REPUBLIQUE ISLAMIQUE DE MAURITANIE

Ministere du Développement Rural

RECLAMATION AND CONSTRUCTION OF 15 DAMS IN THE BRAKNA & GORGOL REGIONS

STUDIES FINANCED BY USAID

CONTRACT N° AID 682 - C O - P M & R - 80-01

PROJECT : E B U 2

TECHNICAL STUDIES

GENERAL REPORT

A. SYNTHETIC REPORT

B. P. 321
NOUAKCHOTT

JULY 1980

RELLAMATION AND CONSTRUCTION OF 15 DAMS IN THE BRAKNA ET GORGOL REGIONS

GENERAL REPORT

A - SYNTHETIC REPORT

B - TOTAL COST ESTIMATE

C - SPECIFICATIONS

D - HYDROLOGY

E - HYDROGEOLOGY

F - SOIL SYRVEY

G - TECHNICAL COMPUTATIONS

H - STANDARD DRAWINGS

CO.NA.DE.R U S A I D

DESIGN OF FIFTEEN DAMS
IN THE BRANNA AND GORGOL REGIONS

MAIN FEATURES OF THE DESIGN .

1. CHOICE OF DIMENSIONS .
2. SELECTION OF DAM TYPE .
3. APPURTENANT STRUCTURES .

JUNE 1980

1. CHOICE OF DIMENSIONS

Three criteria were employed in determining the dimensions of the projected dams :

a. comparison between available water volume and available storage ;

b. pedological datas ;

c. sociological aspects .

The first criterion is the most important . Surveying provides for each dam a curve V(H) : stored volume versus water level . Hydrology on the other hand yields the volume of average yearly runoff Vd . Let now Vmax be the maximum storable volume in the reservoir . The water level selected will be then the level H1 such that the stored volume for this level H1 equals the lesser of the quantities Vd and Vmax :

$V(H1) = \mathrm{Inf}\ (Vd\ ,\ Vmax)$.

The second criterium allows to exclude some pedologically unsuitable areas . In the fifteen dam basins under study , the lowest parts are richest in alluvia and hence most fertile , whereas the higher parts are often covered with stony "reggs" . Let Hmax be the highest water level suitable for runoff agriculture . The water level selected is H2 , which equals the lesser of the quantities H1 determined above , and Hmax .

The third criterion , sociology , was not systematically resorted to , but only when it appeared that the water level determined by using the two first criteria yielded economically unacceptable results . Normally this criterion means adjusting the reservoir area to the actually cultivable area taking into account the available agricultural manpower .

Actually , the sociological study performed during the identification studies (1978) gives no quantitative information . Finally , we used this criterion only for the site of Ameira , near which we met no farmer during the campaign 1979 - 1980 .

Once we had thus determined the normal water level , the dimensions of the structures were computed as follows :

- the elevation of the spillway - if there is one - equals the normal water level ;
- the elevation at crest of embankment dams equals the normal water level , plus the water height above spillway (generally 0.50 m) plus 1 m freeboard ; could be too high
- for concrete dams , the freeboard is reduced to 0.30 m above highest water level ;
- finally , for total storage dams , the freeboard is 1.00 m above normal water level .

The dimensions of structures , computed by application of these rules , are given below , § 2 .

2. Selection of dam type

2.1. We considered three dam types for the present project :

(a) embankment dams with spillway
(b) overflow dams
(c) total storage embankment dams .

$Q = CLH^{3/2}$

$(.5)^{3/2} = .3536$

$(1.5)^{3/2} = 1.8371$

$(1.0)^{3/2} = 1.000$

(a)- Compacted embankment dams are constructed using machinery , with compaction by sheepsfoot rollers to 90 % of the modified Proctor optimum . The results of the geotechnical study having shown the availability of good quality clayey material , we selected the following embankment slopes : 2/1 downstream and 2.5/1 upstream . why?

Taking into account the low height of the structures , we performed no stability computations for these dams , following the recommendations of USBR (Design of Small Dams , sec.133) .

The spillways have the same characteristics as the overflow dams described in (b) below .

A standard section of embankment dams under project is to be found in the drawings . All appurtenant structures , I.e. cutoff trench , toe drain , outlet works ,upstream and downstream protections , are described § 3 below .

(b)- Overflow dams are of two types :

1. Concrete dams
2. Compacted embankment dams protected by gabions ?

(b1)- An example of concrete dam is to be found in report N°6 (Moudi Founti dam) . The shapes were chosen in order as to simplify as much as possible forming and placing problems for concrete ; moreover the selected shape allows fractioning the overfall height , thus contributing to energy dissipation .

The dam is continued below foundations by a cutoff wall which either reaches the sound bedrock when the latter outcrops at low depth , or is computed by application of Lane's rule as modified by Terzaghi .

The protection against scouring downstream is ensured by gabions , on 2 m length at least . One gabion placed vertically forms with the horizontal gabion a stilling basin , as well as providing an abutment for the latter . Its elevation equals the average elevation of the area downstream from the dam .

In the ouadi bed , riprap will be placed on 10 m length . Whenever possible , the floor downstream from the dam is thus set to a uniform level . However , when the topography requires it (example : case of Moudi Founti) parts of the floor will have to be set at higher levels . In such a case , a training dyke in gabions , perpendicular to the dam axis , is designed for preventing an overflow to occur from the upper floor to the lower floor . This training dyke has a length varying from 10 to 20 m generally . (Example : report N°6 , Moudi Founti , parts 03 and 06).

(b2)- Compacted embankment dams protected by gabions . Why?

This type of dam was selected several times , either as an overflow dam (4 dams) , or as aspillway for an embankment dam . (3 dams) . An example of this type of structure is to be found in report N°4 (Ameira) .

These dams are designnd as compacted embankment dams covered with an unweaved semi-pervious membrane acting as a filter (of the BIDIM type) , protected :

- downstream , by gabions , size 2 x 1 x 0.5 m , with partial overlapping ;
- upstream , and over crest , by a continous gabion ("mattress" gabion) , thickness 20 cm .

The structure is equipped with a cutoff trench , the dimensions of which are computed by application of the Lane-Terzaghi rule .

The protection downstream is ensured by gabions , with the same disposition as for concrete structures in section (b1) above .

The main advantages of this type of structure are as follows :

1- good behaviour on pervious foundations . A stability computation by Fellenius'method (2 circles upstream , 5 circles downstream) was performed using a program on a HP 41 C computer and yielded safety coefficients of 2.35 upstream and 2.37 downstream (see computational note) . For this computation , performed on the example of the Mint Aouaou dam , we used the average characteristics recommended by USCS for the soil types identified during the geotechnical studies , i.e. types ML and ML-CL . Indeed , the reference terms of the geotechnical studies allowed this type of classification , but did not provide for determining the values of shearing strength and angle of internal friction .

2- in the case when topography demands a very long dam (4: Ameira , 1: Çag el Mohor) , building an overflow dam in gabions (i.e. without freeboard) allows an important cut-down in earthwork volumes .

(c)- Total storage embankment dams

For 3 sites we selected total storage dams , i.e. without a spillway . However on one of these dams (10 : Toueiz Krett Tagatt) there exists a natural sill which may act as an emergency spillway .

Two rules were decisive in selecting this type of structure :

1. Small watershed area :

Boussouedilif	: 9 km^2
ToucinKrettTagatt	: 11 km^2
Lemaoudou	: 34 km^2 .

2. Topography allowing easy construction of a dam capable of storing the total fifty years annual runoff , with one meter freeboard .

These total storage dams provide a safe and economical solution , the only appurtenant being the outlet works .

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The next page shows a synoptical table allotting the projected dams to the various types described in sections (a) , (b) and (c) above . Some dams (3 : Toucidima , 10 : Toucin Krett Tagatt) simultaneously appear in two classes , since they belong to an intermediate type .

(a) Embankment dams with spillway :

(a1) gabion spillway :	(a2) concrete spillway :	(a3) natural spillway :
2:Timbara	3:Toueidima	7:Ouaci Chrak
5:Zmeilatt	8:Lehmeikatt	10:Toueiz Krett Tagatt
9:Anguellem	14:Jrékaya	

(b) Overflow dams :

(b1) concrete :	(b2) gabions :
6:Moudi Founti	1:Gag el Mohor
	4:Ameira
	11:Mint Aouaou
	13:Boudjoungal

(c) Total storage embankment dams :

10 : Toueiz Krett Tagatt
12 : Lemsuiou
15 : Boussoucilif

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The table next page sums up the main dimensions and elevations of projected structures .

NWL : normal water level , i.e. level at full capacity without overflow

HWL : highest water level , i.e. maximum level during overflow on spillway .

Main dimensions of projected structures .

Nº	site	type	total length	spillway length	crest elevation	NWL	HWL	HEIGHT OF DAM
1	Çag el Mohor	(b2)	1496.0	939.0	102.10	101.50	101.79	101.79
2	Timbara	(a1)	295.0	41.0	99.00	97.80	98.30	
3	Toueidima	(a2)	595.0	40.8	10.70	9.65	10.15	
4	Ameira	(b2)	1375.0	933.0	101.30	100.80	101.06	
5	Zmeilatt	(a1)	886.6	224.0	9.00	7.50	8.20	
6	Moudi Founti	(b1)	325.0	325.0	9.50	9.50	9.73	
7	Oudei Chrak	(a3)	1596.5	200.0	9.60	8.00	8.60	
8	Lehneikatt	(a2)	1026.6	228.0	11.35	9.75	10.35	
9	Azgueilem	(a1)	1135.5	166.5	12.50	11.00	11.50	
10	ToueizKrettTagatt	(c)	715.0	-	10.75	-	9.75	
11	Mint Aouaou	(b2)	149.85	113.6	100.00	99.00	99.67	
	" "		833.0	-	100.50	"	"	
12	Lemaoudou	(c)	158.0	-	101.30	-	100.30	
13	Boudjoungal	(b2)	450.5	302.0	100.25	99.00	99.25	
14	Jrékaya	(a2)	244.0	-	96.20	95.00	95.20	
	"		297.5	222.0	95.50	"	"	
15	Boussoueilif	(c)	135.0	-	98.00	-	97.00	

3. APPURTENANT STRUCTURES

3.1. Outlet works .

The outlet works plays a fundamental role in a dam designed for runoff agriculture : indeed the function of such a dam is to allow a maximum quantity of water to be absorbed by the soil , which will later give the water back to the crops . But to bring the basin under cultivation , it must first be emptied .

As a general rule , the farmers leave the basin under water for one month or so . We assumed that the duration of the emptying process might also be one month , or even six weeks for very large basins : this duration actually allows to bring the basin under cultivation at a normal rhythm .

We chose between the two following types of structures :

a) open channel with stoplog gate : this structure consists of a floor and two vertical walls , at 2 or 2.50 m distance , in which vertical grooves allow insertion of wooden or metal stoplogs . When emptying the dam , the stoplogs are removed one after the other .

b) conduit with trashrack and upstream gate : in this type of structure , the flow occurs under pressure . The gate is a sliding gate ; the access to it is over a gangway on an embankment from the dam crest .

The second type is much more economical than the first because it allows to dispense with a generally important and expensive retaining wall .

So we chose to use a conduit with pressure flow for the outlet works . The main problems to be solved were as follows :

a) avoiding the obstruction of the conduit : to this effect , a trashrack placed upstream prevents coarse materials from entering the conduit . In order as to limit the introduction of fine materials , we generally placed the entrance to the conduit 0.50 m above the bottom of the basin , thus allowing for some silting upstream from the conduit . Moreover , the diameter selected being always the smallest possible to comply with the required emptying time , the speed in the conduit reaches high values (up to 5 m/s at the beginning of the emptying process) thus providing some flushing effect .

b) avoiding piping : to this effect we placed concrete cutoff masks along the conduit . We moreover selected for the conduit a material capable both of total tightness and of great suppleness in case of settling of the foundations : the conduit shall be made of ductile cast-iron , with bolted Express joints .

A standard drawing of the outlet works is to be found in the general drawings , with variable dimensions and the values of these dimensions for each site .

For one site (Lehneikatt) , the speed reaching 5 m/s , we provide downstream from the conduit a dissipation structure of the "impact" type (see report N°8 : Lehneikatt) .

For the other dams , the dissipation structure is made of gabions .

32. Cutoff trenches and walls .

Under the embankment , a cutoff trench in compacted earthfill will be constructed to a depth allowing the prevention of piping by application of the Lane-Terzaghi rule , which is similar to Lane's rule but with following coefficients :

sand , very fine or silt	:	4.7
, fine	:	4.5
, average	:	4.0
, coarse	:	3.5
gravel , fine	:	3.6
, average	:	3.15
, coarse	:	2.7
pebbles + stones + gravel	:	2.5
clay , plastic	:	4.2
, hard or very hard	:	2.5 or 2.2

The same device is used when one of the abutments of the embankment consists of a dune (report N°6 : Boussoueilif).

In the same way , under concrete works , a cutoff wall in unreinforced , unformed concrete allows either junction with the bedrock , or compliance with the Lane-Terzaghi rule .

33. Toedrain .

A toedrain will be constructed at the foot of the downstream slope of embankment dams . This drain consists of riprap , laid over a filter of unweaved fabric of the BIDIM type (see below) .

The height of the drain above natural soil level is as a general rule taken equal to h/2 where h is the normal water level in the reservoir .

34. Filters .

To avoid the important difficulties that may arise when manufacturing and placing classical controlled gradation filters , we decided to use filters made of an unwoven textile membrane , of the type BIDIM U24 , the characteristics of which are listed in the technical specifications .

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PROJECT : E B U 2

TECHNICAL STUDIES

GENERAL REPORT

B. - TOTAL COST ESTIMATE

B. P. 321
NOUAKCHOTT

JULY 1980

ESTIMATES OF QUANTITIES AND COSTS

-=-=-=-

OVERALL ESTIMATE

-=-

AVANT_METRE REC

DESIGNATION DU BARRAGE	DEBROUSSAILLAGE	DECAPAGE	DEBLAI	DEBLAI EN PLEINE MASSE	P.V ROCHER	REMBLAI COMPACTE	ENROCHEMENT	GRAVIER	GABION CONTINU	GABION	BETON ORDINAIRE A 250 kg/m³ EN FONDATION
	m2	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3
1 ÇAG EL MOHOR	23 800	2650	5800	500		8500			840	3350	280
2 TIMBARA		70	310			290	50		20	260	
3 TOUEDIMA							750	150			
4 AMEIRA	22 300	2600	3950	3450		7500			1200	3400	240
5 ZMEILATT			2750	5650	80	5200	1200	275	195	1100	
6 MOUDI FOUNTI	3300		1300	2200	130		80			160	430
7 OUDEI CHRAK	107000	5400	1660	13500	200	38500	6200	510			
8 LEHNEIKATT	44 500	4300	4650	1000	900	40300	5700	280		500	315
9 AZGUEILEM	15900	1360	6200		300	6200	1350	360		600	390
10 TOUEIZ GRETT TAGATT	18500	3400	660		150	20000	4200	265			
11 MINT AOUAOU (PRINCIPAL)	2700	360	1100	3000	100	1400	500		140	540	17
(SECONDAIRE)	22 500	4200	2700			26800	4050	320			
12 LEMAOUDOU	2900	400	180			2500	650	60			
13 BOUDJOUNGAL	7500	270	1300	3000	50	2950	350	25		380	235
14 JREKAYA OUDEI LEFKARINE DIGUE	6000	1050	310		150	7700	1400	90			
MUR			310		190					230	150
15 BOUSSOUEILIF	4000	800	2200			7950	1200	45			
TOTAUX	280 900	26860	35380	32 300	2250	175790	27 80	2380	2395	10520	2057

ECAPITULATIF

250kg/m³ EN FONDATION	DITO EN ELEVATION	B A DOSE A 350kg/m³	PERRE MACONNE	ACIER POUR B A	ACIER POUR GRILLE	CONDUITE								VANNE A GLISSEMENT								JOINT WATER STOP	MEMBRANE SYNTHETIQUE	PV TRANSPORT AU DELA DE 1 000 m
						Ø 200	Ø 250	Ø 300	Ø 350	Ø 400	Ø 500	Ø 600	Ø 700	Ø 200	Ø 250	Ø 300	Ø 350	Ø 400	Ø 500	Ø 600	Ø 700		EP 0 8	
3	m³	m³	m²	kg	kg	ml	ml	ml	ml	ml	ml	ml	ml	u	u	u	u	u	u	u	u	ml	m2	T/km
0	195	2	10	150	30				14								1					65	12 700	
	12																						500	
	170	2	3	120	40			7								1							3080	
	05	5	50	400	70		16								1							47	13 300	
)	300							1,50								1							10550	
	2	12	10	900	80						22								1			45		
	770	60	25	4800	85								20								1		15 800	
	540	58		4500		2																55	12 070	
	2	10	15	800	80					19				1								45	4050	
	30																	1					10060	
	2	5		400	60							18										20	17 80	
	2	6,5	7	500						15									1				9 900	
	215	32	20	2500	60						22							1					1100	
	1	7,5	40	650	70		18												1			45	8 20	
	95				70									1									3100	
	2,5	9	30	800	70			19														35		
															1								2350	
2339	209	210	16520	715	2	34	27,5	14	34	44	18	20	1	2	3	1	2	2	1	1	357	101160		

