plan a terrace system on a topographic map are also used for planning in the field. However, the terraces are staked in the field as the system is planned.

SECTION 5—CONSTRUCTION

5.1 Many different machines are successfully used to build terraces. These include elevating terracers, whirlwind terracers, graders, and scrapers all powered by farm tractors. Heavy construction machinery includes the grader, elevating grader, bulldozer, and scraper. The haul distance and amount of soil to be moved are factors to consider in selecting construction equipment.

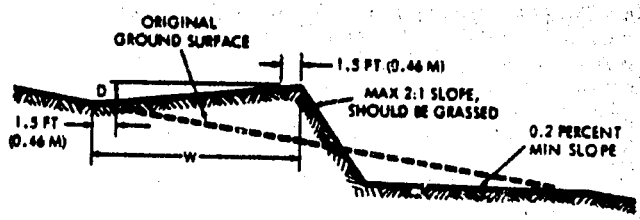

FIG. 3—STEEP-BACKSLOPE TERRACE CROSS SECTION†

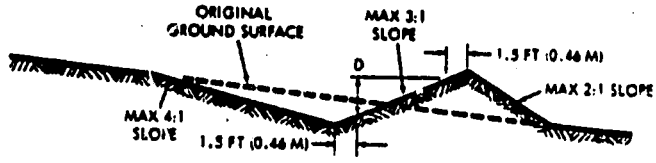

FIG. 4—NARROW-BASE TERRACE CROSS SECTION†. Slopes are the maximum allowable and should be grassed.

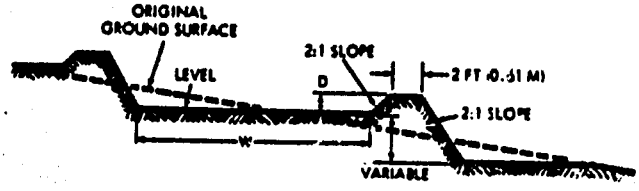

FIG. 5—BENCH TERRACE CROSS SECTION†

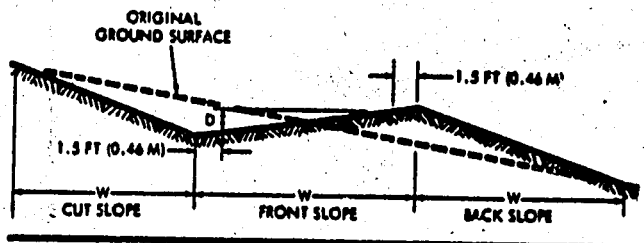

FIG. 1—BROADBASE TERRACE CROSS SECTION†

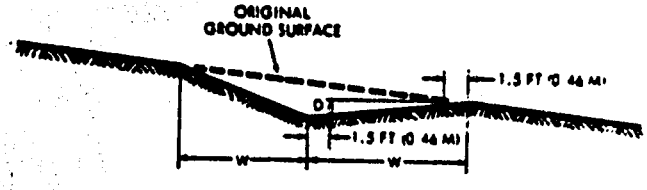

FIG. 6—RIDGELESS CHANNEL TERRACE CROSS SECTION†

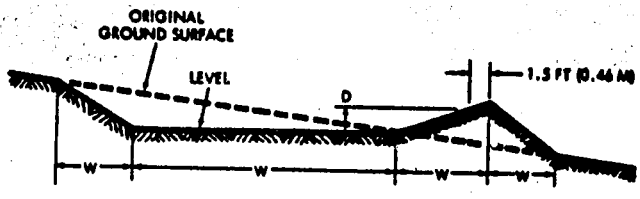

FIG. 2—FLAT CHANNEL TERRACE OR ZINGG CONSERVATION BENCH TERRACE CROSS SECTION†

†W is multiple of machinery width used to farm the land.
d is the design depth of terrace channel.

The maximum constructed slope allowed is 6:1 unless local conditions permit modification of the design criteria, or the drawings show a steeper maximum slope.

In each state, Soil Conservation Service Engineering Standards and Specifications designate channel depths, cross sectional areas and terrace slopes recommended for all locations and terrace configurations.

D-4-3

SECTION 6—MAINTENANCE

6.1 General. Adequate maintenance is mandatory to retain terrace ridge height and shape, at or near design specifications and to insure proper functioning of the system. Erosion by water and/or wind and normal tillage operations tend to fill terrace channels and reduce ridge height. Sediment deposited in the terrace channel should be removed when channel capacity is restricted, and low spots in the ridge should be filled. Periodic maintenance is usually required to insure proper functioning of the terrace system. Immediate maintenance is required after any damaging storm. Failure of one terrace frequently results in serious field erosion and failure of terraces downhill.

6.2 Maintenance during plowing. Where moldboard or disc-type plows are used for one tillage operation, normal terrace maintenance may be performed at the same time the field is plowed.

6.3 Maintenance when plows are not used. In regions where moldboard or disc-type plows are not used for tillage operations, terraces must be maintained with graders, land levelers, bulldozers or similar equipment. This type of equipment may also be used when extensive repair and maintenance are required to reshape the land prior to normal tillage operations.

6.4 Maintenance in arid and semi-arid regions. In arid and semi-arid areas, terrace maintenance should be performed during the season when wind erosion is least likely and the establishment of plant cover most likely..

6.5 Maintenance of terrace ends. The ends of graded terraces or level open-end terraces should be maintained so that runoff from the terrace channel is not restricted. The ends of closed-end level terraces should be properly closed at all times.

6.6 Maintenance of underground outlets. Sediment deposited near the intake of underground outlets and earth banked up around the intake in tillage operations should be redistributed so that the intake is located in the lowest section of the storage section of the terrace. Remove trash collected on intakes after each runoff producing storm and repair or replace damaged outlets as needed.

SECTION 7—SAFETY

7.1 Caution should be used when operating equipment on the terrace. Slopes steeper than 4 to 1 should not be farmed except with special equipment. Safety devices such as protective frames or protective canopies may be required to protect equipment operators.

7.2 The design engineer should design structures with safety in mind. He should visualize how the structures will be constructed and used. There should be information in the final design on the limitations and safety features of the structure. If hazards do exist, it should be so stated to the person or agency responsible for construction and maintenance of the structure. A record of this information should be kept on file.