LISTE DES ABBREVIATIONS / LIST OF ABBREVIATIONS

DEBROU	débroussaillage	clearing
DECAP	décapage	stripping
DEBLAI	déblai en terrain de toute nature	common excavation
DEBPLM	déblai en pleine masse	open-cut excavation
PVROCH	plus-value pour déblai dans le rocher	overcost for rock-excavation
REMB.C	remblai compacté	compacted embankment
ENROCH	enrochement	riprap
GRAVIE	gravier	gravel
GABMAT	gabion matelas	continuous steel gabion
GABION	gabion	steel gabion
BET250	béton ordinaire dosé à 250 kg/m3 en fondation	ordinary concrete dosed 250 kg/m3 in foundations
BETELV	" en élèvation	" in structures above foundations
B.A350	béton armé dosé à 350 kg/m3	reinforced concrete dosed 350 kg/m3
PERMAC	perré maçonné	masonry pitching
ACIERB	acier pour béton armé	steel for reinforced concrete
ACGRIL	acier pour grille	steel for trashrack
COND.	conduite	conduit
VANNE	vanne à glissement	slide gate
W.STOP	joint water-stop	waterstop
BIDIM	membrane synthétique semi-perméable ép.0,8 mm	semi-pervious synthetic membrane width 0.8 mm
TRANSP	plus-value pour transport au-delà de 1000 m	overcost for transportation over more than 1000 m
EAU	alimentation en eau du chantier	providing water for the works

	PU	Q	MONTANT
DEPRON	4,6	0	0
DECOP	170	70	11900
DEPLAI	170	310	52700
DEPPLM	150	0	0
PYROCH	750	0	0
REMB.C	250	290	72500
ENROCH	740	50	37000
GRAVIE	1200	0	0
GABNAT	2475	20	49700
GABION	1450	260	377000
BET250	9000	0	0
BETOLV	10000	12	120000
R.A350	15000	0	0
PERMAC	2000	0	0
ACIERB	115	0	0
ACCRIL	150	0	0
COND	11200	0	0
VANNE	320000	0	0
M.STOP	2500	0	0
BIDIM	120	500	60000
TRANSP	6,0	0	0
INSTAL	200000	1,0	200000
EQU	100000	1,0	100000

TOTAL = 1.079.800,UM

ACTUALISE= 1.171.583.UM

+IMPREVU = 1.250.000,UM

	PU	Q	MONTANT
DEPRON	4,6	0	0
DECOP	170	0	0
DEPLAI	170	0	0
DEPPLM	150	0	0
PYROCH	750	0	0
REMB.C	250	0	0
ENROCH	740	750	555000
GRAVIE	1200	150	180000
GABNAT	2435	0	0
GABION	1450	0	0
BET250	9000	0	0
BETOLV	10000	0	0
R.A350	15000	0	0
PERMAC	2000	0	0
ACIERB	115	0	0
ACCRIL	150	0	0
COND	11200	0	0
VANNE	320000	0	0
M.STOP	2500	0	0
BIDIM	120	3080	369600
TRANSP	6,0	0	0
INSTAL	200000	1,0	200000
EQU	100000	1,0	100000

TOTAL = 1.404.600,UM

ACTUALISE= 1.523.991,UM

+IMPREVU = 1.700.000,UM

4 AMEIR-

	PU	Q	MONTANT
DEBROU	4,6	22300	102580
DECAP	170	2600	442000
DEBLAI	170	3950	671500
DEBPLM	150	3450	517500
PVROCH	350	0	0
REMB.C	250	7500	1875000
ENROCH	740	0	0
GRAVIE	1200	0	0
GABMAT	2435	1200	2922000
GABION	1450	3400	4930000
BET250	9000	240	2160000
BETELV	10000	170	1700000
B.A350	15000	2,0	30000
PERMAC	2000	3,0	6000
ACIERB	115	120	13800
ACGRIL	150	40	6000
COND	8800	7,0	61600
VANNE	260000	1,0	260000
W.STOP	2500	47	117500
BIDIM	120	13300	1596000
TRANSP	6,0	0	0
INSTAL	871974	1,0	871974
EAU	348789	1,0	348789

TOTAL = 18.660.243,UM

ACTUALISE= 20.246.364,UM

+IMPREVU = 22.300.000,UM

5 ZNEILATT

	PU	Q	MONTANT
DEBROU	4,6	0	0
DECAP	170	0	0
DEBLAI	170	2750	467500
DEBPLM	150	5650	847500
PVROCH	350	80	28000
REMB.C	250	5200	1300000
ENROCH	740	1200	888000
GRAVIE	1200	275	330000
GABMAT	2435	195	474825
GABION	1450	1100	1595000
BET250	9000	0	0
BETELV	10000	0,5	5000
B.A350	15000	5,0	75000
PERMAC	2000	50	100000
ACIERB	115	400	46000
ACGRIL	150	70	10500
COND	7000	16	112000
VANNE	260000	1,0	260000
W.STOP	2500	0	0
BIDIM	120	10550	1266000
TRANSP	6,0	0	0
INSTAL	354266	1,0	354266
EAU	141706	1,0	141706

TOTAL = 8.301.297,UM

ACTUALISE= 9.006.907,UM

+IMPREVU = 9.900.000,UM

6 MOUDI-FOUNTI

	PU	Q	MONTANT
DEBROU	4,6	3300	15180
DECAP	170	0	0
DEBLAI	170	1300	221000
DEBPLM	150	2200	330000
PVROCH	350	130	45500
REMB.C	250	0	0
ENROCH	740	80	59200
GRAVIE	1200	0	0
GABMAT	2435	0	0
GABION	1450	160	232000
BET250	9000	430	3870000
BETELV	10000	300	3000000
B.A350	15000	0	0
PERMAC	2000	0	0
ACIERB	115	0	0
ACGRIL	150	0	0
COND	8800	1,5	13200
VANNE	288000	1,0	288000
W.STOP	2500	45	112500
BIDIM	120	0	0
TRANSP	6,0	0	0
INSTAL	411969	1,0	411969
EAU	164787	1,0	164787

TOTAL = 8.763.336,UM

ACTUALISE= 9.508.220,UM

+IMPREVU = 10.500.000,UM

7 OUDEI CARRE

	PU	Q	MONTANT
DEBROU			
	4,6	107000	492200
DECAP			
	170	5400	918000
DEBLAI			
	170	1600	272000
DEBPLM			
	150	13500	2025000
PYROCH			
	350	200	70000
REMB.C			
	250	38500	9625000
ENROCH			
	740	6200	4588000
GRAVIE			
	1200	510	612000
GABMAT			
	2435	0	0
GABION			
	1450	0	0
BET250			
	9000	0	0
BETELV			
	10000	2,0	20000
B.A350			
	15000	12	180000
PERMAC			
	2000	10	20000
ACIERB			
	115	1580	181500
ACCRIL			
	150	80	12000
COND			
	5400	80	432000
VANNE			
	416800	1,0	416800
K.STOP			
	2500	0	0
BIDIM			
	120	10970	1316400
TRANSP			
	6,0	0	0
INSTAL			
	897045	1,0	897045
EAU			
	300810	1,0	300810

TOTAL = 22.[illegible].763,UM

ACTUALISE= 24.864.600,UM

+IMPREVU = 27.400.000,UM

8 VEHNEIKATT

	PU	Q	MONTANT
DEBROU			
	4,6	44500	204700
DECAP			
	170	4300	731000
DEBLAI			
	170	4680	796000
DEBPLM			
	150	1000	150000
PYROCH			
	350	900	315000
REMB.C			
	250	40300	10075000
ENROCH			
	740	5700	4218000
GRAVIE			
	1200	280	336000
GABMAT			
	2435	0	0
GABION			
	1450	500	725000
BET250			
	9000	315	2835000
BETELV			
	10000	770	7700000
B.A350			
	15000	60	900000
PERMAC			
	2000	25	50000
ACIERB			
	115	4800	552000
ACCRIL			
	150	85	12750
COND			
	31900	20	638000
VANNE			
	525000	1,0	525000
K.STOP			
	2500	55	137500
BIDIM			
	120	12070	1448400
TRANSP			
	6,0	0	0
INSTAL			
	1446192	1,0	1446192
EAU			
	578477	1,0	578477

TOTAL = 34.368.519,UM

ACTUALISE= 37.289.843,UM

+IMPREVU = 41.000.000 UM

9 AZGUEILEM

	PU	Q	MONTANT
DEBROU			
	4,6	15900	73140
DECAP			
	170	1360	231200
DEBLAI			
	170	6200	1054000
DEBPLM			
	150	0	0
PYROCH			
	350	300	105000
REMB.C			
	250	6200	1550000
ENROCH			
	746	1350	999000
GRAVIE			
	1200	360	432000
GABMAT			
	2435	0	0
GABION			
	1450	600	870000
BET250			
	9000	390	3510000
BETELV			
	10000	540	5400000
B.A350			
	15000	58	870000
PERMAC			
	2000	0	0
ACIERB			
	115	4500	517500
ACCRIL			
	150	0	0
COND			
	5400	2,0	10800
VANNE			
	236302	1,0	236800
K.STOP			
	2500	45	112500
BIDIM			
	120	4050	486000
TRANSP			
	6,0	0	0
INSTAL			
	732397	1,0	782397
EAU			
	312959	1,0	312959

TOTAL = 17.553.296,UM

ACTUALISE= 19.045.326,UM

+IMPREVU = 21.000.000,UM

[illegible]			
	PU	Q	MONTANT
[illegible]			
	4.6	2700	12420
[illegible]			
	170	360	61200
[illegible]			
	170	1100	187000
[illegible]			
	150	3000	450000
[illegible]			
	350	100	35000
[illegible]			
	250	1400	350000
[illegible]			
	740	500	370000
[illegible]			
	1300	0	0
[illegible]			
	2435	140	340900
[illegible]			
	1450	540	783000
[illegible]			
	9000	17	153000
[illegible]			
	10000	30	300000
[illegible]			
	15000	0	0
[illegible]			
	2000	0	0
[illegible]			
	115	0	0
[illegible]			
	150	0	0
[illegible]			
	0	0	0
[illegible]			
	0	0	0
[illegible]			
	2500	20	50000
[illegible]			
	120	1700	213600
[illegible]			
	6.0	0	0
[illegible]			
	150306	1.0	150306
[illegible]			
	60122	1.0	60122

TOTAL = 3.516.548.UM

ACTUALISE= 3.815.455.UM

+IMPREVU = 4.100.000.UM

MINT AOUAOU

BARRAGE 1 ...17 000 000

BARRAGE 2 ... 4 200 000

TOTAL 21 200 000

10 MOUSSA KOUIE

	PU	Q	MONTANT
IEBROU			
	4,6	18500	85100
DECAP			
	170	3400	578000
DEBLAI			
	170	660	112200
IEBPLM			
	150	0	0
PVROCH			
	350	150	52500
REMB.C			
	250	20150	5038000
ENROCH			
	740	4200	3108000
GRAVIE			
	1200	265	318000
GABMAT			
	2435	0	0
GABION			
	1450	0	0
BET250			
	9000	0	0
BETELY			
	10000	2,0	20000
B.A350			
	15000	6,5	100000
PERMAC			
	2000	15	30000
ACIERB			
	115	800	92000
ACGRIL			
	150	[illegible]	12000
COND			
	13400	19	254600
VANNE			
	350400	1,0	350400
W.STOP			
	2500	0	0
BIDIM			
	120	10060	1207200
TRANSP			
	6,0	0	0
INSTAL			
	442500	1,0	442500
EAU			
	177000	1,0	177000

TOTAL = 11.909.500,UM

ACTUALISE= 13.000.600,UM

+IMPREVU = 14.300.000,UM

12 LEMAOUDOU

	PU	Q	MONTANT
IEBROU			
	4,6	2900	13340
DECAP			
	170	400	68000
DEBLAI			
	170	180	30600
IEBPLM			
	150	0	0
PVROCH			
	350	0	0
REMB.C			
	250	2500	625000
ENROCH			
	740	650	481000
GRAVIE			
	1200	60	72000
GABMAT			
	2435	0	0
GABION			
	1450	0	0
BET250			
	9000	0	0
BETELY			
	10000	2,0	20000
B.A350			
	15000	6,5	97500
PERMAC			
	2000	7,0	14000
ACIERB			
	115	500	57500
ACGRIL			
	150	0	0
COND			
	13400	15	201000
VANNE			
	350000	1,0	350000
W.STOP			
	2500	0	0
BIDIM			
	120	1100	132000
TRANSP			
	6,0	0	0
INSTAL			
	200000	1,0	200000
EAU			
	100000	1,0	100000

TOTAL = 2.461.940,UM

ACTUALISE= 2.671.205,UM

+IMPREVU = 2.950.000,UM

14/1 O.LEFKARINE

	PU	Q	MONTANT
DEBROU	4,6	0	0
DECAP	170	0	0
DEBLAI	170	310	52700
DEBPLM	150	0	0
PYROCH	350	190	66500
REMB.C	250	0	0
ENROCH	740	0	0
GRAVIE	1200	0	0
GABMAT	2435	0	0
GABION	1450	230	333500
BET250	9000	150	1350000
BETELV	10000	95	950000
B.R350	15000	0	0
PERMAC	2000	0	0
ACIERB	115	0	0
ACCRIL	150	70	10500
COND	0	0	0
VANNE	0	0	0
W.STOP	2500	35	87500
BIDIM	120	0	0
TRANSP	6,0	0	0
INSTAL	0	0	0
EAU	0	0	0

TOTAL = 2.850.700,UM

ACTUALISE= 3.093.010,UM

+IMPREVU = 3.400.000,UM

14/2 O.LEFKARINE

	PU	Q	MONTANT
DEBROU	4,6	6000	27600
DECAP	170	1050	178500
DEBLAI	170	310	52700
DEBPLM	150	0	0
PYROCH	300	100	52500
REMB.C	250	7700	1925000
ENROCH	740	1400	1036000
GRAVIE	1200	90	108000
GABMAT	2435	0	0
GABION	1450	0	0
BET250	9000	0	0
BETELV	10000	1,0	10000
B.R350	15000	7,5	112500
PERMAC	2000	40	80000
ACIERB	115	650	74750
ACCRIL	150	70	10500
COND	11200	18	201600
VANNE	320000	1,0	320000
W.STOP	2500	0	0
BIDIM	120	3100	372000
TRANSP	6,0	0	0
INSTAL	320617	1,0	320617
EAU	131447	1,0	131447

TOTAL = 5.021.714,UM

ACTUALISE= 5.448.560,UM

+IMPREVU = 6.000.000,UM

OUDEI LEFKARINE

BARRAGE 1 ... 3 400 000

BARRAGE 2 ... 6 000 000

TOTAL 9 400 000

17 BOUDJOUDAL

	PU	Q	MONTANT
DEBROU			
	4,6	7500	34500
DECAP			
	170	270	45900
DEBLAI			
	170	1300	221000
DEBPLM			
	150	3000	450000
PVROCH			
	350	70	24500
REMB.C			
	250	2950	737500
ENROCH			
	740	350	259000
GRAVIE			
	1200	35	42000
GARMAT			
	2435	0	0
GABION			
	1450	0	0
BETON			
	9000	235	2115000
BETELY			
	10000	215	2150000
B.A350			
	15000	32	480000
PERMAC			
	2000	23	46000
ACIERB			
	115	2500	287500
ACGRIL			
	150	60	9000
COND			
	11200	22	246400
VANNE			
	320000	1,0	320000
W.STOP			
	2500	45	112500
BIDIM			
	120	820	98400
TRANSP			
	6,0	0	0
INSTAL			
	399760	1,0	399760
EAU			
	159904	1,0	159904

TOTAL = 8.761.064,UM

ACTUALISE= 9.509.877,UM

+IMPREVU = 10.500.000,UM

15 BOUSSOUEILIF

	PU	Q	MONTANT
DEBROU			
	4,6	4000	18400
DECAP			
	170	800	136000
DEBLAI			
	170	2200	374000
DEBPLM			
	150	0	0
PVROCH			
	350	0	0
REMB.C			
	250	7950	1987500
ENROCH			
	740	1200	888000
GRAVIE			
	1200	45	54000
GARMAT			
	2435	0	0
GABION			
	1450	0	0
BETON			
	9000	0	0
BETELY			
	10000	2,5	25000
B.A350			
	15000	9,0	135000
PERMAC			
	2300	30	69000
ACIERB			
	115	800	92000
ACGRIL			
	150	70	10500
COND			
	8800	19	167200
VANNE			
	288000	1,0	288000
W.STOP			
	2500	0	0
BIDIM			
	120	2350	282000
TRANSP			
	6,0	0	0
INSTAL			
	189880	1,0	189880
EAU			
	75952	1,0	75952

TOTAL = 4.733.432,UM

ACTUALISE= 5.190.024,UM

+IMPREVU = 5.700.000,UM

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DEVIS RECAPITULATIF /OVERALL ESTIMATE

1.	CAG EL MONOR	22.000.000 UM
2.	TIMBARA	1.250.000
3.	TOJEIDIMA	1.700.000
4.	AMEIRA	22.300.000
5.	ZMEILATT	9.900.000
6.	MOUDI FOUNTI	10.500.000
7.	OUDEI CHRAK	27.400.000
8.	LEHNEIKATT	41.000.000
9.	AZGUEILEM	21.000.000
10.	TOUEIZEKRETT TAGATT	14.300.000
11.	MINT AOUAOU	21.200.000
12.	LEMAOUDOU	2.950.000
13.	BOUDJOUNGAL	10.500.000
14.	OUDEI LEFKARINE	9.400.000
15.	BOUSSOUEILIF	5.700.000
	TOTAL	221.100.000 UM

REPUBLIQUE ISLAMIQUE DE MAURITANIE

Ministère du Développement Rural

RECLAMATION AND CONSTRUCTION OF 15 DAMS IN THE BRAKNA & GORGOL REGIONS

STUDIES FINANCED BY USAID

CONTRACT N° AID 682 - C O - P M & R - 80-01

PROJECT : E B U 2

TECHNICAL STUDIES

GENERAL REPORT

C. - SPECIFICATIONS

B. P. 321
NOUAKCHOTT

JULY 1980

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.../...

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INTRODUCTION

The present technical specifications apply to earthwork and civil engineering works relating to the construction of 15 dams in the Brakna and Gorgol regions, whose names follow :

1. ÇAG EL MOHOR
2. TIMBARA
3. TOUEIDIMA
4. AMEIRA
5. ZMEILATT
6. MOULI FOUNTI
7. OUDEI CHRAK
8. LEHNEIKATT
9. AZGUEILEM
10. TOUEIZ KPETI TAGATT
11. MINT AOUAOU
12. LEMAOUDOU
13. BOUDJOUNGAL
14. JREKAYA OUDEI LEFKARINE
15. POUSSOUEILIF

.../...

1. GENERAL , INSTALLATION OF THE WORKS

The installation of the works , the progress schedule and the methods used will be submitted to the approval of the Engineer in order as to ensure completion of the works within prescribed time limits and in conformity with the technical specifications and the rules of the art .

2. FIELD LABORATORY

The works will be equipped with a laboratory making it possible to perform the following usual tests (relating to concrete and soil tests) :

- Atterberg limits(liquidity , plasticity , shrinkage)
- grain size analysis
- dry density and water content
- Standard and Modified Proctor tests
- permeability

The laboratory will include at least one 50 m2 room , one 15 m2 office , one room with a water basin for preserving the samples and storing the equipment . The management of the laboratory will be entrusted to a skilled technician capable of performing the prescribed usual tests , with th help of unskilled labour for the sampling operations . All the tests will be performed after the indications of the Engineer .

The plan of the laboratory and the list of equipment and furniture will be decided by the Engineer prior to the beginning of the works .

.../...

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3. TECHNICAL SPECIFICATIONS AND SPECIAL PROVISIONS FOR EXECUTION OF THE WORK

3.1. Clearing

Clearing refers to taking away all vegetation on the whole aerea to be occupied by the works including an additional 5m on the border .

Materials from clearing operations such as trees , shrubs , brush , or unearthed materials such as stumps or roots or rock blocks will be removed from the site of the work .

It is important that all necessary precautions should be taken to avoid destroying any bench-mark installed on both sides of the site during this operation . Should any bench-mark be within the aerea of the work , it will be replaced by another bench mark , to be located outside of the aerea of the work and connected vertically and horizontally with previously existing bench-marks , to ensure a safe lay-out of the works .

3.2. Stripping

Stripping on the site of the compacted embankment includes removal of topsoil on a depth of 30 cm eliminating weeds , grass , vegetal rubbish , muck and compressible earth that may be encountered.

The topsoil and other products from stripping operations will be piled outside of the cleared aerea and will in no case be used for construction of the embankment .

.../...

3.3. Excavations

All excavations will be executed to the width , length , depth and sections shown on the execution drawings .

The dimensions or sections shown on the execution drawings may be modified by the Engineer during construction works .

Excavated materials will be used for embankment each time when the earth will be suitable for such use and the resulting transportation distance will remain less than 1000 m . In this case , the topsoil on these excavated materials will be stripped in the same way as for borrow aereas .

Whenever they will not be used for embankment (surplus , unsuitable material , too great distance to the location of use in embankment) the materials will be removed and piled according to the instructions of the Engineer .

The measurement of excavations will always be done on the basis of the sections shown on the execution drawings .

Excavation for possibly necessary widening to make space for moving the engines , stops and disposal during execution of the works , will not be taken into account .

3.4. Open-cut excavation

We shall consider as open cut excavation any excavation performed on already existing embankment which may be either totally disposed of , or only modified and improved .

.../...

Open-cut excavation material may be used for embankment whenever it will be rated as suitable . Otherwise it will be disposed of according to the instructions of the Engineer .

3.5. Rock excavation

Rock excavation will be performed according to the nature of the encountered rock after decision by the Engineer .

Excavation may be done by hand with heavy mining bars (15 to 20 kg) for fissured rock , with a wedge and 5 kg hammer for solid rock or by using mechanical tools such as a pneumatic drill .

Explosives will be used after decision by the Engineer and will consist of : gunpowder for soft fissured rock , dynamite for hard and moderately humid rock , and cheddite for rocks of average hardness and low humidity .

3.6. Compacted embankment

3.6.1. Materials for constructing compacted embankment

a) Materials for constructing compacted embankment will satisfy the following requirements :

. Gradation

The gradation analysis curve will be between the curves joining the following minimum , respectively maximum percentages :

.../...

Dimension (mm)	20	2	0.2	0.1	0.02	0.002
% minimum	100	85	60	33	20	10
% maximum	100	100	96	80	55	34

. Modified Proctor test - Maximum dry density ≥ 1.6
. Plasticity index more than 8
. Liquid limit less than 50

b) The characteristics of materials for constructing embankments should however not be less than those used in the project studies for computing stability of slopes .

c) Materials for constructing compacted embankment will consist , if the nature of soils allows it , of excavated material from excavations for constructive works within a short distance .

d) If it is not possible to use such materials , materials will originate from borrow pits located at a minimal distance of 50 m from the toe of the embankment .

e) If the borrow pits shown on the project drawings are not sufficient for constructing the embankment , other borrow pits will have to be located , for which the following measurements will be performed : Atterberg limits , grain size analysis , density in place , and maximal dry density for Modified Proctor test , as well as distance to the place of implantation.

.../...

3.6.2. Construction procedures for compacted embankment

All embankments shall be constructed to the lines and grades shown on the execution drawings or specified in the course of the works .

Earthfill shall be placed in horizontal layers on the whole width of the aerea to be covered by earthfill . It shall not be widened by unloading loose material from the crest .

Earthfill shall be compacted to the lines , levels and grades shown on the execution drawings .

The embankments shall be trimmed in order as to obtain a total height not exceding the specified height by more than 10 cm and in such way that the slopes do not exceed specifications .

The width at crest must not be less than that shown on the execution drawings .

Before and while compacting , the water content of the materials shall be uniform throughout the whole layer . The water content for compaction will be that of the Modified Proctor Optimum $\pm$ 2 % .

If the material is too dry , each layer shall be sprinkled and moisture shall be homogenized by harrowing or any other appropriate method . Material too wet in earthfills shall be harrowed for drying .

The thickness of each layer shall as a rule be 20 cm as measured after compacting , but may vary according to materials , equipment used and results obtained by compaction .

.../...

Compaction will be performed in successive horizontal layers on the whole width of the earthfill including an excess width necessary for levelling the earthfill to its final shape .

Compacity throughout the earthfill shall at least be equal to 90 % of the modified Proctor Optimum (MPO) .

3.6.3. Required characteristics of compacted embankment

Preliminary tests will be performed on soils from excavations or borrow aereas in order as to determine the physical and mechanical qualities of materials to be used for compacted earthfill .

For each type of soil encountered , these tests will consist of :

- gradation analysis (sieve) and hydrometer analysis of material (5 results) .
- measurement of Atterberg limits (5 results)
- measurement of water content and density in place
- standard and modified Proctor tests (3 results) and when possible oedometer tests.

These tests will define reference standards that will be used for control of materials during and after construction .

Compaction control will be performed during compaction works and after their completion . If control tests give a result lower than required by standards ,

.../...

the compaction operations shall be resumed until the the required minimal values are obtained . Should it prove impossible to reach these minimal values , the defective section shall be taken away and reconstructed .

All test soils mentionned shall be performed in the field laboratory .

As an indication , control tests may be performed with the following frequencies :

- Atterberg limits	daily or every 500 m3
- gradation analysis	daily
- density-in-place	daily or every 1,000 m3
- Proctor	control test
- shrinkage limit	control test
- water content when placing	daily

Control tests will be performed when anomalies will be detected in the compacted layers , originating either from a change in the nature of borrow materials , or from any other cause .

3.6.4. Execution tolerances for earthwork

Tolerances for earthwork are set as follows :

Definition	Minus tolerance	Plus tolerance
Embankment		
- crest level	0	+15 cm
- width at crest	0	+30 cm
- slope	3 %	+ 3 %

.../...

3.7. Riprap - Masonry pitching

After completion of the compacted earthfill , protection by riprap will be provided , to avoid erosive furrowing .

The protection of slopes will be ensured by a layer of riprap 30 cm and 20 cm thick (upstream and downstream slopes respectively) .

The rock fragments shall be disposed according to the indications of the Engineer . The layer of bedding will previously undergo a minimal compaction , in order as to reduce to a minimum the volume of voids , light elements being placed towards the interior of the embankment .

During placement , sprinkling shall be used to eliminate dusts and to favour sliding of rock fragments upon each other .
The toedrain downstream shall also be constructed in riprap .

The voids between the boulders will be filled with a sieved sand+gravel mix , and stuffed with rock fragments .
In the case of masonry pitching , this bonding will be done with mortar , also followed by stuffing with rock fragments . The surfacing shall be level and regular .

3.8. Gravel

A protective layer of gravel shall be placed on the crest of the embankment . Its thickness shall be 10 cm after compaction including a lower layer less than 2 cm thick of small grain size , 0.3 to 1 cm . The gravel shall be well graded to ensure a minimal void ratio . The dimensions of gravels will as a rule vary from

.../...

1 to 7 cm . The fraction smaller than 3 cm shall not exceed 40 % and the fraction bigger than 5 cm shall not exceed 15 % . The locations of rock quarries shall be chosen before beginning the works , and shall be cleared of trees , brush and stumps .

The top layers shall be stripped until the material to be used shows sufficient qualities of homogeneity and cleanliness .

3.9. Steel gabions .

The steel gabions used include following types : 2.00 x 1.00 x 0.50 ; 3.00 x 1.00 x 0.50 ; 1.00 x 1.00 x0.50; 2.25 x 1.00 x 0.30 ; 2.00 x 0.50 x 0.50 , and continuous gabions of 0.20 m thickness .

Gabions shall not have meshes broader than 10 x 12 cm and shall be manufactured out of strongly galvanized iron , with hexagonal mesh and double twisting .

The wire used for manufacturing gabions shall be of a diameter not less than 3 mm for the 10 x 12 cm mesh .

Materials used for filling gabions shall be hard , neither porous nor friable . Preference shall be given to eruptive rocks (granites) and secondly to sedimentary rocks (quartzites , sandstones , laterite , limestone) .

Stones in contact with the meshes shall have a size in every direction at least 1.5 times the size of the meshes. To ensure the finish of the fill , small stones or flat stones shall be avoided when ending , and should be placed below the last stone layer .

.../...

Filling material should not pass through the 8 cm ring .

In some cases , continuous gabions are required . They will be placed along the slopes as shown on the execution drawings .

3.10. Concrete

3.10.1. Origin of aggregates

Aggregates used (sands and gravels) for manufacturing concrete will originate from suitably chosen quarries .

The gradation of aggregates shall be checked before use . The gradation analysis curve differ by more than 5 % from the gradation analysis curves in the project documents of each dam .

3.10.2. Aggregates

Sand shall be free of fine clayey materials and shall satisfy to the test called Sand Equivalent test . This test will give a result over 65 . Quartzite or schist gravels shall be washed if necessary , and sieved in order as to produce 3 classes of gravels :

	Sieve	Type 1	Type 2	Type 3
N° 20	80 µ	0 - 1	0 - 1	0 - 1
N° 35	2.5 mm	0 - 2	0 - 2	0 - 2
N° 38	5 mm	30 - 60	"	"
N° 41	10 mm	90 -100	0 - 10	"
N° 43	15 mm	100	30 - 60	"
N° 44	20 mm	"	85 -100	0 - 10
N° 46	30 mm	"	95 -100	30 - 60
N° 47	40 mm	"	100	85 -100
N° 49	63 mm	"	"	100

.../...

3.10.3. Cements

a) Cements used shall be of the type Portland Artificial class CPA 325 (French AFNOR standard P15 302) or equal .

They shall satisfy to the following requirements :

- (C3A) $\leq$ 10 %
- (C3A) + 0.27(C3S) $\leq$ 23.5 %
- (SO3) $\leq$ 2.5 %
- (MgO) $\leq$ 3 %
- (Al2O3) $\leq$ 8 %
- Blaine fineness 3,000 to 3,500 cm2/g

b) For each delivery , tests shall be performed if required by the Engineer on samples taken at the factory before loading or after the arrival of the cement on the site .

c) The cement shall be stocked by skilled warehousemen in warehouses well ventilated and protected against sun and moisture .Each delivery of cement shall be stored separately and the date of effective arrival shall be clearly shown . They will be used in the chronological order of arrival . Sacks having suffered damage , stale or having been stored for more than 5 months on the site shall not be used .

3.10.4. Water

Water used for mixing and curing concrete and mortar.

a) It will originate from any source agreed upon by the Engineer and will be used after laboratory analysis .

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b) Water shall conform to the following requirements :

- solid materials and salts in suspension $\leq$ 2g/l
- dissolved salts $\leq$ 6 g/l
- alcaline bicarbonate (with HCO3) $\leq$ 400 mg/l
- sulfates (SO3) $\leq$ 400 mg/l
- pH between 6 and 8
- organic materials $\leq$ 1 g/l .

c) Turbidity : Water used for curing concrete shall not visibly colour the facings . Atest by evaporation of 3 liters of water on a hollow surface of plaster of Paris or cement may be performed .

d) Storage : Water pipes and tanks shall be protected against sun .

3.10.5. Proportioning of concrete

According to its use , concrete shall be proportionned as follows :

Type of concrete	Allowable use
60 / 250	Ordinary concrete, foundation
40 / 250	" " in elevation
25 / 350	Concrete for reinforced concrete works

≠ The first figure shows the maximum dimension of aggregates in mm .

≠ The second one shows the weight in kilograms of concrete per m3 of concrete after placing .

These tables give a possible classification of concretes used . However , final decisions shall only be taken after the results of grain size analysis and concrete proportioning tests . Maximal dimensions of aggregates shall remain close to those indicated above .

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3.10.6. Mechanical strength of concrete

Nature of stresses	Cement proportion	Strength in kg/cm2 for a 0.20 m cube 7 days	28 days
Compression	250 kg/m3	105	150
Compression	350 kg/m3	155	225
Tension	350 kg/m3	14.5	18.5

The strengths adopted relate to the average strength of at least three test cubes .

3.10.7. Testing strength of concrete

The number and frequency of tests will be about 15 times 4 samples per works .

The objective of tests is to determine mechanical strength (compression and tension) ,watertightness and slump (using Abrams'cone) of concrete . For mechanical strength tests , prismatic test-pieces of size 20 x 20 x 20 cm shall be used . Four prisms will be taken for each test : 2 for 7-days tests , 2 for 28-days tests . Test-pieces shall be identified by unerasable inscriptions in fresh concrete , containing the date of manufacture .
Test-pieces shall be stored in a damp room and precautions shall be taken against any damage .
All sampling of test-pieces shall be registered in a report containing all details about sampling and especially the part of the works for which the concrete being subjected to sampling was destined .

.../...

Any concrete giving an average strength lower than , or a strength on one test-piece lower by 25 % than the specified mechanical strength , shall be submitted to special controls and may have to be pulled down and built again .

3.10.8. Manufacture of concrete

All concrete shall be manufactured mechanically . The batching equipment shall as a rule be of the weighing type ; volumetric batching shall only be tolerated for some concretes mixed in small quantities .

Tolerances in weighing are ±3% of the specified weight of each type of aggregate and 2 % of the total weight of the aggregates necessary for manufacturing one cubic meter of concrete .

Cement and water shall be introduced in the batching machine by weighing with a precision of 2 % in weight respectively .

Admixtures may be added to concrete .

Addition of water is not allowed after mixing .

Concrete too wet or not having the required consistency shall be disposed of as refuse .