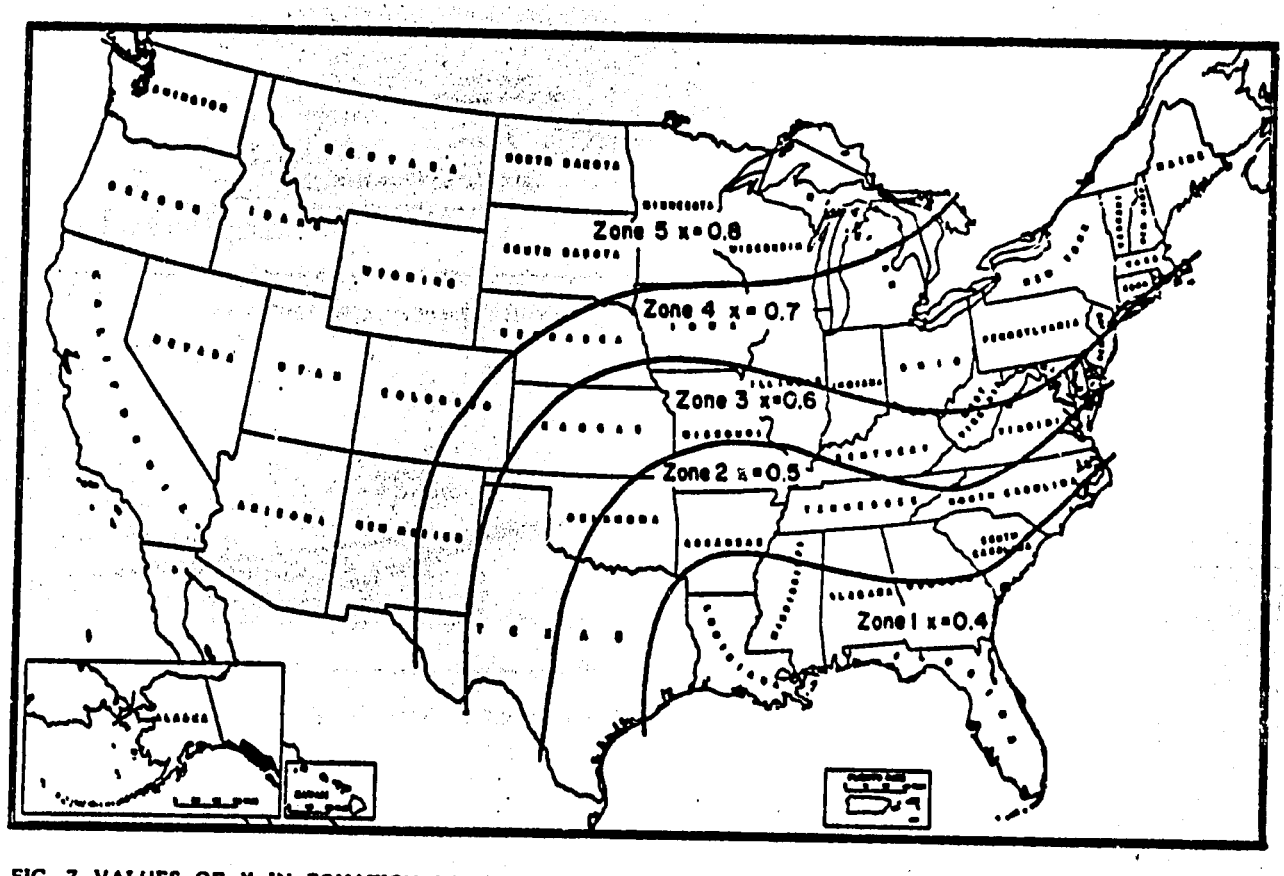

FIG. 7—VALUES OF X IN EQUATION $VI = XS + Y$ (See Paragraph 3.1.1.2)

APPENDIX E

COMMUNITY DEVELOPMENT TRAINING PROGRAM

APPENDIX E

COMMUNITY DEVELOPMENT TRAINING PROGRAM

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APPENDIX E

COMMUNITY DEVELOPMENT TRAINING PROGRAM UTILIZED BY PROYEK CITANDUY FOR RELATED TRAINING OF GOVERNMENT OFFICIALS AND LEAD FARMERS FOR THE UPPER CITANDUY WATERSHED

General

The following pages describe in some detail the work plan for the training of 38 students as a nucleus -cadre unit to understand the principles of erosion control, correct farming practices, and the structure of the Indonesian government well enough to improve their areas and teach others by their example and through newly aquired knowledge and experience.

The training program was divided into three phases and included students from five areas of activity. The four different government agencies : Kabupaten, Kecamatan, Agriculture Extension, and Proyek Citanduy were organized to support selected lead farmers in a coordinated effort for improved farming methods and erosion control practices within four Bupati Districts within the Upper Citanduy River Basin Watershed.

This training was divided into three phases involving the following categories of students:

Phase I

Four Kabupaten staff and one Proyek Citanduy Staff attended a Community Development course in leadership training in Solo, Central Java. This leadership training course lasted for seven weeks and was conducted by the Indonesia Sejahtera Foundation. This course was designed to prepare future leaders in the program and to apply their new skills in Phase III of the overall program.

Phase II

Twenty lead farmers and three extension service agents were trained for one week in erosion control methods and improved farming practices for upland farming methods at the Panawangan Pilot Demonstration Project in the Ciamis Bupati District. This instruction was organized and directed under the authority of Bupati Ciamis at the request of the Director of Rivers.

Phase III

This course combined the students and activities of personnel from Phase I and Phase II and also included an additional ten Kecamatan staff members to act as team leaders to the lead farmers and to report team activity to their newly trained Kabupaten supervisors.

The following paragraphs describe in detail the various phases of the training programs.

Phase I

Kabupaten Staff School at Solo :
YAYASAN INDONESIA SEJAHTERA
Jalan Kenanga 163
Solo, Tlp. 5127
Ir. Soetrisno, Director.

Aim

1. To build up the self confidence and awareness of the trainees of their own potential and ability to play a role in the development of their own area.
2. To prepare workers to become skilled and knowledgeable community development workers so that :
   a. they can approach and work together with communities;
   b. they are capable of developing a program in and with the community, aiming and achieving a state of greater welfare.

Length

Seven weeks

Place

Theoritical background is given in Solo, using the urban field for visits, observations, etc. Practical field work takes place in the rural area of Banjarnegara where an extensive community development program is being developed in many villages.

Trainees

A multi-professional group who have extensive field experience

Curriculum

1. Principles of Community Development
   - an introduction to C.D.
2. Development of attitudes, including
   - co-operation
   - leadership
   - ability to communicate
3. Skills required by a field worker, including :
   - survey (data collection, analysis, report)
   - ability to discuss and lead discussions
   - extension work
   - making and using visual aids
   - planning
   - program evaluation
4. Introduction to government and community organizations
5. In-depth study of specific activities, including :
   - various aspects of a community health program
   - agriculture
   - non-formal education
   - cadre programs

The curriculum is continually adjusted, based on the weekly evaluations of the trainees, the final evaluation of the trainees, and the evaluation of the training team.

Methods

Training methods include :
Introductory lectures, discussions, role play, structures, exercises, case discussions, field observation and work, workshop.

Emphasis on both theory and practice is maintained throughout the training program. For each topic trainees are exposed to a practical experience, either in the field, or through structured exercises, which is then analysed together and conclusions drawn on the basic principles invloved and the relevance in their work.

Trainees are also given the opportunity, in a field placement of two weeks, to exchange ideas with government leaders and community leaders and members in villages where community development programs have been initiated. They are also given limited opportunities (limited because of time) to practice their newly acquired skills.

Throughout the training an effort is made to create an atmosphere in the training center and in the accomodation (in homes of community people) in which trainees are encouraged to develop co-operation, leadership qualities, and other attitudes needed by a community worker.

Trainees are also divided into small groups each with a trainer acting as tutor. Individual difficulties and problems are discussed in this forum.

Trainees

1. Trainees must be sent by an organization, government or private, which will provide guidance and backing in program implementation.
2. Trainees are only received in teams of 2-3 people, so that they can eventually work as a team in the field. The support of a fellow worker with similar convictions is important when facing problems.
3. Basic education of junior secondary school (minimum), or primary school with extensive experience, is required.
4. Trainees should have background education in family welfare, community welfare, education, health or agriculture.
5. Trainees must be prepared to follow the complete course and be prepared to return and develop a program in his own area.