The amount of water added to concrete may vary according to the instructions of the Engineer , as well as the overall gradation of concrete .

The operator of the concrete plant shall be experienced and able to evaluate the qualities of concrete .

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3.10.9. Placing concrete

The foundation surface of concrete shall be carefully cleaned and if necessary levelled and compacted . Since placing should be done on dry soil , all precautions and measures shall be adopted to deviate or drain all water inflow , whatever its origin . When the foundation surface is considered as ready , placing may follow .

Concrete will be placed as soon as possible after mixing . Concrete having dried up or begun setting shall not be accepted and shall be disposed of outside the limits of the site .

Concrete shall be placed in successive layers deposited continuously . In the case of starting again on a concrete having already set , partially or totally , this concrete shall be treated and if necessary stripped in order as to eliminate the superficial layer of water and fines and lay bare the mosaic of concrete . The concrete shall then be abundantly sprinkled until moisture has well penetrated , and the new concrete shall be carefully vibrated .

All necessary measures shall be taken to avoid segregation of concrete , either during transportation or during placement . Whatever the means employed , concrete shall never fall from a height above 2 m .

Concrete shall be carefully pervibrated as soon as placed ; the excess water shall be disposed of accordingly . Any breakdown of the pervibrator shall cause immediate stop of the concrete work in progress , which will later be treated as for starting again .

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3.10.10. Allowable temperatures for concrete

The temperature of concrete during placement should not exceed 32° C . Should the ambient temperature be such that this value might be exceeded , concrete works shall be suspended , or all useful precautions shall be taken so that the temperature of concrete during placement should always remain below the limit specified above . In any case the storage areas for aggregates should be efficiently protected against sun as well as the water supply system of the batchers .

3.10.11. Placing the reinforcement bars

The horizontal distance between 2 contiguous bars in the same layer should be at least 6/5 of the maximal dimension of aggregates used .

Unless they overlap at their contact and are considered as such in computations , two bars in the same line should be kept at a vertical clear distance between them at least equal to three quarters of the rated diameter of the thickest of both , provided that this distance is not less than one half of the maximum size of aggregates used .

Should no indication be shown on the execution drawings , the clear distance between the outermost part of any bar and the closest form should be at least three centimeters .

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The main bars shall be covered by a thickness of concrete at least equal to :

- the rated diameter of bars , if this diameter exceeds 20 mm ;
- 2 cm if the diamater of bars is less than 20 mm .

The spacings specified above shall be obtained by placing concrete spacers in which splicing wire shall have been embedded to ensure fixation of the bars . These spacers shall be prepared at least seven days before use . Any hole that might be left by the spacers after removing the forms shall be filled with mortar using expansive concrete .
The overlap areas and the length of lap of reinforcement bars shall be those approved by the Engineer .

3.10.12. Curing concrete

- Submitting fresh concrete to any load is forbidden .

- Concrete curing shall be ensured by moistening , using a method agreed upon by the Engineer . It shall allow concrete to set and harden in normal conditions . It shall be continued for 15 days after placing concrete .

3.10.13. Forms

Forms shall have sufficient rigidity and shall be maintained in position in such a way that they should undergo no deformation or displacement during the operations of placing , pervibrating or hardening concrete .

.../...

If wooden forms are employed , the boards used shall have not less than 2.5 cm thickness . Unless plywood is used for lining , they will necessarily be planed for all visible surfaces and for some other parts of the works .

All junctions between form panels shall be horizontal or vertical . Form junctions shall be designed in order as to be tight enough to prevent any loss of laitance or mortar during pervibration .

Before use , forms shall be cleaned and cleared of all traces of laitance ; they shall then be oiled to prevent any sticking with the concrete . All precautions shall be taken while placing forms to avoid moving the reinforcement bars .

All parts of works that are suspended shall necessarily be formed by means of metallic forms propped up by metal tubes or hangers .Metal forms shall be rid of any stain and oiled before each use with a lubricating agent free of any dye .

No form shall be removed before concrete has reached sufficient strength . Orders to remove forms shall be given after laboratory results , or,if these are not available ,according to prevailing technical rules .

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3.10.14. Tolerances on specified dimensions for concrete works

Maximum allowable tolerances for concrete shall be as follows :

On levels :
- for slopes : ± 1 cm
- for the upper parts of works : ± 2 cm

On plane coordinates :
- for parts of works where water flow occurs : ± 1 cm
- for other parts of works : ± 3 cm

On thicknesses :
- thicknesses of concrete shall not be less than specified on execution drawings .

These tolerances refer to dimensions specified on the execution drawings .

Maximum tolerances for surface irregularities , or resulting from shift between forms , after forms are removed , is 5 mm .

Should one or several of the above specified tolerances be exceeded , there shall occur :
- either repairs ,
- or pulling down and reconstruction of the works or part of works .

3.10.15. Cleaning surfaces , finishing

After the removal of forms the surfaces of works shall be cleaned and the remainders of mortar shall be taken away .

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All mortars used for finishing or filling holes shall contain an admixture against any shrinkage of the mortar .

At the end of the works , all visible surfaces shall be clean , smooth and free of any stain .

3.11. Steel for concrete

Steel used for reinforced concrete shall as a rule be of the types F and E 22 . The rated elastic limit of such steel shall be at least 24 kg/mm2 .

Splicing wires shall be made of supple iron wire or soft reheated steel . Reinforcing materials shall be cleaned of any trace of flaky rust , earth , paint or any other objectionable substance .

Steel bars shall be stored with care and laid on props so that they be raised above soil surface and remain rigid .

3.12. Steel for trashrack

Trashracks are used to prevent trash carried by the flow from entering the outlet conduit of the dam .

The bars used shall be round steel bars 20 mm in diameter , with a spacing of 7 cm between center-lines and welded at each end upon a flat steel bar of size 40 x 10 .

To protect them against oxydation , steel bars shall receive one layer of red lead and two layers of paint .

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3.13. Conduits

The procedure employed to build outlet conduits will be as follows .

The compacted earthfill of the dam shall be built until an elevation equal to the upper elevation of cutoff masks .

When this elevation is reached , a trench shall be dug along the axis specified for the outlet conduit ,with a width equal to the diameter of the conduit + 0.60 m , to the depth specified for the lower generant of the conduit. If the bottom of the trench hits the bedrock , the trench shall be dug on an additional depth of 1/2 of the diameter of the conduit , then filled on that depth with the same material as the embankment,then compacted using hand tampers.

Trenches necessary for the construction of cutoff masks along the conduit shall then be dug .

Conduit elements in ductile cast-iron with bolted Express joints (or equal) , 6 m in length , shall be laid in such a way that there be always one joint between two cutoff masks , the distance between a joint and the center line of the nearest cutoff mask being not less than 2 m .

Concrete shall then be placed in the unformed trenches of the cutoff masks , with forms only on the free vertical faces .

Finally the trench around the conduit shall be filled with earth and compacted , by hand tampers until 20 cm above the upper generant , then by mechanical tampers .

.../...

3.14. Slide gates

The gates controlling the opening at the upstream end of the outlet conduits shall be slide gates upon walls operating under pressure .

Their characteristics shall be as follows :

- model : LEMEYGPIC VG or similar
- nature of metal :
  - +of frame : structural steel E24-1 or equal
  - +of gate : folded steel sheet
- protection :sandblasting , zinc metallisation , glycerophtalic enamel paint
- detail of the tightness joint : "music note" type , material : neoprene .
- leakage discharge : less than 0.2 l/s per meter along joint

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3.15. Waterstops

The waterstops , the locations of which are shown on the execution drawings , shall be made of neoprene or any equivalent material . They shall have the following characteristics :

- tensile strength , minimum	210 kgf/cm2
- tensile strength at 300 % modulus , minimum	80 kgf/cm2
- elongation at break , minimum	450 %
- hardness , durometer type A	60 to 70
- specific gravity	1.15 ± 0.03
- absorption of water , percentage by weight , maximum(2days at 70° C)	5 %
- constant deflection after compression percent of original deflection	30 %
- tensile strength after oxygen pressure test (48h,70° C,21kgf/cm2)percent of strength before aging , minimum	80 %
- elongation after oxygen pressure test (48h,70° C,21kgf/cm2)percent of elongation before aging , minimum	80 %

Waterstops shall be stored under shelter from light . They shall be placed before placing the concrete of the adjoining walls . Special care shall be exercised during vibration about the joints to ensure a continuous bond between the concrete and the waterstop at all points around the periphery of the waterstop .

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3.16. Synthetic membrane

The membranes in synthetic material , type BIDIM U24 used as a filtering layer between the earth and the riprap cover shall have the following characteristics:

Thickness under	0.005 bar	: 1.9 mm
	2 bar	: 0.8 mm
porosity under	0.005 bar	: 92 %
	2 bar	: 81 %
normal permeability under	0.020 bar	: 3.10^{-3} m/s
	2 bar	: 7.10^{-4} m/s

tensile strength : 9.8×10^{3} N/m

surface-mass : 0.21 kg/m2

Synthetic membranes shall be used in the following structures , according to the drawings :

-downstream foot of embankment slopes
-riprap over embankment surfaces
-gabions and riprap protecting spillways

Placing shall be performed after grading the plane of placement by taking off the largest unevennesses .

The membrane rolls shall then be unrolled , beginning with the trench of the toe riprap downstream and the cutoff spur of the riprap upstream . The overlap between membranes shall be at least 50 cm .

REPUBLIQUE ISLAMIQUE DE MAURITANIE

Ministère du Développement Rural

RECLAMATION AND CONSTRUCTION OF 15 DAMS IN THE BRAKNA & GORGOL REGIONS

STUDIES FINANCED BY USAID

CONTRACT N° AID 682 - C O - P M & R - 80-01

PROJECT : E B U 2

TECHNICAL STUDIES

GENERAL REPORT

D. - HYDROLOGY

B. P. 321
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SOCIETE NATIONALE POUR
LE DEVELOPPEMENT RURAL

S O N A D E R

Département Etudes et Travaux

H Y D R O L O G Y

D A M S I N T H E B R A K N A
A N D G O R G O L REGIONS

N.B. Important : The dimensions of structures contained in the present hydrological report are those that were known writing this report . For the dimensions finally chosen please refer to the drawings of each dam .

H Y D R O L O G Y

1. - RAINFALL DATA

2. - DETERMINATION OF EXCEPTIONAL DAILY RAINFALLS.

3. - AVAILABLE VOLUMES

4. - PROJECT FLOOD

4.1. DECENNIAL FLOOD

4.2. FIFTY-YEAR AND HUNDRED YEAR FLOOD

4.3. PROJECT FLOOD

5. - DETERMINATION OF DAM HEIGHTS

6. - SPILLWAY DESIGN

BIBLIOGRAPHY

ANNEXES : DATA

ISOHYETS AND ABAQUES.

1 - RAINFALL DATA

The 15 dams we have surveyed are all located in the Brakna and Gorgo areas and in the Aleg-M'Bout triangle. The data have been collected from the 'Service Météorologique de Nouakchott'. The daily and annual rainfalls in the stations of Kaedi, M'Bout, Aleg and Moudjeria have been taken into considération because they were quite close to the sites surveyed. The periods of observations have stretched over 50 years except for the M'Bout station where there are noticeable gaps (36 years only of observations). All the data are to found in annexes.

2 - DETERMINATION OF EXCEPTIONAL DAILY RAINFALLS.

On the basis of available data, the maximumdaily rainfalls per year have been computed according to a statistical law (Gumbel law) which the on-the-field observations match quite well. Working out the quantiles of dam sites from those of hydrometric stations was done by a 3-points interpolation based on geographic coordinates.

MAXIMUM DAILY RAINFALL (in mm)

Stations	Length of observation (in years)	Frequency of rainfalls					
		1/2	1/5	1/10	1/20	1/50	1/100
BOGHE	51	51,7	70,8	83,5	95,6	111,4	123,1
ALEG	47	36,7	58,4	71,5	84,0	100,2	112,4
KAEDI	53	58,7	94,5	118,2	140,9	170,2	192,3
M'BOUT	38	52,1	74,2	88,8	102,8	121,0	134,6
MOUDJERIA	46	36,0	57,5	71,8	85,4	103,1	116,4
KIFFA	20	43,2	56,9	66,0	74,7	86,0	94,5

.../...

3 - AVAILABLE VOLUMES

Considering the lack of experimental data, the rain-off coefficients have been estimated in ratio to the surface slope of the watershed.

Experiments made by Brunet Mored in Mauritania (Tagant and Brakna) give, for 150 to 250 mm rainfalls and 40 to 100 km2 watersheds, coefficients raiging from 10 to 20 % on an average year.

The average rainfalls have been computed either graphically on isohyets or through interpolations from the selected stations.

To compute the available volumes, the average interpolated rainfalls in Aleg, M'Bout and Moudjeria have been chosen.

4 - PROJECT FLOOD

Considering the lack of hydrometric data, the estimate of floods have been made according to the method of Rodier and Auvray "estimate of decennal flood run offs for watershed surface inferior to 200 km2". Slight alterations have been made as regards the calculation of the scalefactor * by a more recent statistical study (VILLAUME DU CIEH)resting on more important expérimental data.

VILLAUME suggests a formula, the scale factor (SF) being function of recurrence time (r), average rainfall on the spot (R) and the watershed area (A).

$$SF = 0{,}001\ (9 \log 10\ r - 0{,}042\ R + 152) \log 10\ A$$

In the diagrams of the annexes refering to the Sahelian zone, the formula adopted is the following :

$$SF = 1 - 0{,}136 \log.10\ A \text{ with } R = 600 \text{ mm}$$

RODIER an AUVRAY use the method of the unit hydrogram, that is, for a storm, homogeneous in space and whose duration at high and average intensity is inferior to a given limit (in practice, less than half the time in hours from start to peak flood) all the run off hydrogram per unit implies to be curves of similar schapes. The method of the hydrogram per unit implies.

* used to compute average rainfall from pint rainfall.

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DAMS	PERMEABILITY AND SLOPE CLASS		AREA	COEFFICIENTS RUNOFF	AVERAGE ANNUAL RAINFULL (1) en mm	(2)	AVAILABLE MILLIONS (1)	(2)	VOLUMES M3
1. CAG EL MOHOR	R_2	P_2	80	0,075	262,5	253,7	1,57		1,52
2. TIMBARA	R_3	P_3	106	0,075	255	251,1	2,20		2,00
3. TOUEIDIMA	R_2	P_2	8	0,100	260	261,5	0,21		0,21
4. AMEIRA	R_2	P_2	13	0,100	250	249,1	0,32		0,32
5. ZMEILATT	R_3	P_2	120	0,150	312,5	299,3	5,62		5,39
6. MOUDJ FOUNTI	R_2	P_3	90	0,100	315	307,8	2,83		2,77
7. OUDEI CKRACK	R_3	P_2	106	0,150	340	328,3	5,41		5,22
8. LEHNEIKATT	R_3	P_2	389	0,100	360	342,1	14,0		13,3
9. AZGUEILEM	R_3	P_2	73	0,150	365	352,9	4,0		3,86
10. TOUEIZ KRETT TAGATT	R_3	P_2	11	0,175	355	339,3	0,68		0,65
11. MINT AOU AOU	R_3	P_3	350	0,075	245	244,3	6,43		6,41
12. LEMAOUDOU	R_3	P_3	34	0,075	285,5	279,1	0,73		0,71
13. BOUDJOUNGAL	R_3	P_3	61	0,100	290	283,8	1,33		1,30
14. JREKAYA	R_3	P_3	14	0,100	275	275,1	0,38		0,38
15. BOUSSOUELIF	R_3	P_3	9	0,125	280	293,9	0,31		0,33

(1) on isohyets

(2) interpolation in three points ALEG-M'BOUT-MOUDJERIA.

theoretically, that the special distribution of water on the watershed is always identical to itself. The smaller the watershed, the better this hypothesis becomes. Besides, it is the only case of application of the method. For the great watershed such as Mint Aouaou and Lehneikatt, the results arrived at though extrapolation must be considered with the utmost caution.

4.1. Decennal flood

The average flood discharge is function of the decennal point rainfalls (R 10), the scale factor (SF), the watershed area (A), the run off coefficient (KR) and the time-base (tb). To this average discharge is applied a multiplying coefficient adjusted to the hydrogram shape. (K)

$$Q_{10} = K\ (R_{10} \times Sr \times A\ KR/tb)$$

The climatic conditions are Sahelian and subdesertic, the watershed areas being known, the other determining parameters are slope and permeability.

Estimating slopes and permeabilities have been done on a map at 1/200,000, on aerial photographs and through field work observations.

Watersheds are thus classified :

in slope - R2 weak between 2°/00 an 5°/00
- R3 moderate between 5°/00 and 1°/00
- R4 fairly strong lenghtwise between 1 an 2%
  crosswise more than 2 %

in permeability

- P2 almost impervious basins
- P3 fairly " "

.../...

The decennal discharges are computed in the form of diagrams with a supposed point decennal rainfall equal to 100 mm. Diagrams were drawn in function of areas for a slope R and a permeability K. For application to the discharge of the surveyed area, we can use the formula

$$Q_{IO} = Q\ IO \times \frac{PIO}{100}$$

4.2. Fifty-year and hundred-year flood

Discharges are computed in the same way as for the ten-year flood by adding 15 % according to the author's formula :

$$Q_n = Q_{10} \quad \frac{P_n}{100} \times 1,15$$

As a comparison, calculations with the GUILLOT and DUBAND gradex method were made. This method is based on the assumtion the the additional rainfall in excess of a certain value with low frequency runs off in its entirety.

The more impervious soils are, the closer we get to the actual run offs, beyond the P IO

$$Q_n = Q_{IO} + \frac{KSFA}{tb} \quad (P_n - P_{IO}) \quad \frac{(tb)^n}{(24)}$$

$$Q_n = Q_{IO}\ (1 = \frac{Pn - PIO}{P_{IO}})\ (\ \frac{tb/24)^n}{K_r})\ )$$

$$Q_n = Q_{IO} \text{ with } C = I + \frac{P_n \quad -P_{IO}}{P_{IO}} \quad \frac{(tb/24)^n}{K_r}$$

C = multiplying coefficient with K_r

.../...

C^I = multiplying coefficient by taking a run off coefficient in between K_r and I

$$C^I = \frac{P_{I00} - P_{I0}}{P_{I0}} \quad (tb/24)^n \; \frac{I + K_r}{2 - Kr}$$

tb = time base

Kr = run off coefficient

DAMS	CLASS	AREA	Q*10m3/S	Pmm10	Q10m3/S	Q10m/S/Km2	P50	Q50	P100	Q100	Q50/Q10	Q100/Q10
1. CAG EL MOHOR	R2 P2	80	38	81	30,8	0,38	115	50,2	130	56,6	1,63	1,84
2. TIMBARA	R2 P2	106	45	76	34,2	0,32	113	58,5	127	65,7	1,71	1,92
3. TOUEIDINA	R2 P2	8	20	82	16,4	2,05	117	26,9	131	30,2	1,64	1,84
4. AMEIRA	R2 P2	13	21	76	16,0	1,23	108	26,1	122	29,4	1,63	1,86
5. SMEILATT	R3 P2	120	98	100	98,0	0,82	144	162,3	162	182,6	1,66	1,84
6. MOUDI FOUNTI	R3 P3	90	42	93	39,0	0,43	132	63,7	149	71,9	1,63	1,84
7. OUEI CHRACK	R3 P2	106	97	94	91,2	0,8[illegible]	132,5	147,8	148,5	165,6	1,62	1,81
8. LEHNEIKATT	R3 P2	389	153,8	95	146,1	0,37	134	237,0	149	163,7	1,62	1,80
9. AZGUEILEM	R3 P2	73	84	97	81,5	1,12	135,5	130,9	152	147,1	1,61	1,80
10. TOUEIZ K. TAGATTR	R3 P2	11	44	94	41,4	3,76	132	66,8	147,5	74,6	1,61	1,80
11. MINT AOU AOU	R3 P3	350	75,5	73	55,1	0,16	104	90,3	117	101,4	1,64	1,84
12. LEMAOUDOU	R3 P3	34	28	91	25,[illegible]	0,75	130	41,5	147	47,5	1,64	1,86
13. BOUDJOUNGAL	R3 P3	61	46	91	43,2	0,71	135	71,4	152	80,6	1,65	1,86
14. JREKAYA	R4 P3	14	48	94	42,2	3,02	126	69,5	143	75,4	1,65	1,79
15. BOUSSOUBILIF	R3 P3	9	1.8	88	14,9	1,16	117	24,2	131	27,1	1,62	1,82

METHOD RODIER - AUVRAY

DAMS	Q_{10}	$\frac{P_{100} - P_{10}}{P_{10}}$	$\frac{P_{50} - P_{10}}{P_{10}}$	tb	Kr	C_{100}	C_{100}'	C_{50}	C_{50}'
1. CAG EL MOHOR	30,8	0,60	0,42	58,7	0,34	2,96	1,98	2,37	1,59
2. TIMEARA	34,2	0,67	0,48	27,8	0,22	4,44	2,71	3,36	2,11
3. TOUEIDIMA	16,4	0,60	0,42	14,5	0,58	2,09	1,65	1,76	1,39
4. AMEIRA	16,0	0,60	0,42	18,7	0,52	2,12	1,61	1,78	1,35
5. ZMEILATT	98,0	0,62	0,44	37,2	0,40	2,63	1,84	2,16	1,51
6. MOUNDI FOUNTI	39,0	0,60	0,41	26,3	0,20	4,03	2,42	3,12	1,87
7. OUDEI CHRACK	91,2	0,58	0,41	34,0	0,41	2,47	1,74	2,04	1,44
8. LEHNEIKATT	146,1	0,57	0,41	76,2	0,14	5,68	3,24	4,46	2,54
9. AZGUEILEM	81,5	0,57	0,40	24,0	0,43	2,32	1,66	1,93	1,38
10. TOUEIZ K. TAGATT	41,4	0,57	0,40	8,4	0,53	1,95	1,49	1,67	1,27
11. MINT AOU AOU	55,1	0,60	0,43	770,0	0,19	4,59	2,73	3,57	2,12
12. LEMAOUDOU	25,5	0,62	0,43	15,7	0,22	3,68	2,24	2,86	1,74
13. BOUDJOUNGAL	43,2	0,62	0,43	21,3	0,21	3,91	2,36	3,02	1,83
14. JREKAYA	42,2	0,62	0,43	5,0	0,35	2,47	1,67	2,02	1,36
15. BOUSSOUEILIF	14,9	0,58	0,41	7 5	0,28	2,80	1,79	2,27	1,45

GUILLOT AND DUBAND METHOD.

4.3. PROJECT FLOOD

The inaccuracy of flood estimates is conditioned by the uncertainty which prevails in parameters P and R.

A priori, the method will not enable us to evaluate floods with great precision but only to give a rough estimate.

For security reasons and to the cheap side, we shall consider the fifty-year flood as project flood.

5. DETERMINATION OF DAM HEIGHTS

The height of dams was chosen in function of the following criteria :

- Volume which can be stored : topography
- Available volumes : rainfalls
- Pedoligical and sociological considerations : cultivable areas and populations living in the neighbourhood of the site.

It was decided that the crest of dams should be fixed at 1,50m above the height of the reservoir water surface (spillway level) except in case of total storage dam where freeboard was fixed at 1 m.

As regards dams to be repaired, the heights remain the same as initially.

The total storage dams were based on a fifty-year maximal annual rainfall.

TOUEIZ KRETT : Average annual rainfall R + 339 mm
Fifty-year rainfall R 50 = 637,5mm

BOUSSOUEILIF : R = 294 mm and R 50 = 579 mm.

.../...

DAMS	AVAITABLE VOLUMES / M3	STORAGE VOLUME	WET AREAS	ELEVATION NORMAL WATERLEVEL	CREST ELEVATION	LENGTH OF THE DAM
1. CAG EL MOHOR	1.520.000	260.000	57	101,0	102,5	1588
2. TIMBARA	2.000.000	-	-	-	-	-
3. TOUEIDIMA	210.000	-	-	-	-	-
4. AMEIRA	320.000	300.000	55	100,8	101,3	1375
5. ZMEILATT	5.390.000	450.000	75	7,75	9,0	900
6. MOUDI FOUNTI	2.800.000	500.000	80	9,5	9,5	277
7. OUED CHRACK	5.220.000	2.125.000	205	8,0	9,5	1600
8. LEHNEIKATT	15.300.000	7.500.000	750	10,0	11,6	1100
9. AZGUEILEM	3.860.000	300.000	45	11,0	12,0	1133
10. TOUEIZ KRETT	650.000	1.200.000	95	9,75	10,75	715
11. MINT AOU AOU	6.410.000	4.250.000	350	100,0	101,5	330
12. LEMAOUDOU	710.000	800.000	120	99,8	101,3	90
13. BOUDJOUNGAL	1.300.000	1.500.000	140	99,0	100,5	550
14. JREKAYA	350.000	400.000	52	95,0	96,5	445
15. BOUSSOUEILIF	330.000	600.000	53	97,0	98,0	135

THE TOTAL STORAGE DAMS WERE BASED ON A FIFTY YEAR MAXIMAL ANNUAL RAIN-FALL

WET AREA ON AVERAGE ANNUAL RAIN FALL : 47,5 HA - BOUSSOUEILIF

65 HA - TOUEIZ KRETT

6. SPILLWAY DESIGN

The 50 years routed flood was chosen as project flood. The effect of routing leads to an important decrease in the length of spillways.

The graphical method of the "Centre Technique du Génie Rural, des Eaux et Forêts" (CRAGEF) was used for flood routing. It is based on resolution of the differential equation expressing routing :

$$Qc\ (t) = Qe\ (Z)\ dt + A\ (Z)\ dz$$

Where
- t = time
- z = water level above spillway
- Qc = inflow
- Qe = out flow
- $A(z)$ = reservoir

For a given level above spillway or a fixed spillway length, the ratio Qe/Qc may be read.

The routed 50 year flood is close to the 10-y flood without routing, except for large, impervious water sheds with steep slopes.

.../...

DAMS	Q = Q50m3/s / SPILLWAY DAM (m)	Q10 / SPILLWAY DAM	tm/ HOURS	Zc / a	AZc / Tm Qc	Qe / Qc gr %	Qe = SPILLWAY DAM
1. CAG EL MOHOR	50,2 - 79	30,6 - 49	12,2	0,67	0,21	85	42,7 - 67
2. TIMBARA	58,5 - 92	34,2 - 54	6,7	-	-	-	-
3. TOUEIDIMA	26,9 - 42,5	16,4 - 26	3,0	-	-	-	-
4. AMEIRA	26,1 - -	16,0 - -	4,0	0,48	-	-	Digue devers.de 933 m
5. ZMEILATT	162,3 - 257	98,0 - 154	7,3	0,43	0,09	95	154,2 - 244
6. MOUNDI FOUNTI	63,7 - -	39,0 - -	6,0	0,67	-	-	Digue devers.de 277 m
7. OUDEI CHRACK	147,8 - 233,5	91,2 - 144	6,7	0,43	0,22	80	118,2 - 187
8. LEHNEIKATT	237,0 - 285	146,1 - 231	15,1	0,48	0,35	77,5	183,7 - 221
9. AZGUEILEM	113,8 - 180	81,5 - 128	5,7	0,71	0,09	92,5	105,3 - 166,5
10. TOUEIZ KRETT	66,8 - -	41,4 - -	2,1	0,42	-	-	retenue totale
11. MINT AOU ACU	90,3 - -	55,1 - 87	10,8	0,43	-	-	Déversoir naturel de 110 m
12. LEMAOUDOU	41,9 - -	25,5 - 40	3,8	0,30	-	-	Digue de 90 m
13. BOUDJOUNGAL	71,4 - -	43,2 - 68	5,2	0,37	0,52	62,5	Digue de 305 m
14. JREKAYA	69,6 - -	42,2 - -	1,2	0,44	-	-	Dévers.naturel de 200 m
15. BOUSSOUEILIF	21,1 -	14,9	1,9	0,31	-	-	retenue totale

* All dams, the water level about spillway has been set to 50 cm except LEHNEIKATT 60 cm

For spillways dams and total storage dans cf. computation of spillways with a given length.

COMPUTATION OF SPILLWAYS WITH A GIVEN LENGTH

- LEMAOUDOU dam

Length = 90 m
Fifty-year discharge Q50 = 41,9 m3/3
Without flood-routing level above spillway he = 40 cm
With flood routing $\frac{Zc}{n}$ = 0,30, $\frac{AZe}{QcTM}$ = 0,84, $\frac{Qe}{Qc}$ = 0,60, he = 24 cm

- MOUDI FOUNTI dam

Spillway dam = 277 m long
Fifty-year discharge Q50 = 63,7 m3/5
Without flood-routing level above spillway he = 25 cm
With flood-routing $\frac{Zc}{n}$ = 0,33, $\frac{AZc}{TMQc}$ = 0,14, $\frac{Qe}{Qc}$ = 0,925, he 23 cm

- JREKAYA dam

Natural spillway = 200 m long
Q50 = 59,5 m3/5, without flood-routing he = 33 cm
With flood-routing $\frac{Zc}{n}$ = 0,44, $\frac{AZc}{TMQc}$ = 0,58, $\frac{Qe}{Qc}$ = 0,70 he = 23 cm

- AMEIRA dam

Spillway dam = 933 m long, without flood-routing he = 6 cm
$\frac{Zc}{n}$ = 0,46, $\frac{AZc}{TMQc}$ = 0,09, $\frac{Qe}{Qc}$ = 0,95, he 6 cm

- BOUDJOUNGAL DAM ET MIST AOUAOU DAM

Total storage dams dimensioned to 50 year annual rainfall

TOUEIZ KRETT Average rainfall R = 339 mm R 50 = 637,5 mm

.../...

BOUSSOUEILIF R = 294 mm, R 50 = 579 mm

From the report of 'Mission d'Etudes hydroagricoles en Mauritanie 1959 SOGETA

Existing dams with no topographic maps available

- TIMBARA Qc = 58,5 m3, without flood-routing, and, the sheet of water being 50 cm high, the width of overflow is 92 m

- ROUEIDIMA Qc = 26,9 m3/s, he = 50 cm and the width of overflow without flood-routing = 42,5 m.

ADDED INFORMATION

COMPUTATION OF SPILLWAY WITH A GIVEN LENGTH

BOUDJOUNGAL DAM

Spillway dam = 305 m long
Fifty-year discharge Q50 : Qc = 71,44 m /s
Without flood-routing, level above spillway he = 26 cm
With flood-routing $\frac{Zc}{n}$ = 0,37, $\frac{AZc}{QcTM}$ = 0,27 $\frac{Qe}{Qc}$ = 0,85 cm

he = 22 cm

MIET AOUAOU

Length of dam = 117 m
Qc = 90,3 m3/s without flood-routing he = 57 cm
With flood-routing $\frac{Zc}{n}$ = 0,43 $\frac{AZc}{TMQc}$ = 0,50 $\frac{Qe}{Qc}$ = 0,75

he = 43 cm.

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REMARKS

The lack of hydrometric measurements offers a big gap in this hydrological survey. It would be good if, in the future, hydrometric stations could be built before undertaking any survey of this kind of dam.

In the present survey, we should consider a hydrological survey follow-up on certain sites, which might minimize errors in the estimation of flood discharges.

Silting time has not been looked into as hydric erosion was weak, owing to gentle slopes and the nature of watershed soils.