The total number of trainees for each course is limited to a maximum of 16, or 7-8 teams. An attempt is made by the training center to form a heterogeneous group in terms of education, work experience,and sponsoring organization (government and private).

The adaption required to fit into such a group helps promote the development of attitudes appropriate for community workers.

Guidance

Follow-up of trainees as they attempt to develop a community development program in their own areas is considered essential. On completion of training, the training center endeavours to keep in contact with the ex-trainees. Regular contact is maintained through letters, both personal and serial, a twice-monthly magazine,and activity reports,sent quarterly,to trainees.

If it is possible, and considered necessary trainer endeavour to visit trainees in their work situations.

A cost estimate for a complete program for a full class of 16 students is detailed below:

Component	Cost per student		Cost per 16 students	
	Rp.	$	Rp.	$
Community Development Training Program	137,000	330.12	2,192,000	5,281.93
Transportation	2,000	4.82	32,000	77.11
Fees	3,438	8.28	55,000	132.53
Pocket Money	12,250	29.52	196,000	472.29
Snacks	26,250	63.25	420,000	1,012.05
Estimated Total	180,938	436.00	2,895,000	6,975.90

Services furnished for tuition costs include the following :

a. Room and board for the school for dormitory style quarters and meals.

b. There are 12 staff members, typists and other leaders.

c. The organization is financed partly by the German government and partly by the German Luthern Church on a 60-40 Basis.

d. There is a mix of religions preferences among the staff of Islam, Catholic and Protestant denominations. It is not religiously oriented and is also directed and administered by a Jakarta Office. Names of Solo and Jakarta Directors are as follows :

Ir. Soetrisno, Director
Yayasan Indonesia Sejahtera
Jalan Kenanga 163, Telephone 5127
Solo, Central Java

Dr. Muki Reksoprojo, Director
Dr. Lukas Hendrata, YIS, Executive Secretary
Jalan Wahid Hasyim 153 A
Jakarta

The training center is essentially health oriented, with family planning as one of the subjects taught. There are, however, several agriculture specialists on the staff and the teaching PPL's and Kabupaten Subdistrict Officials would be within their capabilities.

Fieldwork in the villages requires that the students be housed and fed under the sponsorship of the village chief.

The Camat of the Banjarnegara area is very helpful in securing the cooperation of the villages in the area. The villages benefit from the student projects and are also anxious to learn from the students and the school.

A very definite attempt is made to teach the structure of the Indonesian government, and the ability to communicate among the various offices is also stressed to secure a cooperative effort in the solution of various problems.

Conclusions and Recommendations

1. The course material, as presented and understood, has some very positive benefits to develop the leadership talents of technically trained people.

2. The ideal is to teach well enough so that the students are able to return to their jobs, and by assignment, be able to teach others as well as define problems, plan alternate solutions, and exhibit leadership in in securing cooperative solutions to definite problems.

   The "follow up" contact several months after the course in completed is intended to check up and evaluate student mastery of Community Development principles as taught at the school.

   Letters, magazines, activity reports and personal follow-up visits to the students in their various work situations are by permission and invitation of the student's work supervisors.

   If the follow-up visits are controlled, there should be some additional benefits for review for the students of planning goals project status, and future plans for action and progress.

Phase II

Technical Staff Training and Farm Leader Training for the Panawangan and Cikawung Watershed Pilot Projects.

This phase of the training program was organized under the leadership of Mr. Rachlan, BAPPEDA Ciamis, as Chairman of the Local Steering Committee and Ir. Nurdin, Chief of the Soil and Water Conservation Section for the Forestry Ciamis District, as Chairman of the Local Organizing Committee.

A cost estimate for this training program follows :

Budget Proposal

A. Participant Expenses

1.	Meal, 23 people x 6 days x Rp. 1500,-	= Rp. 207,000
2.	Snack, 23 people x 6 days x Rp. 500	= Rp. 69,000
3.	Incidental expense/pocket money 23 people x 6 days x Rp. 250	= Rp. 34,500
4.	Field trips, 23 people x 2 x Rp. 1500	= Rp. 69,000
5.	Trip allowance, 23 people x Rp. 2000	= Rp. 46,000
6.	Materials (books, pencils, jackets), 23 people x Rp. 10,000	= Rp. 230,000
	Total (A)	Rp. 655,500

B. Teacher Expense

1.	32 teaching hours, 1 hour x Rp. 2000	= Rp. 64,000
2.	2 people, practical supervisors x 2 x Rp. 5000	= Rp. 20,000
3.	2 people, discussion supervisors x 2 days x Rp. 5000	= Rp. 20,000
4.	Trip expenses for 9 teachers x Rp. 2500	= Rp. 22,500
	Total (B)	Rp. 126,500

C. Others

1. Opening ceremony		= Rp. 25,000
2. Administration & secretary expense		= Rp. 100,000
3. Accomodation		= Rp. 50,000
4. Closing ceremony		= Rp. 25,000
5. Documentation		= Rp. 8,000
	Total (C)	= Rp. 208,000
D. Miscellaneous		Rp. 10,000
Grand total (A+B+C)		Rp.1,000,000
		(One million Rupiahs)

The following class schedule was followed and subjects were taught at the Panawangan and Cikawung Watershed Pilot Project Training Program.

Time	Monday 26	Tuesday 27	Wednesday 28	Thursday 29	Friday 30	Saturday 31
07.30-09.00 AM	Opening	5	4	7	8	10
09.30-11.00 AM	1	3	4	7	11	10
11.00-01.00 PM	1	3	2	6	-	12
04.00-05.30 PM	5	9	2	6	12	Closing

Curriculum/Topic	Total Hour	Instructor	Remarks
1. Land Use & Land Classification	4	E.C.I.	
2. Soil & Water Conservation	4	E.C.I.	
3. Dryland/Upland Farming	4	Ag. Service	
4. Livestock & Grazing	4	Animal Husbandry	
5. Natural Resources Conservation	4	Forestry/P_3RP DAS Cit.-Cisanggarung	
6. Fisheries	4	Fishery Agencies	
7. Nutrition (Gizi)	2	Public Health	
8. Extension	4	Ag. Extension Centre	
9. Bee & Honey Management	2	Forestry	
10. Tour to Singaparna	4		
11. Field Trip	2		
12. Discussion	4		

This short course of one week taught a few simple principles of erosion control structures, good terrace construction and new methods for increased food production through demonstration plot instruction and the example of a successful project.

Phase III

Technical Staff Training and Farm Leader Training

Local Community Development Training Class in Ciamis, YIS Instruction from Solo Teaching Kabupaten, Kecamatan, Agriculture Extension Service and Lead Farmers. This final please of the Upper Citanduy Watershed Training Program was also organized under the able leadership of Mr. Rachlan, BAPPEDA Ciamis, as Chairman of the Local Steering Committee and Ir. Nurdin, Chief of Section for Soil and Water Conservation of Forestry Ciamis District, as Chairman of the Local Organizing Committee.

A cost estimate for this combined training program follows

1. YIS Instructor Expense

Per Diem, 2 teachers x 11 days x 7,000 Rp./day	= Rp. 155,000
Instructor Fee, 2 teachers x 10 days x 4 hrs/day x Rp. 2000/hr.	= Rp. 160,000
Travel Expenses 4 teachers (Round Trip) x Rp. 10,000	= Rp. 40,000
Materials for Students 38 students x Rp. 5,000	= Rp. 190,000
Total Instruction Expense	= Rp. 545,000

2. Student Expense

Lodging & meals, 38 students x 11 days x Rp. 3,500/day	= Rp.1,463,000
Snacks & pocket money, 38 students x 11 days x Rp. 750/day	= Rp. 315,000
Travel, 38 students x Rp. 1,000/student	= Rp. 38,000
Field Trip Expense, 38 students x 2 trips x Rp. 1500/student/trip	= Rp. 114,000
Subtotal	Rp.1,930,000
Miscellaneous	545,000
Total Student Expense	Rp.2,475,000

Students attending the Local Community Development Class in Ciamis were selected from the Bupati District and the Proyek Citanduy as noted below:

Selection of Students

Kabupaten	Districts	Team	Kabupaten in Solo in Jan.	Kabupaten in Ciamis in April	Kecamatan Team Leader in April	Lead Farmers in April	POPs and PPLs in Panawangan in March	Lead Farmers in Panawangan in March
Ciamis	19	4	1	1	4	8	1	8
Cilacap	11	3	1	1	3	6	2	6
Tasikmalaya	9	2	1	1	2	4	0	4
Kuningan	2	1	1	1	1	2	0	2
Cit. Project	0	0	1	1	0	0	0	0
Total	41	10	5	5	10	20	3	20

Principles of Leadership Training by the Community Development (YIS) to improve student skills abilities, and knowledge through invloved activity are summarized as follows :

1. Monitor : Monitoring a development program
2. Supervisor : Movement and dynamics of existing work groups
3. Instructor : Give technical and non-technical instruction to the people
4. Motivator : Motivating the people and encouraging them so that they are eager to do something
5. Communicator : Delivering and translating ideas and new concepts and new problems from above and below
6. Executor : Assume responsibility and be able to execute the activity as planned
7. Coordinator : Attending the activities at the village level

Skill and Activities

1. Communications
2. Collecting and evaluating data
3. Taking charge of technical matters and people development principles
4. Instructing or teaching
5. Concluding and summarizing discussions
6. Adapting to certain situations
7. Presenting the plan with assurance
8. Being able to manage

Knowledge

1. Communication
2. Visual aids
3. Instruction
4. Monitoring
5. Principles of people development
6. Management
7. Group dynamics
8. Planning

Eight instruction days will be devoted to the above subjects with two days devoted to field trips where problems will be presented with suggested solutions.

APPENDIX F

FIVE YEAR PROGRAMS AND ANNUAL PLAN PROJECTS

IMPLEMENTATION PLANNING FOR CITANDUY ACTION PROGRAM

FROM

R. RACHLAN

CHIEF OF CIAMIS DISTRICT PLANNING BOARD

APPENDIX F

FIVE YEAR PROGRAMS AND ANNUAL PLAN PROJECTS

IMPLEMENTATION PLANNING FOR CITANDUY ACTION PROGRAM

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FIGURE F-2 Annual Project Implementation

FIGURE F-3 Five Year/Programs Annual/Projects Implementation Planning

ORGANIZATION FOR THE UPPER CITANDUY BASIN DEVELOPMENT

OUTLINE/MASTER PLAN

1. Citanduy Project/ECI/Counterparts (as one body) is to set up the Outline/ Master Plan for the Upper Citanduy Basin Development. (Based on : (1) Loan Agreement between USA and the Republic of Indonesia; (2) The theory of One River System One Plan; (3) The interdependency of the lower watershed with the upper watershed).
   Citanduy Project/ECI/Counterparts is responsible to the Citanduy Project Steering Committee.

2. In the process of creating the Outline/Master Plan, Citanduy Project/ECI/ Counterparts works in coordination with the Bupatis (of Ciamis, Tasikmalaya, Majalengka, Kuningan, Cilacap) in social, economic and political matters, and with the Greening and Reforestation Planning Office for Citanduy and Cisanggarung Watershed in land and soil conservation measures.

3. Each Bupati designates the Kabupaten Development Planning Board to assist Citanduy Project/ECI/Counterparts in the process of setting up the Outline/ Master Plan. (Especially in (1) Providing socio-economic and political, cultural data; (2) Synchronizing the technical aspects with the people aspiration; (3) Ensuring the implementation of top-down and bottom-up approaches on request).

4. The District Planning Board coordinates the Bupati's Special Staff and Technical Staff, Subdistrict Officials and Village Heads.

5. On request of the Citanduy Project/ECI/Counterparts, the District Development Planning Board could provide assistance in :
   a. Collecting data/information required.
      Blank lists of data should be provided by the Citanduy Project/ECI/ Counterparts.
   b. Collecting people aspiration.
   c. Visiting places in reconnaissance and survey.

6. On request of the Citanduy Project/ECI/Counterparts, the District Development Planning Board could make a contact with the Provincial Planning Board.

7. The Citanduy/ECI/Counterparts could designate one of the District Development Planning Boards (Tasikmalaya, Ciamis, Kuningan, Cilacap, Majalengka) as the coordinator in providing points 5a, 5b, 5c.

8. The District Development Planning Boards of Tasikmalaya, Ciamis, Kuningan, Cilacap, and Majalengka work in coordination with the Greening and Reforestation Planning Office for Citanduy and Cisanggarung Watershed.

9. Discussions in the process of creating the plans are held by the Citanduy Project/ECI/Counterparts where the Planning Boards of the five Districts act as one group.

10. All District Development Planning Boards receive the Rough Draft for further study and take an active part in the creation of the Final Draft of the Outline/Master Plan.

11. The Final Draft of the Outline/Master Plan agreed upon by the Citanduy Steering Committee will be received by the District Planning Boards and be used as reference/basis for the setting up of each District Upper Watershed Five Year Development Plan and Annual Plan.

THE FIVE YEAR/PROGRAMS AND THE ANNUAL PLAN/PROJECT

(IMPLEMENTATION PLANNING)

F O R

THE UPPER CITANDUY ACTION PROGRAM

A. Five Year Plan

1. Based on Outline/master Plan for the Upper Citanduy Basin Development agreed upon by the Citanduy Project Sterring Committee, the District Planning Boards of Tasikmalaya, Ciamis, Kuningan, Cilacap and Majalengka in coordination, create a synchronized Five Year Plan for their respective District.

2. The Citanduy Project/ECI/Counterparts and Greening and Reforestation Planning Office give technical advices and informations to ensure an efficient and effective plan.

3. Each District Planning Boards submits the plan to the Bupati.

4. The Bupati together with the District People Representative Body legalize the plan.

5. The Bupati submits the plan to the Governor for Legalization.

6. The Governor uses the District Five Year Plan as reference for the setting up the Provincial Five Year Plan which has to be legalized by the Provincial Representative Body.

7. The Governor submits the Provincial Five Year Plan to the Minister of Interior and the President to be used as reference in the setting up ot the National Five Year Plan.

B. Annual Plan

1. Based on the Five Year Plan, the District Development Planning Boards of Tasikmalaya, Ciamis, Kuningan, Cilacap and Majalengka, in coordination, create a synchronized Annual Plan for their respective District.