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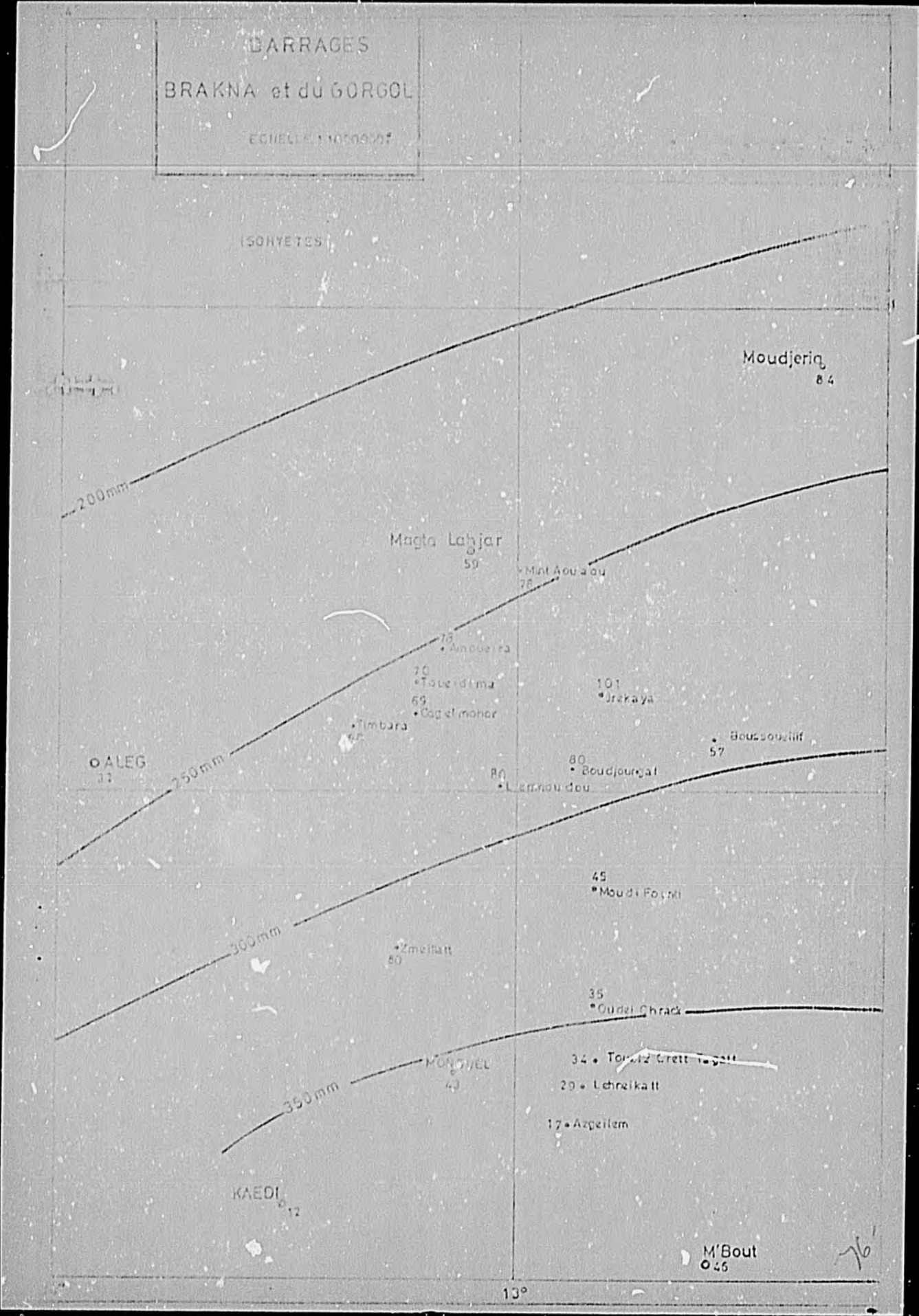
BARRAGES
BRAKNA et du GORGOL
ECHELLE 1/1050000e
ISOHYETES
Moudjeria
84
200mm
Magta Lahjar
59
Mint Aoudou
78
Amoueira
70
Touerdima
69
Cagelmoner
Timbara
101
Brekaya
Boussouilif
57
ALEG
31
250mm
80
Boudjourjat
80
Lemhoudou
45
Moudi Fouki
300mm
Zmeitat
80
35
Oudei Chrack
MONGUEL
40
350mm
34
Lehreikatt
29
Azgeilem
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KAEDI
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M'Bout
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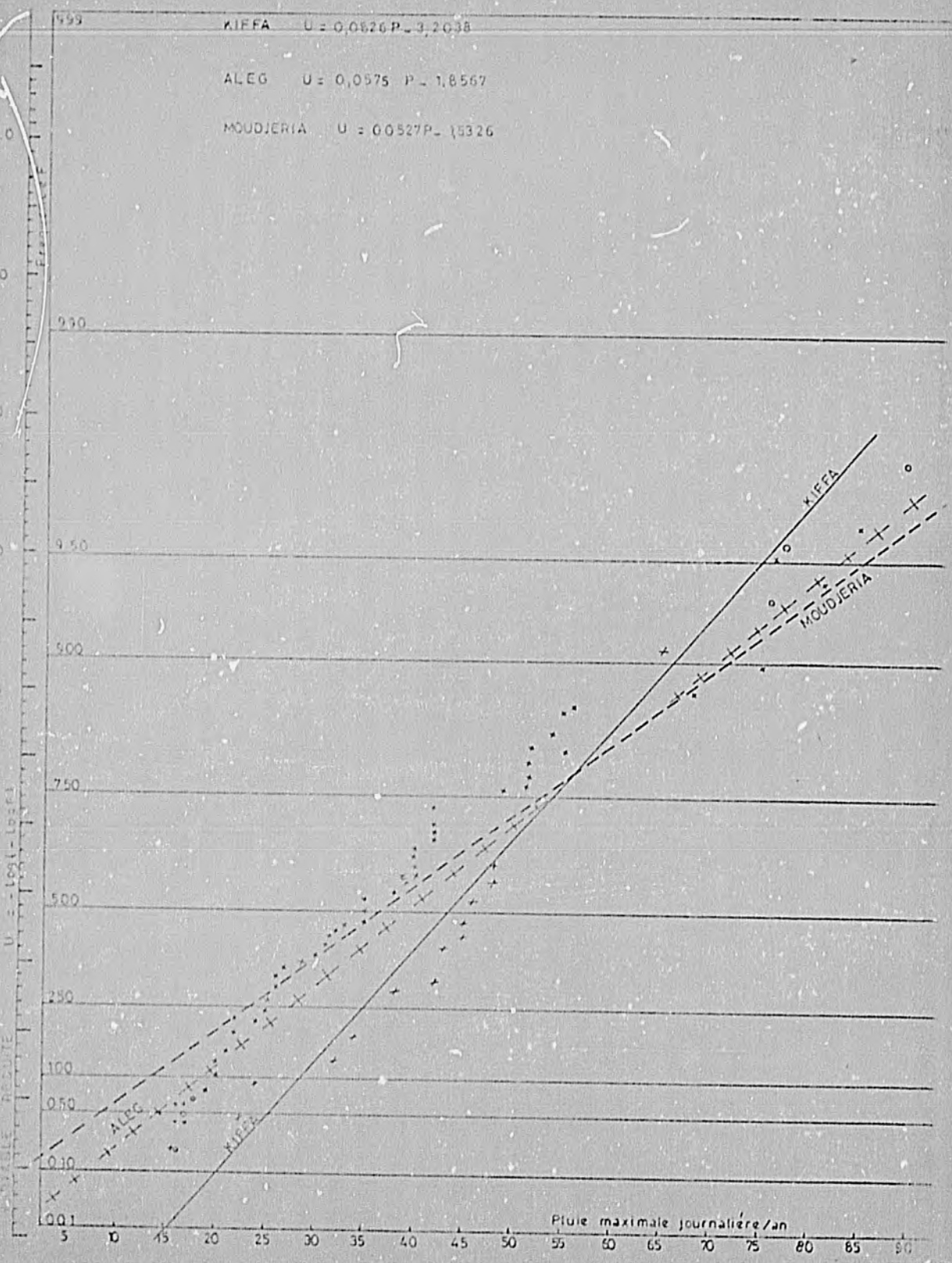
13°

AJUSTEMENT GUMBEL PLUIE PONCTUELLE MAXIMALE

JOURNALIERE



AJUSTEMENT GUMBEL PLUIE PONCTUELLE MAXIMALE

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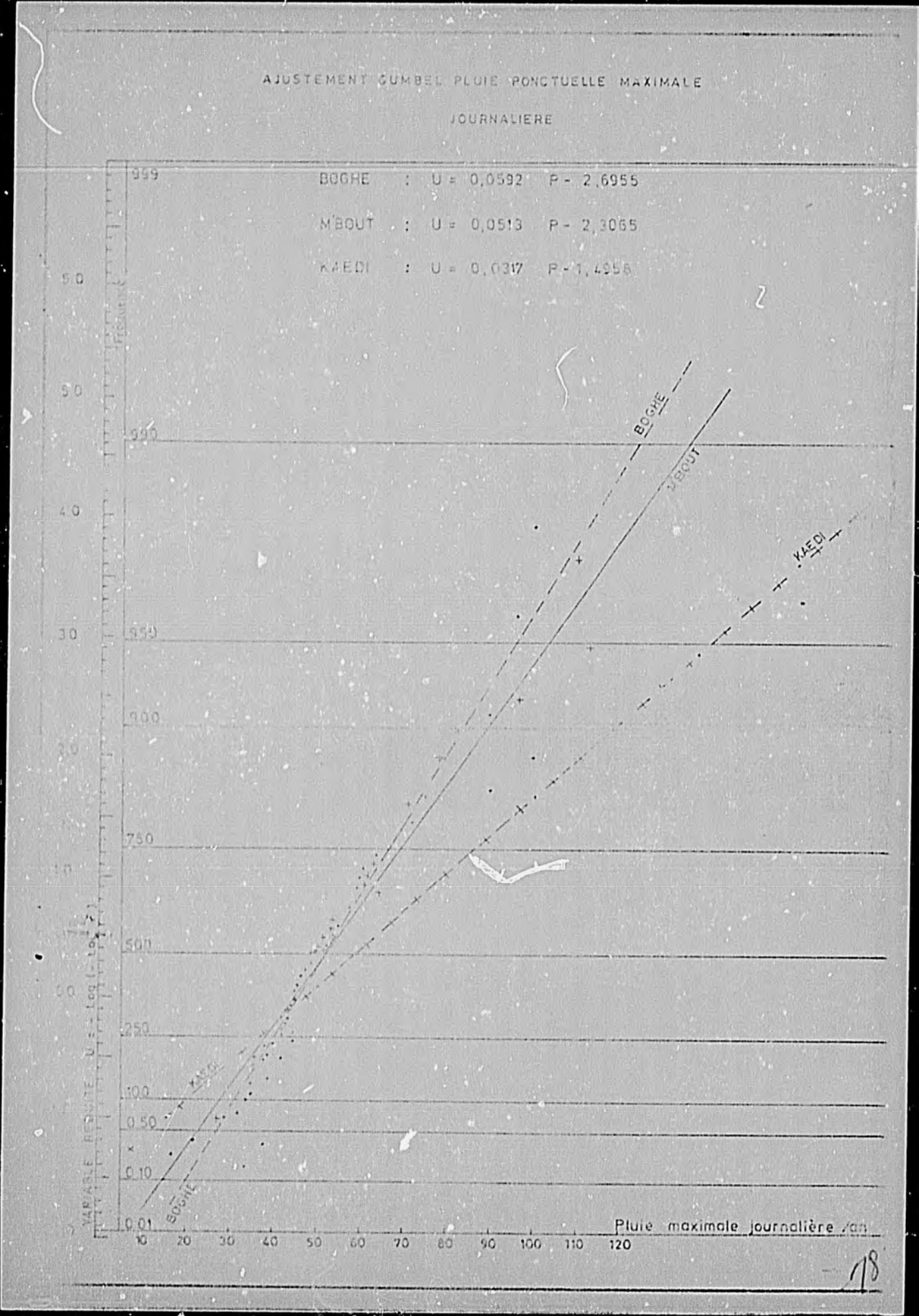
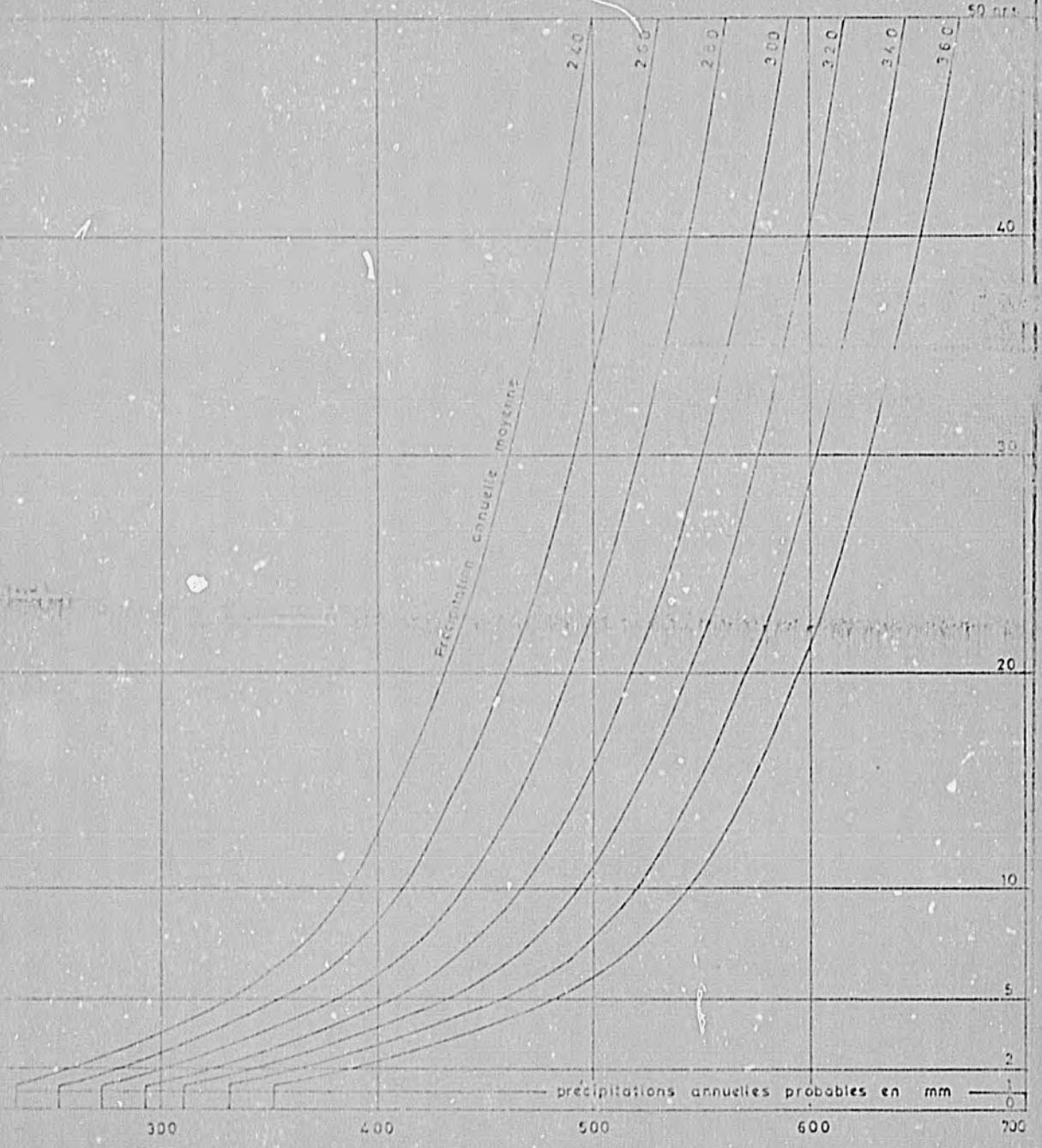


Pluviométrie annuelle ponctuelle "probable" en fonction de la pluviométrie annuelle moyenne et de la "période"