2. The Citanduy/ECI/Counterparts and Greening and Reforestation Planning Office give technical advices and informations to ensure an efficient and effective Annual Plan.

3. The Annual Plan consists of projects that should be done and financed by :
   a. The Department of Public Works (Dams, Checkdams).
   b. The Presidential Instruction Projects (Reforestation and Greening, Checkdams).
   c. Provincial Administration (Greening Projects, Horticulture, Animal Husbandry, Fishery).
   d. District Administration (Greening Projects, Horticulture, Rice, Animal Husbandry, fishery).
   e. Village Administration and Farmers Association (complementing and supllementing the INPRES and District Projects).
   f. Special Presidential Assistance Projects (Animal Husbadry etc.).
4. Coordinated by the District Development Planning Board, the agencies involved propose parts of the annual projects within their respective authority to their higher level agencies (Provincial and National level) to be operated and financed sectorally.
5. The District Development Planning Board proposes all kinds of sectoral projects to the Provincial Development Planning Board and further forwarded to the National Development Planning Board, including the projects that should be the Presidential Instruction Programs/Project.
6. The District Development Planning Board proposes the projects that should be done and financed by the District Administration to the Bupati. The Bupati and the District Representative Body legalize the projects.
7. The District Development Planning Board makes contact with the Subdistrict Officials and Village Heads to plan village and farmers association projects.
8. a. The Sectoral/Departments' projects are stated in the National Annual Budget.
   b. The Presidential Instruction Projects are stated in the District Annual Budget.
   c. The Provincial projects are stated in the provincial Annual Budget.
   d. The District projects are stated in the District Annual Budget.
   e. The Village projects are stated in the Village Annual Budget.
   f. The Special Presidential Assistance Projects are stated as Provincial and District Agencies projects.
   g. The Farmers Association projects are reported by the Village Heads via Sub-District Officials to the District Development Planning Board.

ANNUAL PROJECT IMPLEMENTATION

A. Sectoral Projects

1. Sectoral Project are done by Special Agencies of Provincial Technical Agencies. Provincial Agencies usually delegate the implementation of the projects to the District Agencies.

2. The Departments inform the Governor about the projects.

3. The national Development Planning Board assisted by the Provincial Development Planning Board monitors or gives correction on the way to the Sectoral Projects. In certain cases (but usually all the time), the District Development Planning Board has to record and report the progress of the projects to Provincial Development Planning Board.

B. Presidential Instruction Projects

1. The District Administration/Executives implement the INPRES programs/ projects.

2. The Provincial Development Planning Board assisted by the District Development Planning Board monitors/gives correction on the way to the projects.

3. The Subdistrict officials, Village Head and Village Development Planning Board has to record and report the progress of the projects.

C. Provincial Projects

1. Provincial projects are implemented by the Provincial Technical Agencies or the District Administration. Provincial agencies and the Bupati usually delegate their authority to the District Technical Agencies.

2. The Governor informs the Bupati about the projects.

3. The Provincial Development Planning Board assisted by the District Development Planning Board monitors/gives correction on the way to the Provincial projects.

4. The District Development Planning Board records and reports the progress of the projects for the Provincial Development Planning Board.

D. District Projects

1. District projects are implemented by the District Technical Agencies.

2. The Bupati informs the Subdistrict Official about the projects.

3. The District Development Planning Board assisted by the Subdistrict Officials, Village Head and Village Development Planning Board monitors the projects.

4. The Village Development Planning Board records and reports the progress of the projects for the District Development Planning Board.

E. Special Presidential Assitance Projects

1. Depending on the volume and kind of the projects, the projects are implemented by the Bupati who delegates his authority to his Technical Agencies.

2. The same as point D.2, D.3, D.4.

F. Village Projects

1. Village projects are done by the Rural Social Committee.

2. In the implementation of the projects, the Rural Social Comittee gets technical advice from the District Technical Agencies.

3. The Village Development Planning Board monitors the projects and reports the progress of the projects to the District Development Planning Board.

G. Farmers Association Projects

1. Farmer Association projects are complementing and supplementing the or Provincial, or INPRES, or District, or Village Irrigation projects, or the combination of them.

2. The Village Development Planning Board reports the progress of the projects to the Village Head and the District Development Planning Board.

H. Others

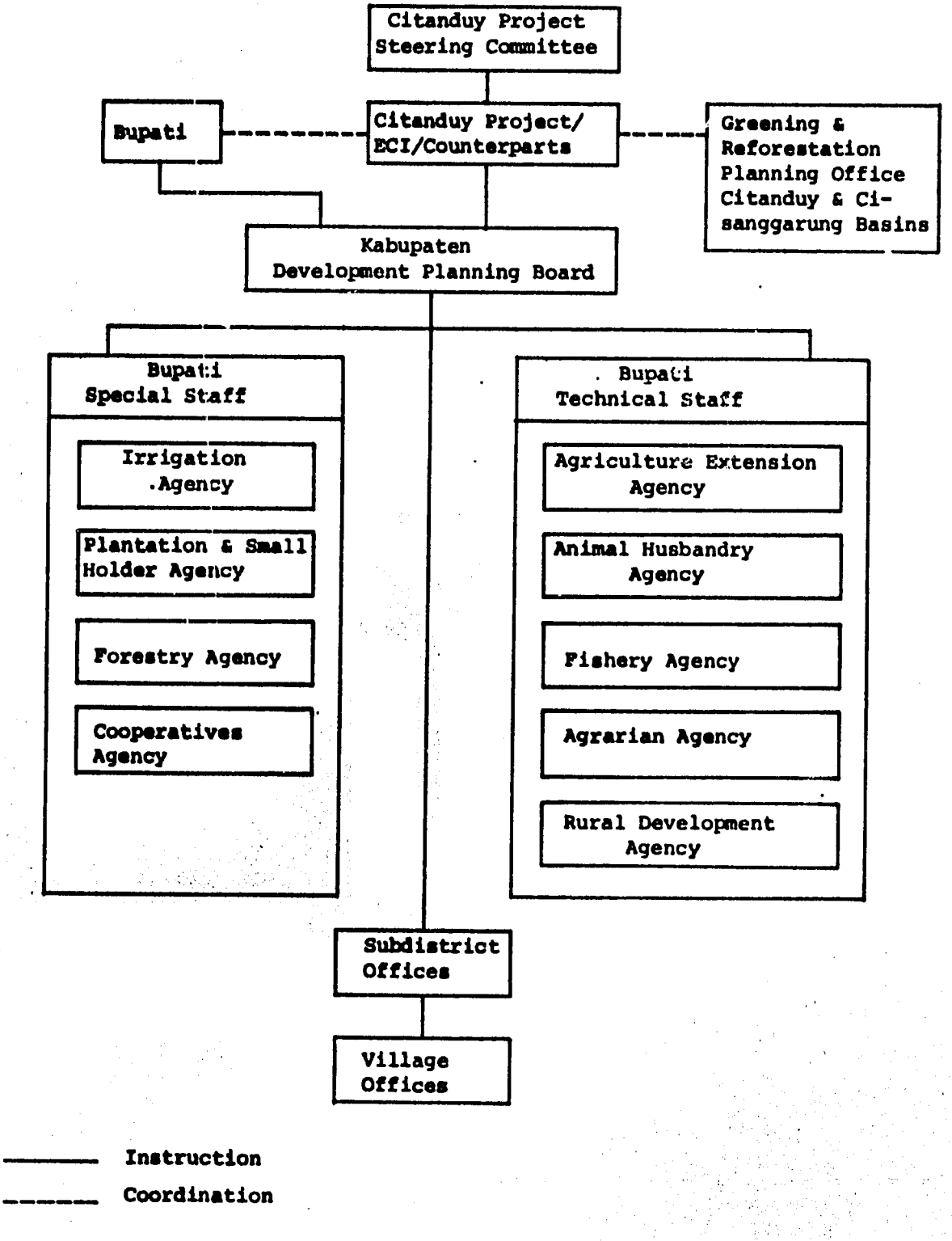
The Bupati could ask technical assistance/advice from any agencies both Governmental and Private if need be.

ORGANIZATION CHART FOR THE SETTING UP

OF

THE UPPER CITANDUY BASIN DEVELOPMENT

OUTLINE/MASTER PLAN



ANNUAL PROJECTS IMPLEMENTATION

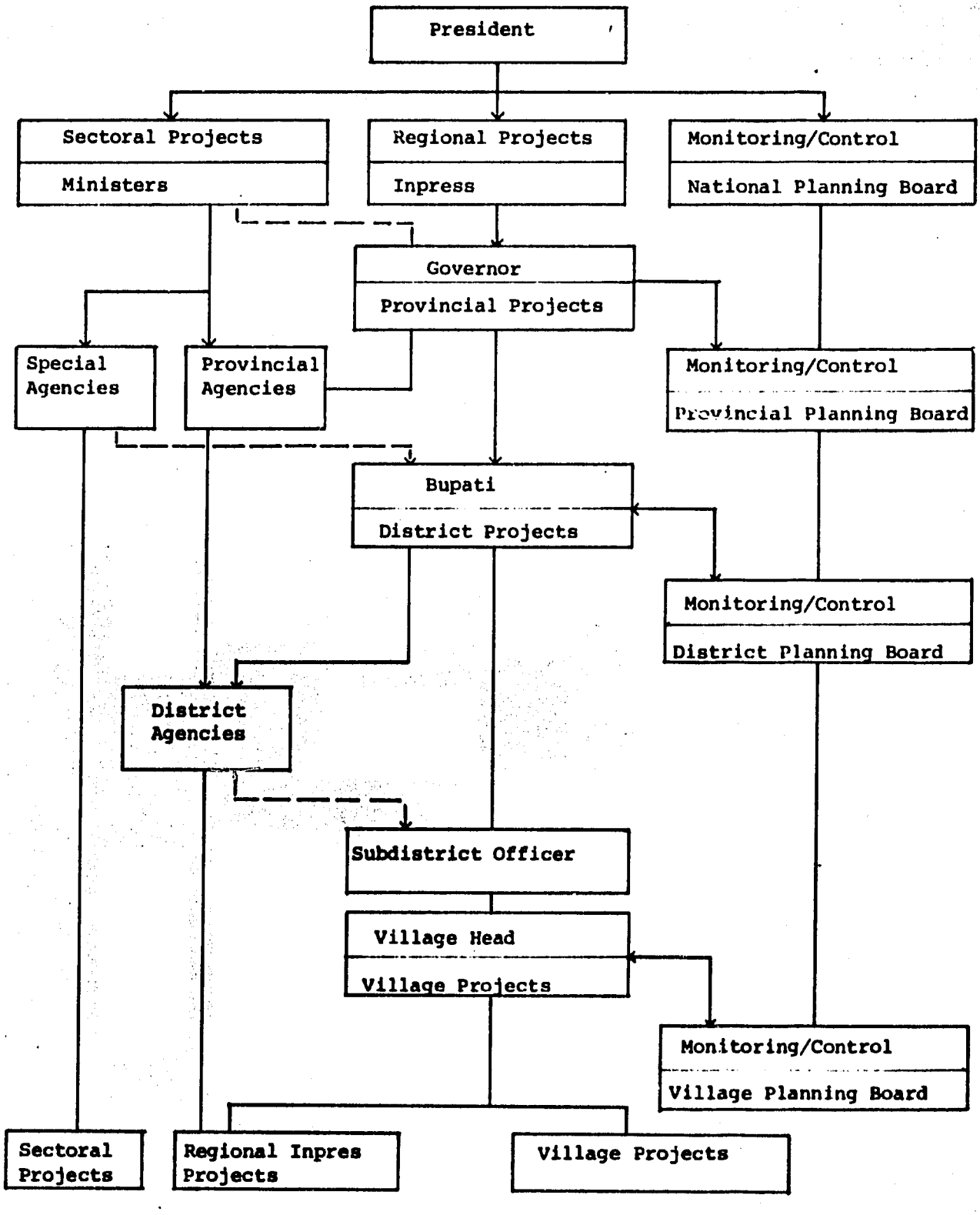
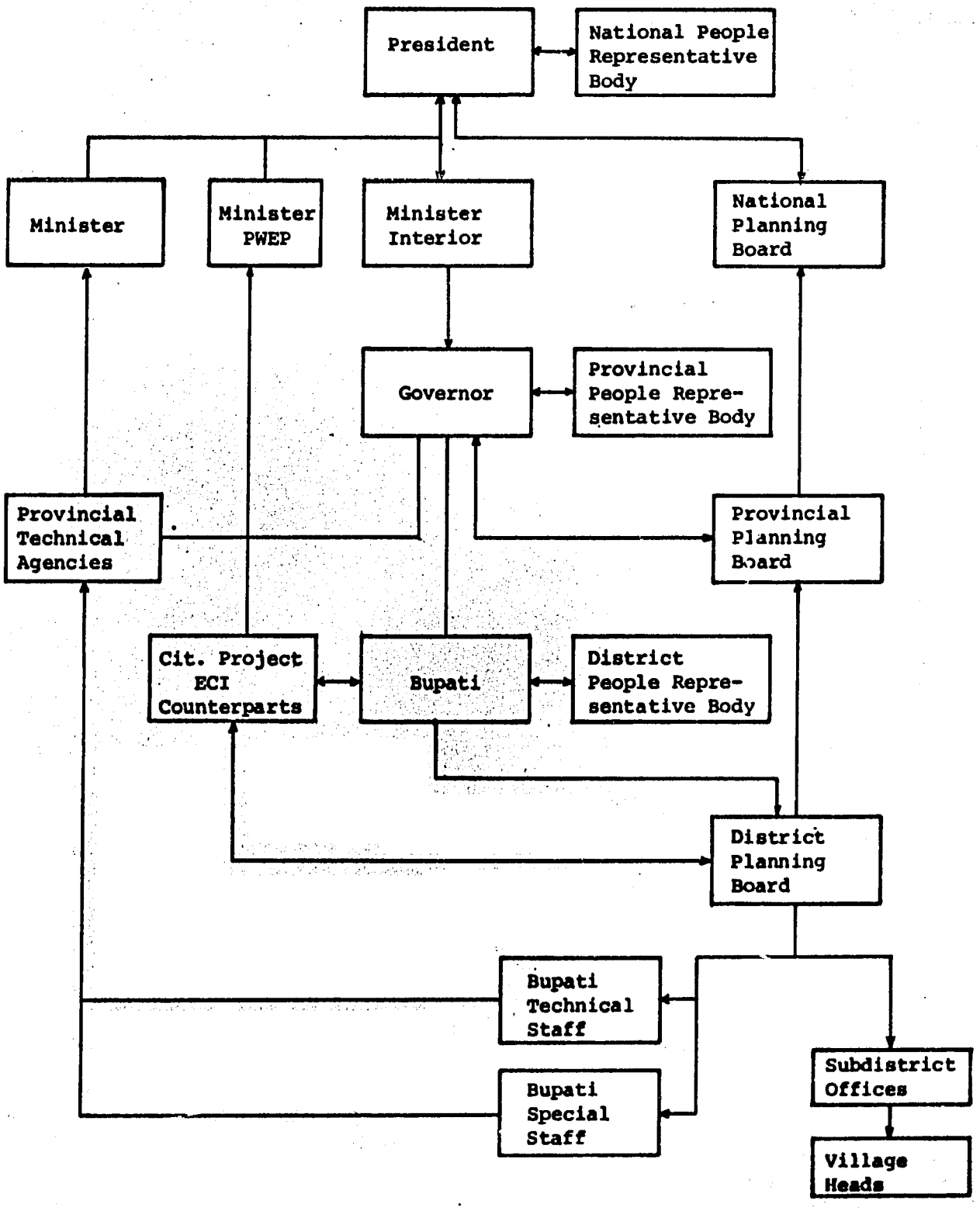