années fortes



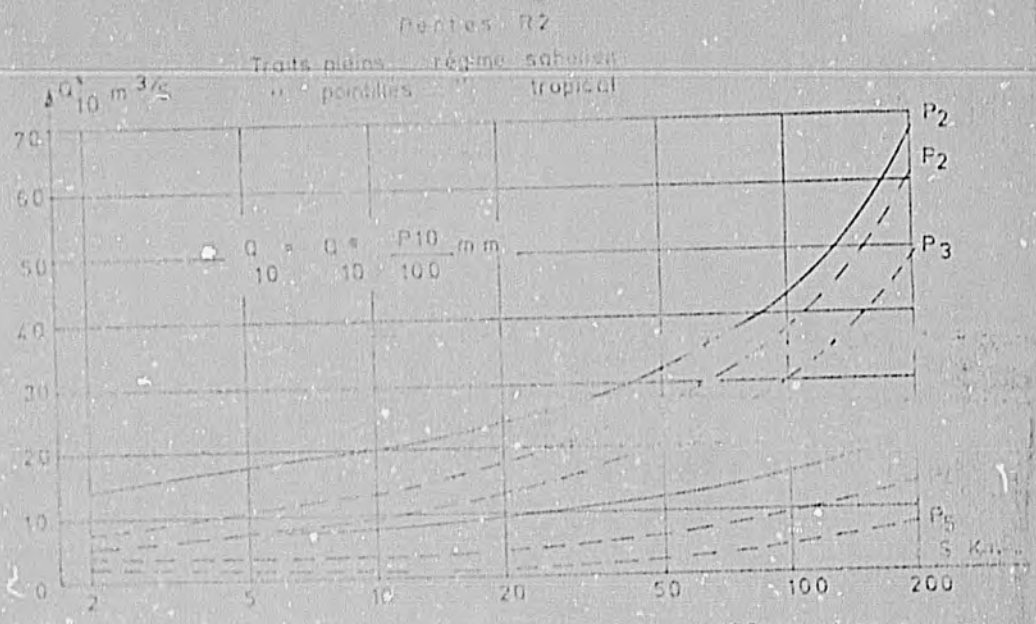


Fig 1 Débit décennal pour une pluie décennale de 100 mm et pour des pentes R2

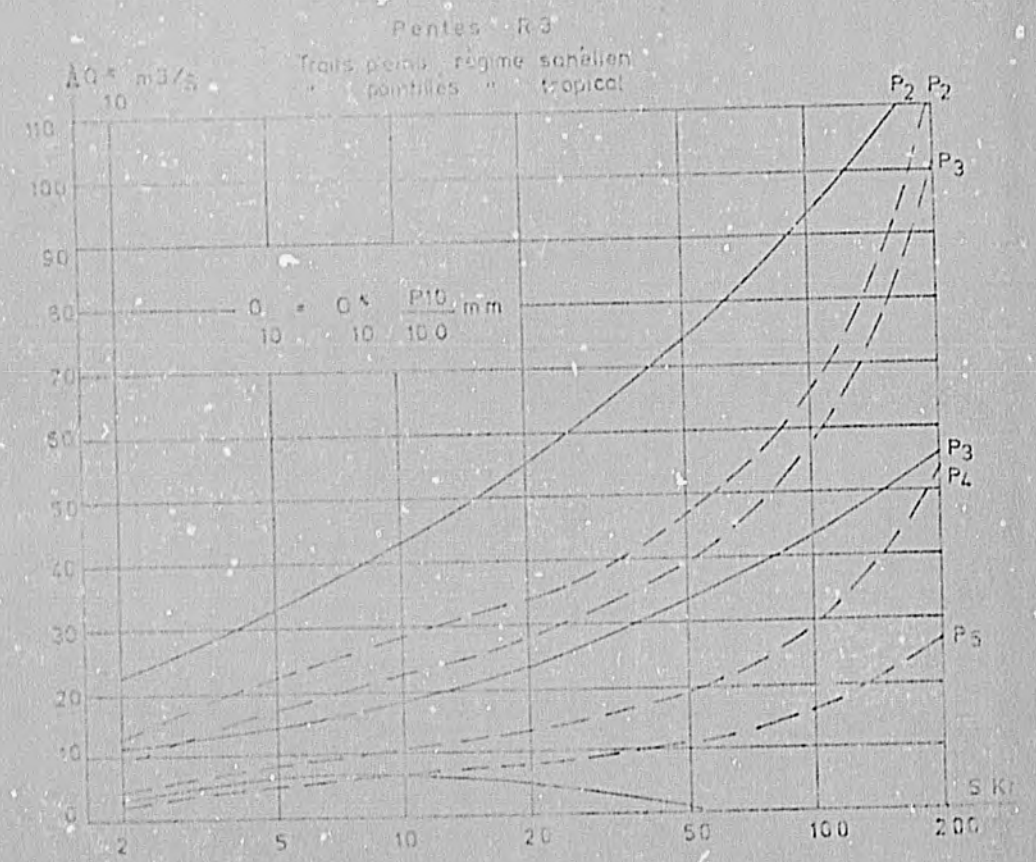


Fig. 2 Débit décennal pour une pluie décennale de 100 mm et pour des pentes R3

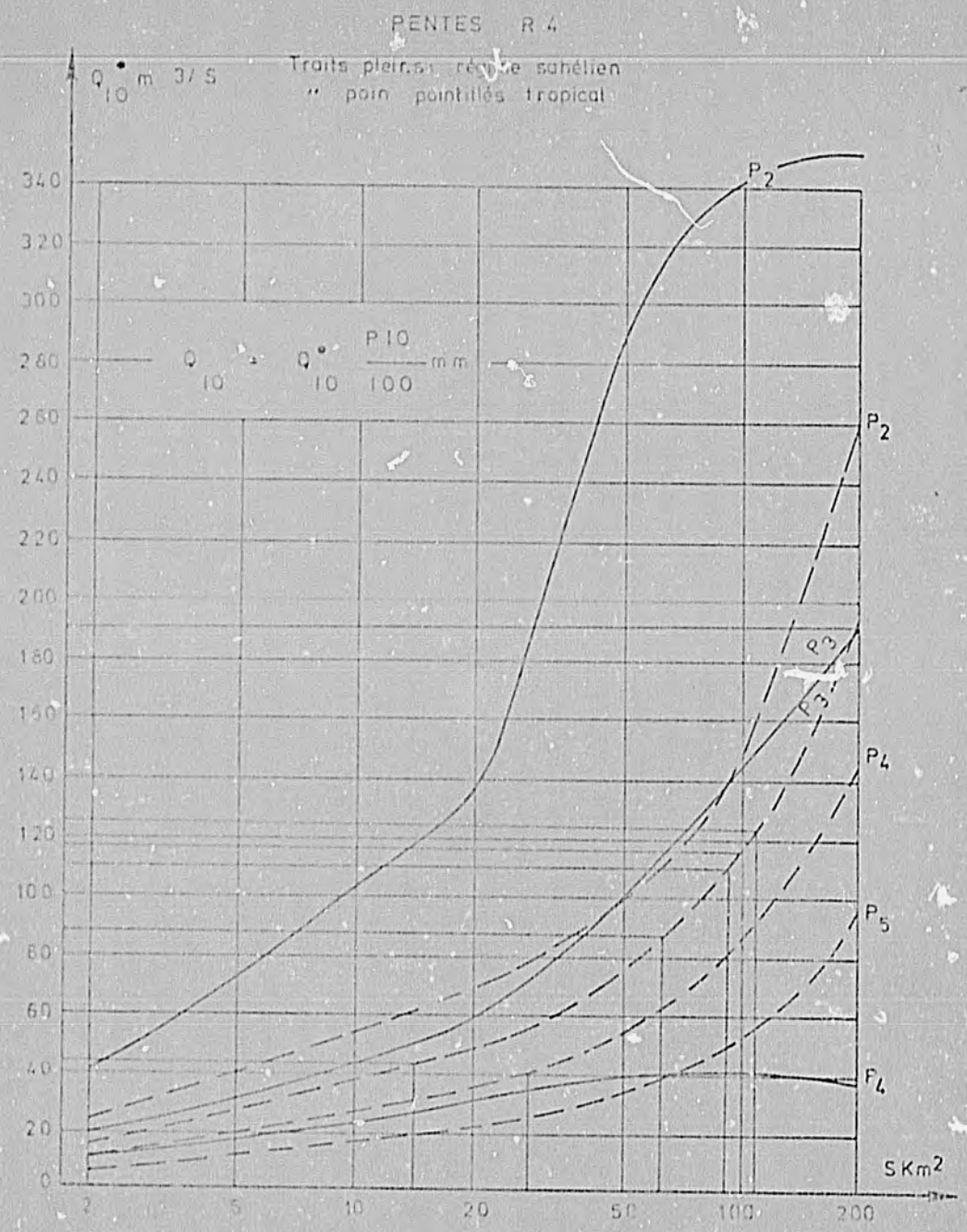


Fig. 3 Débit décennal pour des pentes R 4 et une pluie décennale de 100m

REPUBLIQUE ISLAMIQUE DE MAURITANIE

Ministère du Développement Rural

RECLAMATION AND CONSTRUCTION OF 15 DAMS IN THE BRAKNA & GORGOL REGIONS

STUDIES FINANCED BY USAID

CONTRACT N° AID 682 - C O - P M & R - 80-01

PROJECT : E B U 2

TECHNICAL STUDIES

GENERAL REPORT

E. HYDROGEOLOGY

B. P. 321
NOUAKCHOTT

JULY 1980

S U R V E Y O F I 5 D A M S I N
T H E B R A K N A A N D G O R G O L A R E A S

HYDROGEOLOGY
WATER REQUIREMENTS OF THE WORKS

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1 - Water requirements of the works

2 - Hydrogeology

3 - Alternate solutions

4 - Conclusions

I - ESTIMATE OF THE REQUIREMENTS

As we have not completed the survey yet and taken final options for the works to be undertaken and the way they are to be done we shall now only make assumptions with a view to ascertain needs in function of the two types of works which could be carried out :

- embankment dams
- concrete works

I.1- EMBANKMENT DAMS

We have assumed that they will be built in the usual way by means of the usual machinery. The normal equipment for this type of work consists of 2 motorscrapers of 13m3 with a theoretical capacity of 100 m3/h and a practical capacity of 70 m3/h.

The water requirement is about 10 % in volume, which corresponds to an hourly requirement of 14 m3 or a daily requirement of 112 m3. In case some drilling should be done with an additional reserve at hand of about 100 m3, the discharge to be supplied by the drilling is then 4,7 m3/h. For a standard 1.000 m-long-3 m high dam, the total volume of earth is 17.000 m3 and the volume of water to supply is then 1.700 m3.

A more precise estimate for each site is given in § 1.3 below.

I.2. - CONCRETE WORKS

The works will be equipped with 2 concrete-mixers of 350 l. Each concrete-mixer has an hourly output of 350 l. x 4 = 1.400 l. The daily output of the works is then 1,4 x 2 x 8 = 22,4 m3.

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The water requirement is I80 l/m3, that is, a daily requirement of 4 m3/day. The curing of the concrete requiring 4 m3/day, the total requirement of the works will then be 8 m3/day, phas an additional 2 m3/day for human consumption. giving a total of 10 m3/day.

Such requirement can easily be met if we use a tank-wagon of 10 m3 which will make a daily trip to a well ; this well may be located quite a distance away as long as it can give more than 10 m3/h.

I.3. - DETAIL OF THE REQUIREMENT PER SITE

We have estimated the water requirements for each site with an ambankment dam which would be 3 m at crest, the ambankment slope being I/2,5 upstream and 1/2 downstream.

The estimate does not take into account the fact that part of the dam is made of concrete (spillway), which causes the needs to be overestimated.

NAME OF DAM	HEIGHT (m)	LENGTH (m)	EARTHWORK (m3)	WATER REQUIRED (m3)
CAG EL MOHOR	4	2.000	54.000	5.440
TIMBARA	/	/	1.600	I60
TOUEIDIMA	/	/	1.900	I90
AMEIRA	1,5	1.375	7.800	780
ZMEILATT	/	/	7.300	730
MOUDI FOUNTI	3,5	350	694 *	300
OUDEI CHRAK	4.5	1.600	53.300	5.330
LEHNEIKATT	4,75	925	33.800	3.380
AZGUEILEM	3,5	1.133	24.600	2.460
TOUEIZ KRETT TAGANT	4,25	700	21.I00	2.110
MINT AOUAOU	4,35	900	28.300	2.830
LEMAOUDOU	3,5	250	5.400	540
BOUDJOUNGAL	4	520	I4.I00	I.4I0
IREKAYA ALEFKARINE	3,70	220	5.300	530
	2	340	3.000	300
BOUSSOUEILIF	3,5	I80	3.900	390

* this is not earthwork but concrete.

II - HYDROGEOLOGY

All the information available has been gathered under 3 headings

2.I. Bibliography

2.2. Geological and hydrological characteristics of the project area

2.3. Location of wells and drillings. Discharges.

2.I - BIBLIOGRAPHY

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2.2. - GEOLOGICAL AND HYDROGEOLOGICAL CHARACTERISTICS OF THE PROJECT AREA

2.2.1 - Geology

The 15 sites are all located in the Mauritanides ridge. In this area, which extends to the North as far as the Akjoujt area, the matérials of the substratum of precambrian and cambrian age, plicated during the hercynian orogenesis, come up to the surface.

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The precambrian materials are particularly represented by :

- granites in the Boudjoungal and Moudi Founti areas
- micaschists with 2 micas, locally evoluting to gneiss, very altered superficially (numerous limestone concretions) on the Toueidima, Cag el Mohor, Oudei Lefkarina sites.

The cambrian materials belong to the metamorphic series of M'Bout. In the project area there can be found essentially sericotoschists (schists carrying sericites, very fine white micas with a silky appearance) mainly at Boudjoungal, Moudi Founti, Timbara, Lemaoudou, and some chloritoschists in the Gorgol : Toueiz Krett Tagatt, Oudei Chrek, , Lehadikatt, Azgueilem. These schists show a 30 to 60 % dip to the West. They are generally very friable on 2 or 3 m at least. At Boussoueilif there can be found a <u>tillite</u> to be classified also in the M'Bout series a series which is equally schistous. Finally the Zmeilatt site is on the West border of the Mauritanides, next to the atlantic sedementary basin.

The data of the geological map at 1.000.000 (ref. 3) match the findings of our field-work with a certain lack of detail, though, as regards the North area (Tachout el Haratin, Toueidima, Cag el Mohor) where the map only indicates "precambrian". Besides, the map overlooks a great number of quartzites in beds, though they form a very characteristic landscape (sites of Toueidima, Oudei Chrak, Toueize Krett Tagatt).

These materials of the substratum are visible on a great part of the surface. The rest is covered by a generally thin layer which form :

- dunes, rather few. The North of the area (Ameira site) is at present in the process of being covered over by the sand. A big dune massif, composed of fixed red sand dunes, of a 10 to 12m height, which have partially become alive again and are oriented West-South-West/East-North-East cut the project area into 2 parts.

.../...

The works which are to be built in Lemaoudou, Boudjoungal, Boussoueilif, rest in part on this massif.

- "regs" which are either covered over with a rather thick layer of black-patinaed gravel, with quite often fragments of lateritic hardpan (North and West of the project area) or composed of red, very solid clay with scattered pebbles (terraces overlooking the Gorgol). These formations generally present gentle s slopes and they cover one third of the project area.

- oued alluvia, generally very rich in clay. They are thick, except on certain sites where are artificial (Toueidima) or natural (Mint Aouaou) weirs or along the main oueds (Ketchi, Gorgol).

2.2.2. - Hydrogeology

We shall only give the general characteristics and refer the reader to § 2.3 for a detailed des cription, site after site.

The project area is generally describeb as sterile from the hydrogeological point of view. Thus, for example, the SOGETHA (ref I3) defines the project area as"sterile area" and describes it as follows (p. I5I) :

"This area is formed of metamorphic schists and quartzites of the precambrian region. There exists neither ground-water nor a network of faults". The BURGEAP report (cf 5) it is also categoric on this point. "The series of micaschists and quartzites of the Aftout and Guidimaka areas must be considered as sterile and no new well must be attempted there".

(Note : The Aftout (=plain) is the name of the Mauritanides area which is South of Magta Lahjar. It emcompasses the area of the 15 dams and is continued in the South on M'Bout, hence its other name 'Aftout Of M'Bout').

.../...

This is due to the fact that the schists which are the main matérial of the substratum are impervious when they are sound. The superficial layer of the schists, very altered, is a material which is generally rich in clay and equally impervious. The only 2 types of aquifers, necessarily very localized, are to be looked for :

A - in the area of intense faulting where the schists are likely to bear water at a depth of 50 m.

b - in the oued alluvia

No information is available on the deep aquifers of type A, no drilling having been attempted to this day. We must note first that this area presents few faults, much fewer faults, for instance, than in the area of the primary basin of Tebessa further to the East (aquifers in the pelites of the Hodh). About the site of Dionaba (quite close to Boudjoungal, Boussouellif, etc...) Delpy (1959) says : "The substratum is much less known. According to the people who live there, the schists of the basin should bear a permanent aquifer, unused, because it is over 25 m deep and the schists are too hard.. This information would thus bear out the alleged existence of aquifers associated to facies and structures ill-defined to this day and the example of which Douera and Letiotar would possibly be."

However, Gouze (1962) remarks that fissures and faults are blinded by very argilous materials coming from a process of alteration and he concludes that "we can condider this formation as totally impervious". According to him this impermeability is born out by the topography of the oueds : very dense hydrographic net, minor bed with a flat bottom and vertical sides. The choice of a site for drilling proves then to be problematic from the very first.

The sides of the B type (alluvial aquifers) have been prospected from a geophysician point of view by the PNUD mission (1975 ref. 9) which showed that only the minor beds of the oueds bore water. The discharges obtainable will be generally small and the volume of the reserve will be equally weak.

.../...

In the explanatory note of "Cartes de planification sur l'exploitation des eaux souterraines de l'Afrique Sahelienne" (BRGM, 1975) it is said that "in the north (of area of the cristalline and cristallophyllian substratum of Western Africa) the only resources are contained in the alluvial aquifers which can locally supply discharges of 25 m3/day." The estimation of the discharge, weak as it is, seems to us actually largely overestimated considering the observations we could make (§ 2.3 below). If we examine the available resources on the fringe of the project area, we can see that the only areas hydrogeologically interesting are located in the north and in the east, on a line which runs along the Aleg - Kiffa road. To be more precise, these areas are :

- in the north the Tamourt, Guimi and Magta Lahjar basins with important alluvial aquifers along the Again dunes

- in the east the edge of the Assaba plateau with natural springs and boreholes which have excellent discharges (Achram-Diouk area).

- in the south, on the contrary the Mauritanides ridge extends to the south-east towards M'Bout with as unfavourable hydrogeological characteristics as in the project area.

- in the west there is an area which is part of the Senegalo-Mauritanian sedimentary basin but which, on a width of about 20 to 30 kilomèters from east to west is sterile owing to the rising of the substratum over the piezomet level of the aquifer of the continental terminal : is is what is called "le biseau sec".("dry wedge")

2.3. - LOCATION OF WELLS AND DRILLINGS. DISCHARGES

Thanks to the kind cooperation of the hydraulic Ressources Division attached to the "Direction de l'Hydraulique" we were able to get the following information (in addition to the references mentioned above)

.../...

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A - Situation of the borings undertaken in Mauritania and controlled by the "Direction de l'Hydraulique" in January 1980.

B - Map at 1/100.000, Kaedi and Alag sheets mentioning the wells and drillings classified by the Hydraulic Ressources Division.

Map at 1/200.000, Mouddjeria and M'Bout sheets with hydrogeological interpretation BURGEAP (1966) and annotation done according to the exploratory and field work of the "Direction de l'Hydraulique".

In order to describe things more clearly we have divided the project area into 4 areas.

A - North'West area : Ketchin basin (4 sites : Ameira, Toueidima, Cag el Mohor, Timbara) and Tamourt of Magta Lahjar basin (Mint Aouaou)

B - North-Gorgol area (4 sites : Lemaoudou, Boudjoungal, Oudei Lafkarina, Boussoueilif)

C - South-Gorgol area (5 sites : Moudi Founti, Oudei Chrak, Toueiz Krett Tagatt, Lehneikatt, Azgueilem)

D - Oued Ouelouar basin : 1 single site : Zmeilatt.