FIGURE F-3

FIVE YEAR/PROGRAMS

ANNUAL/PROJECTS

IMPLEMENTATION PLANNING



APPENDIX G

WATERSHED MANAGEMENT ORGANIZATION

DR. HERBERT C. FLETCHER MEMORANDUM TO FILES

May 9, 1979

MEMORANDUM: 1195/037/1979

To : File

From : Dr. Herbert C. Fletcher

Subject : Watershed Management Organization

On Tuesday May 1, 1979 I met with Dr. Emil Salim, Minister of Environment, and Dr. Herman Haeruman regarding the organization chart I have developed for the Provincial and Kabupaten levels.

We spent considerable time reviewing the concept of starting at the farmer level and developing the present Government structure so it could carry out an expanded upper watershed land and water development program.

I explained that it was my observation that unless a farmer felt he had some input into doing a job he was not inclined to accept the assistance as part of his operations. It was something imposed upon him by his superiors and it was their responsibility to maintain or care for the enterprise. A good example is the greening program. After the terraces are built rarely do farmers maintain them. They must participate on their own, and want the terrace. Incentives can be given but these should not buy the farmer.

I pointed out that several new positions would be needed to coordinate existing Government programs with the needs of developing a multiple use plan at the farmer level. We discussed why these new positions would be needed not an existing position or some one that already has a full time job. As the program expands the recommended new positions will be essential to a coordinated program.

We have learned from Solo, Majalengka and Panawangan Projects that the technical help, at the farmer level, is no better than the administrative program that supports it. This is the major reason for developing a governmental structure that comes directly under the accepted chain of command which is from the Provincial and Kabupaten levels.

It has been recognized for some time that the upstream farmers are not managing their resources according to the capabilities of the land. They are not aware of their own problems and the erosion is rapidly destroying the soils' ability to provide an adequate living for their families. Most importantly the farmers need advice and help on developing a multiple use type farming enterprise that will control the soil and water problems and improve their resources instead of destroying them.

It was pointed out that Government had provided considerable help in various ways to farmers but that the programs were not coordinated and lacked focused direction. The suggested organization was designed to accomplish this objective. The program provides a day to day soil and water resource coordinator at the Provincial levels. His assignment would be to see all programs on a Provincial level are coordinated toward the Kabupaten level soil and water development. At the Kabupaten level the day to day coordinator would bring all technical help and facilities, budgets and any other help for the farmer together and focus it to the various Kecamatan levels. The day to day coordinator provides the multiple use plans for farmers. Based on these plans, he provides the implementation of these plans on the hydrologic units. The hydrologic unit is a group of farmers that agree to manage their soil and water resources according to the multiple use plan developed with the farmers and the conservationist.

As presently structured the agricultural administration, including the forest service, is not providing the kind of personnel or expertise which will be needed to prepare and implement a multiple use plan. Soil capabilities and water management are not fully considered.

Dr. Salim had many suggestions and helps to offer and suggested that people and positions could be shifted to meet some of the needs. Some new positions will be required to start the program. He felt education and training was very essential and would require much time to train the technicians and coordinators as well as educating the farmers to what the program is should do and the farmers will participate.

The education and training positions recommended were very essential to the entire program. Dr. Salim felt that at the village level the village association then can fuction as the training center for all educational programs and could be used to train farmers in the new land and water development program.

APPENDIX H

LAWS AND LEGISLATION THAT APPLY TO SOIL CONSERVATION ACTION PROGRAMS

APPENDIX H

LAWS AND LEGISLATION THAT APPLY TO SOIL CONSERVATION ACTION PROGRAMS

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APPENDIX H

COPY OF LETTER FROM MR. SOEDIRO LEGAL OFFICER OF THE DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT

Jakarta, May 26, 1977

Our ref. : H. 3/1/3

Subject : Laws applied to an action program on soil and water conservation works.

Dear Sir :

Referring to your letter of May 4, 1977, concerning the subject as mentioned above, we attached herewith a summary form of the laws requested consists of :

1. The Basic Agrarian Law No. 5 year 1960.
   This law provides for State control over soil conservation, development and utilization.
2. The Basic Forestry Law No. 5 year 1967.
   This law provides for State control over forest protection, administration and utilization.
3. The Water Resources Development Law No.11 year 1974.
   This law adequately provides for State control over water resources conservation, development and utilization in line with the principles of the Basic Agrarian Law No. 5/1960.
4. Instruction of the President R.I. No. 1 year 1976, concerning the synchronization of the implementation of the tasks on the matter of forestry, mining, transmigration and public works.
5. Instruction of the President R.I. No. 8 year 1976, concerning reforestation and greening movement assistance program to Local Government.

We hope this information will be useful on your matter.

Sincerely yours,

Soediro

Legal Officer

Directorate General of Water Resources Development Ministry of Public Works and Electric Power.

CC : Assistant Director General of Water Resources Development.

In connection with the implementation of soil conservation works the following legislation might impede or have a direct bearing on its application.

1. <u>The Basic Agrarian Law No. 5/1960 of 24 September 1960</u>

The essential points :

1.1. Soil, water and space, including the natural resources contained therein, shall be controlled by the State (Section 1 and 2).

1.2. State control as mentioned above empowers the Government to (Section 2) :

1.2.1. regulate and manage the utilization, supply and maintenance/ conservation soil, water and space.

1.2.2. determine and regulate relationships among individuals with soil, water and space.

1.2.3. determine and regulate legal acts among individuals in respect of soil, water and space.

1.3. The power of the Government creates various right of soil surface, which means the right on piece of land given and or owned by individuals, corporation or Government agencies at the central as well as regional level (Section 4).

1.4. Land rights consist of (Section 16) :

1.4.1. hak milik (land ownership right).

1.4.2. hak guna usaha (land utilization right).

1.4.3. hak guna banguman (right build on land).

1.4.4. hak pakai (land use right).

1.4.5. hak pengelolaan (right to manage land).

1.4.6. hak sewa (land lease right; from the land owner to sugarcane plantation firm or other plantation firm with annual crop).

1.4.7. hak membuka tanah (land clearing right).

1.4.8. hak memungut hasil hutan (right to take fruit of the forest).

1.4.9. other land right which will be determined by law f.e. : Water use right, land pawn right etc.

1.5. All of land rights have social function. It means there is no absolute land right and the use must be in accordance with the situation and characteristic of the right for the welfare and prosperity of the owner himself as well as of the people and State (Section 6).

1.6. The protection of the land, including the cultivation and prevention from damages, is the undertaking and responsibility of each individual, corporation or agency which has relationship with the land. Anyone who infringes this provision shall be liable to detention (minor offences) ---- (Section 15).

1.7. Land right can be cancelled if it's necessary for public interest as well as Nation and State, by giving the proper compensation to the owner under procedures of Law No. 20/1961 (Section 19).

1.8. The Government manages land register under procedures of Government Regulation No. 10/1961 (Section 19).

2. <u>The Basic Forestry Law No. 5/1967 of 24 May 1967.</u>

The essential points :

2.1. Forest is an area with trees and as a whole represent a living alliance of natural biology and natural environment, and is decided as forest by Government (Section 1 para 1).

2.2. Forest region is a certain area apointed by the Minister as permanent forest. There are two kind of forest regions (Section 1 para 4) :

2.2.1. Forest region which need to be preserved as permanent forest.

2.2.2. Unforest region which need to be reforested and preserved as permanent forest.

2.3. Forest including natural riches contained therein shall be controlled by the State (Section 5 para 1).

2.4. To secure the maximum and multipurpose utilization of forest the Government in the frame-work of land use planning makes a general planning of utilization of forest and covers the following matters (Section 6) :

2.4.1. In relation with water management : flood and erosion control and soil conservation.

2.4.2. Increasing the production and marketing of forest products to fulfill public needs especially for development, industry and export.

2.4.3. Resource of various profession for the people who lives within the forest area.

2.4.4. Protection of natural biology and natural environment for the interest of knowledge, culture, national defence, recreation and tourism.

2.4.5. Providing land for transmigration, plantation/estate, and cattle breeding.

2.4.6. Other matters which will be useful for public.

2.5. Forest administration is needed to reach optimum and multipurpose utilization of forest, which covers, the following activities (Section 9)

2.5.1. to arrange and execute protection, cultivation/utilization and greening movement.

2.5.2. to manage forest conservation for forest tourism, (wild) animals and hunting.

2.5.3. to execute forest inventory.

2.5.4. to execute survey on forest, forest product and social economy of the people who lives within the forest area.

2.5.5. to arrange guidance and education in forestry.

2.6. The Government can delegate apart of it's owner on forestry management to Local Government with Government Regulation (Section 12).

2.7. Forest protection covers the following efforts (Section 15).

2.7.1. to limit and prevent forest and forest product from damages caused by human and cattle activities, burning and plant diseases.

2.7.2. to protect the state right on forest and forest product.

3. The Water [illegible] Law No. 11/1974 of 20 December 1974.

The essential points :

3.1. Water and water resources, including the natural riches contained therein have a social function and shall be utilized for the welfare and prosperity of the People (Chapter II Article 2).

3.2. Water and water resources including the natural riches contained therein shall be controlled by the state.

State control gives the Government some powers (Chapter III article 3).

3.3. The Government may delegate it's power to agencies at the control or regional level or to specific bodies in accordance with conditions and procedures as specific by Government Regulation (Chapter III Article 4).

3.4. The Minister in charge of water affairs shall be responsible and empowered to coordinate all matters relating to general and project planning and to the supervision, exploitation, maintenance, conservation and utilization of water and water resources, for the interests of the Departments and agencies concerned (Chapter III Article 5).

3.5. Water, water resources, waterworks and structures shall be permanently conserved and protected, to this purpose the following shall be undertaken :

a. soil and water resources conservation

b. the control of harmful effects of water and water resources and on the environment.

c. the control of water pollution harmful to water uses and to the environment.

d. the conservation and protection of waterworks and structures in order to ensure their permanent operation (Chapter VIII Article 13).

3.6. All provisions of the existing water legislation not contradictory to this Law shall continue in force as long as, and until new regulations are issued as provided in this Law (Article 16).

f.e. General Water Regulation (A.W.R.) year 1936.

Provincial Water Regulation (P.W.R.) year 1939.

4. <u>Instruction of the President R.I. No. 1 year 1976.</u>

The essential points :

4.1. Instruction to the Minister of Interior Affairs, Minister of Agriculture, Minister of Mining, Minister of Manpower, Transmigration and Cooperation, Minister of Public Works and Electric Power, to synchronize the implementation of tasks on the matter concerning forestry, mining, transmigration and public works.

4.2. The Governor/Provincial Head has responsibility to secure the providing of land for construction works and undertake the implementation of conservation of soil, water and environment in his jurisdiction (Annex VII point 23).

4.3. The conservation works mentioned above consist of :

4.3.1. regulate/manage the utilization of land.

4.3.2. planting compulsory/reforestation/greening movement.

4.3.3. conservation and protection of land and prevention from erosion.

4.3.4. the control of forest cutting/deforestation.

4.3.5. the control and prevention of air and water pollution.

4.3.6. protection against harmful effects of water resources (Annex VII point 24 ii)

4.4. For implementing conservation works, Governor/Provincial Head must take attention to technical considerations given by the concerned Department (Annex VII point 24.ii).

4.5. If there is an individual right on a piece land, on which conservation works will be implemented the Government must compensate the land owner before execution.

5. Instruction of the President R.I. No. 8 year 1976 on : Greening Movement and Reforestation Assistance Program

The essential points :

5.1. Instruction of the Minister of Interior Affairs, Minister of Agriculture, Minister of Finance and State Minister of Economy, Finance and Industry, to execute greening movement and reforestation assistance program for the fiscal year 1976/1977 in the critical area within a river basin.

5.2. Local Government/Province execute reforestation and supplies seed and seedling for reforestation and greening movement. Regional Government/ Kabupaten executes greening movement (Annex, Article I Section 1).

5.3. - Greening movement means the annual plantation of trees or grass or to build erosion control structure (check dams) outside the state forest area, or in other areas, where based on land use planning not for forest, is set up.

- Reforestation means the planting or rejuvenating trees or other plantation in state forest area and other areas, where based on land use planning for forest, is set up. (Annex, Article I Section 2).

5.4. The purpose of this program is to secure the continuous function of natural resources (soil, forest and water), especially in the critical areas, which according to hydro-crology observation can endanger the continuous development within or outside the river basin (Section 3).

5.5. The Minister mentioned above get the power to decide (Section 5) the following items :

a. Which Province will get reforestation assistance.

b. Which Kabupaten will get greening movement assistance.

c. Location and area for greening movement and reforestation, and the related cost.

d. Location and area for seedling and the related cost.

5.6. Supply of fund for this Program will not vanish or diminish Local Government's undertaking to increase and coordinate the execution of greening movement and reforestation, which financed from other resources, by Local Government, Plantation Cooperation, Forestry Unit and others including forest use right holder, outside the areas of this program (Section 11).