2.3.1. - NORTH-WEST AREA.

The information we could find in the files of the "Direction de l'Hydraulique is very limited : the only well listed is the "oglat" (traditional non cemented well) Toueidima, but there is no mention of any depth or output.

Our observations (1978-1980) confirm the lack of cement wells and the existence of several oglats with an output ranging from weak to very weak.

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Site I : Cag el Mohor

In June 1978 the oglats of the site which had a depth of 4 meters were all dried up. In April 1980 3 productive oglats were observed at a distance of 100 m from each other and there was a variation in the water table depths of 8 to 11 m for practically similar levels at the surface.

These oglats have been mentioned on the tppographic map at 1/5.000 and we shall thus be able to follow them up in the future. The important variation of water-levels observed proves that there are 3 small isolated water pockets in very argillous alluvia located upstream the old dam. The output of each oglat is about 100 1/hour. The pieces of quartzite we observed looked very fissured. This fissuration, however, does not generate water because of the great amount of clay in the environment. The fact that the oglats exist could be due to the presence of numerouslimestone concretion with actual pockets in them. The present reserves would be completely insufficient for the works requirements.

Site 2 Timbara

In April 1980, just behind the present dam which only needs minor repairs 15 oglats were observed on an area covering about 1 ha. The depths vary between 3,40 m and 4 m, which seem to indicate the presence of a continuous aquifers. The heights of water in the wells vary from 10 to 50 cm. The great number of leaks detected under the works of the dam seems to indicate a rather high degree of permeability. If we assume a permeability of 10^{-6} cm/secund which corresponds to this type of soil it follows that, during the month when the dam is filled the Iha area observed stores a certain amount of water.

$$V = 10^{-6} \times 10^{-2} \times 86.400 \times 30 \times 10.000 = 260 \text{ m}3$$

.../...

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This volume fits the one observed by us since with an efficient porosity of 10 % it corresponds to a 26 cm thick aquifer and this thickness is quite close to the heights observed. Supposing that we have the same condition on 3 to 4 ha we shall generally have a total annual reserve of 1.000 m3, a reserve which can meet the needs of pastoralism and will be quite sufficient to meet the needs of the Timbara dam when it is rebuilt. But it is out of question to use this water for the neighbouring sites (Cag el Mohor requires more than 5.000 m3 of water).

Site 3 Toueidima

The site is geologically the same as that of Cag el Mohor. There, too, can be found limestone pockets among micaschist and oglats in the dam basin (one of which only was productive in April 1980) with a discharge of 200 1/s and a depth of 4,30 m. This points to permeabilities in depth which can be locally greater : 10^{-2} cm/S ? On the contrary, due to the fact that permeability on surface is small, the annual storage hence the available reserves will be very weak (cf. the figures we obtained for Timbara).

The underground material being very heterogeneous, we shall have to proceed to a geophysical survey of the 10 ha situated behind the present dam in order to select the type of structure and the optimum depth. This structure will be sufficient to provide water for the Toueidima works but not for the neighbouring works (Cag el Mohor).

Site 4 Ameira

The soil, at a depth of a few meters, is composed of red solid clay, quite impervious. No productive oglat has been observed.

.../...

Site II Mint Aouaou

A weakly productive aquifer, 3,5 m deep, lies right upstream of the projected site. This aquifer will be adéquate for the drinking water requirements of the works but not for the building of the embankment dam As explained in the preliminary study, the works will be supplied with water from the Haneikat reservoir 2 km up North (after a minor repair : filling up the channel dug by the local farmers).

In conclusion

On 3 sites (Timbara, Toueidima, Mint Aouaou) of the North-West area water will be supplied locally.

For 2 other sites (Gag el Mohor, Ameira) another solution will have to be adopted : on the North fringe of this area 2 drillings are available at Magta Lahjar : F I and F 2 of PK I09 drilled at 58 m depth in the alluvia, giving discharges of 44 m3 and 52 m3 respectively with a dynamic level at less than 20 meters depth. These drillings are equipped but they are not in use (january I980). We shall have to get the agreement of local authorities for them to be used.

3.2. - NORTH GORGOL AREA.

For this area maps of the Hydraulic Ressources Division mention several water-points :

- one oglat at Lamaoudou (no available figures)
- one well at Oudei Lefkarine
- several water-points at Ghoggar, Gadel, Gleyta Tor (no figures)
- one local well, fairly productive, at Dienor (1,5 m3/h, 2 m deep)
- " " " " ", at Tichilit and Baydha (over 3 m 3/h 5 m deep).
- one site to be surveyed by geophysic at Oum Arda.

.../...

All these water-points are located on the Gorgol or its near tributories. We were able to make the following observations :

Site 12 Lemaoudou

In 1978 no water-point had been observed on this site. In april 1980 one oglat was used at a depth of about 3 m, with a discharge of 200-300 1/h. This water was taken by the cattle-raisers who had a fairly big herd (horned cattle and smammer ruminants) This site looks rather favourable from a hydrogeologic point of view: the dam basin is blocked by a big sanddune of probably eolian origin and this dune equally blocks two other basins downstream the project basin.

Considering that we are in the rainfall area of 300 mm, we are thus theoritically outside the area where aquifers can be supplied with water by sand-dunes (R > 400 mm). However, other oglats can be observed on the basins downstream, these oglats being used by cattle-raisers. If we take into account the fact that the requirements of the Lemaoudou works are comparatively limited, we suggest the boring of a hole in the basin downstream the projected dam, after geophysical survey.

Site 13 Boudjoungal.

There is a cement-walled well which was built a few years ago. The depth of the static water-table is 20 m, the well being bored into schists Several oglats, 12 m deep, have dug by the local populations. Although it is located at the foot of the same dune as Lemaoudou, the site seems to be much less favourable as the substratum outcrops much nearer the surface. No productive well is available near this site.

.../...

Site I4 Irokam - Oudei Lefkarine

A cement well was built by the "Direction de l'Hydraulique" at a depth of 35 m. When we made observations (April I980), the static water-table was 29 m deep and the discharge of the well was very weak, hardly sufficient for the needs of the population (about 100.000 inhabitants) and the herds. This well cannot possibly be used for anything but the drinking water supply of the works. No other productive site is available in the surrounding area.

Site I5 Boussoueilif

Our observations, in may I978, mentioned the existence of oglats 100 m downstream the présent dam, the aquifer being 4 m deep. On the other hand the white Gorgol flows about 1 km away from the site. Considering that the water requirements of the works are limited, we might bore a hole in the interdune dip downstream the projected dam, after geophysical survey, the conditions being about the same as at Lemaoudou.

In conclusion

For 2 of the sites (Lemaoudou, Boussoueilif) the works could get the necessary water from drillings.

For the others another solution will have to be found. The nearest water supplies are the F I and F 2 drillings of the PK 4 at Achram ; the wells, bored in dolomies at depths of 56 and 35 m, give discharges of about 2 (to I50 m3/hour. They are equipped with pumping machinery but they are not working as they are 60 km away from the project.

.../...

2.3.3. - SOUTH GORGOL AREA

For this area the maps of the "Direction de l'Hydraulique " mentions the following water-points (from North to South) :

- several oglats with 4 m depths and discharges of 1,5 to 3 m3 /h around Moudi Founti
- an area to be prospected by geophysics on the Gorgol near Oudei Chrak
- traditional wells which are rather productive (more than 3 m3/h) at Djib and Ouad Djib.
- a traditional well of 3 m3/h at Bethet Ahel Sidi at a depth of about 5 m.
- a cement-walled well at Boughoul, very little productive.
- a cement-walled well at Bou Bou Aoudi at a depth of 12 m; with discharges of more than 3 m3/h.
- several oglats in the Gorgol, with depths of 3 to 4 m.
- an area to be prospected by geophysics at the confluence of the 2 Gorgols.(Oued el Abyadh and Oued el Akhdou)

We have not much more information to add to this list.

Site 6 Moudi Founti

The 1978 report anticipated a supply from the white Gorgol, 300 m. away. In December 1979, one oglat, 20 m downstream the present dam was full and its 1,70 m. depth was sufficient for the needs of the village (200 inhabitants). In April the level had come down to 4,50 m. Such a variation means that the well is not perennial. Therefore it is out of question to use it for the works. The oglats of the area, in particular El Gouessi, are all used to their full capacity owing to the fact that, in that area, the wells are limited but not the pastures (cf ref. 5). It is then impossible to count on the existing wells. If a solution using wells is adopted, an area favourable to the installation might be considered in the minor bed of the white Gorgol 1km downstream of Moudi Founti where there is a natural weir.

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Site 7 Oudei Chrak

The characteristics are the same as at Mouti Founti. A cement-walled well, built by the "Direction de l'Hydraulique" in the village called Oudei Chrak, 5 km downstream the dam site, is used with a very weak discharge. There is no other water-point within IO km (a few oglats, 3 to 5 m deep at Lebmeisser). We suggest digging guide-pits under the alluvia of the White Gorgol right upstream Oudei Chrak (a cluster of oglats at Boubardjè). This area is mentionned on the map of the Hydraulic Ressources Division as interesting to prospect. According to our observations, the alluvia of the Gorgol are very fine and transmittivity in the wells is weak. Should this area prove to be insufficient, a supplement can possibly be found 8 km to the West where Oued Djib cuts through the North end of Mounts Ouaoua at Gleyta Djib. Several oglats are used and a geophysical survey will bear out the configuration of the weir with the likely existence of a fault. The distance to the works is 23 km.

Site 8 Toueize Krett Tagatt

About 6 km upstream the chosen site a small low dam enables the water to infiltrate through a sandy, silty soil resting on micaschist, which allows the use of oglats at a depth of 4 to 5 m. The other supply of water is the Gorgol, where the alluvia are very fine, hence little pervious ; the discharge of the oglats does not exceed 3 m3/day for the most productive ones. The works will have to be supplied with water from the wells dug for Oudei Chrak, I6 km away from the dam to be built (25 km from Gleyta Djib). An additional supply can also be obtained by the boring of 5 to 6 guide-pits in the Jatout area (about I7 km West of the works). Several oglats are used over an approximately IO km long strip. These oglats, some of which are coffered wiht straw and timber, are not mentioned on the maps of the Hydraulic Resources Division. It is to be noted that these aquifers are not dependable : for instance a cement-walled well recently built by the Hydraulic Resources Division at a depth of 17,5 gives a discharges of 0,5 m3/day.

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Site 9 Lehneikatt

A fault, in an approximately North-South direction, is mentioned on the BURGEAP map (ref. 5) : quite visible on aerial photographs (mission AOF 09I - NE 28/6/54, N° I6I, I65, 224), it intersects Oued Azgueilem and Oued Lehneikatt 5 km upstream the dam projected for Lehneikatt. Since we know that the watershed of Oued Lehneikatt is undoubtedly more important than that of Oued Azgueilem we suggest a geophysic prospection of Oued Lehneikatt along the supposed fault (cf map enclosed) and a subsequent boring of 4 to 5 guide-pits. The use of the Gorgol oglats (with very weak discharges) will provide an alternate solution.

Site IO Azgueilem

On the site, very close to Lehneikatt (IO km away) the same solution can be adopted. A zone of oglats on the Gorgol, 5 km upstream Azgueilem (Tiyab Oulad Ali : 3 m deep, discharge inferior to 1,5 m3/h) can also be used.

In conclusion

The whole area South of the White Gorgol presents an acute problem of water supply, all the more acute as the pastures are comparatively abundant. We noticed, for instance, that, when we passed though this area in March I980 several villages of cattle-raisers were forsaken for lack of water. As a consequence, should be applied there even more than anywhere else the principle that : "the project must be self-sufficient in water". For it is not possible to consider the slightest use of the water supply which is even insufficient for the population. In that case, we shall preferably adopt the solutions (concrete) which involve a minimum use of water.

2.3.4. - Site 5 Zmeillatt

This isolated site, located West of the outcropping zone of the substratum, has very unfavourable hydrogeological characteristics :

.../...

the alluvia in the basin are composed of swelling clay, totally impervious as soon as it is saturated. The map of the Hydraulic Resources Division, Kaedi sheet, mentions several water-points nearby. One ogkat El Aganat gives only 100 l/s and is thus unfit for use. On the contrary the well of Bassi Nguiddi, 21 km away by the dirt road, supplies 10 m3/h and is permanent. Considering that the volume of water necessary for the works is comparatively weak (730 m3) we recommend that the site should be supplied with water from Bassi Nguiddi.

Alternate solutions

The use of local water supply will be adequate for the 5 following sites :

site 2 Timbara
site 3 Toucidima
site 11 Mint Aoumou
site 12 Lemsoudou
site 15 Soussoueilif

For all the other sites, the wells planned at § 2 below are of a considerable interest as being an added investment to that of the dam and they must be built if only for this reason. Their contribution to the project is likely to be insufficient, though, and other solutions must be found.

We have thought of three possible solutions :

A - use of a tank-wagon carrying water from a distant well.

B - building of a temporary reservoir.

Either solution will have to be as cheap as possible to be adopted.

Solution A

The transport of water by tank-wagon 10 m3 capacity cost 14 UM/m3/km (estimate of Il Nuovo Castoro report on the Tagant dam,

.../...

January 1979, brought up to date) depending on an hourly useful speed of 15 km/h.

Solution B

It consists in building with the help of a tractor to work as a bulldozer and a ripper, a small 1,00 m high, non-compacted dam before the rainy season preceding the work. There will be about 1 m3 earthwork for 10 m3 of useful reserve.

The hourly cost of the machine will be : 3,850 UM (Nuovo Castoro report brought up to date) : with an output of 50 m3/h the cost is 193 UM/m3 to which must be added a fixed cost of 100,000 UM for setting up the works per site.

Let us now compare the 10 sites to which can be applied these 2 solutions.

Site 1 Cag el Mohor

Water requirements 5,440 m3
Distance from the site to the nearest water-point (borehole PK 109 at Magta Lahjar) = 41 km ;
Cost of solution A (tank-wagon) = 3,123,000 UM
5,440 x 41 x 14 = 3,123,000 UM
Cost of solution B (temporary reserve)
0,1 x 5,440 x 193 + 100,000 = 205.000 UM

Solution B will be adopted

Site 4 Ameira

Water requirements 780 m3
Distance from the nearest water-point (borehole PK 109 at Magta Lahjar) = 27 km
Cost of solution A (tank-wagon)
780 x 27 x 14 = 295,000 UM
Cost of solution B (temporary reserve)
0,10 x 780 x 193 + 100,000 = 107,500

.../...

Solution B is preferrable : should the needs for organizing the work demand it, though, solution A could also be used on this site.

Site 5 Zmeilatt

Water requirements 730 m3
Distance from the nearest water-point (Nguiddi basin) = 21 km
Cost of solution A (tank-wagon)
730 x 21 x 24 = 215,000 UM
Cost of solution B (Temporary reserve)
0,1 x 730 x 193 + 100,000 = 114,000

Solution B is preferrable, However if required by the organisation of the works, solution A is also practicable.

Site 6 Moudi Mounti

Water requirements = 300 m3 (concrete works)
Distance from the nearest water-point (PK 109, Magta Lahjar) = 87 km

Cost of solution A (tank-wagon)
300 x 87 x 14 = 365,000 UM

Cost of solution B (temporary reserve)
0,1 x 300 x 193 + 100,000 = 105.000 UM

Solution B is preferrable. However, considering the small volume Solution A can be adopted, too, as well as a solution consisting in building wells on the Gorgol. If one considers building these wells, in all cases a more costly solution than A or B, it will not be necessary to resort to solutions A and B.

Note/ : Cost of the wells

Geophysic survey on 2,000 ha
2,000 x 670 = 1,340,000
Drilling of 5 guide-pits at 10 m depth
5 x 10 x 12,000 = 600,000
Total = 1,940,000

.../...

This solution, not only offers chancy results, but it is also much more costly than solution A or B.

Site 13 Boudjoungal

Water requirements 1410 m3
Distance from Magta Lahjar = 57 km
Cost of solution A
1,410 x 57 x 14 - 1,126,000 UM
Cost of solution B
0,1 x 1,410 x 193 + 100,000 = 127,000 UM

Solution B must be preferred

Site I4 Jrekaya Oudei Lefkarine

Water requirements 830 m3
Distance from the nearest water-point = IO km (reserve of Ouad Amour)
Cost of solution A
830 x IO x I4 = II7,000 UM
Cost of solution B
0,1 x 830 x 193 + 100,000 = 116,000 UM

Solution A must be adopted

Other sites of the White Gorgol

Sites 7, 8, 9, 10 Oudei Chrak, Lehneikatt, Azgueilem, Toueiz Krett Tagatt.

For all these sites solution B (temporary reserve) is the only one economically practicable. If the need arises the same temporary reserve may supply several works. For example a reserve built at Oudei Chrak, after a temporary repair of the present dam, will easily supply Toueiz Krett Tagatt.

In conclusion

Here are the solution we advocate for the water supply of the works : site I Cag el Mohor : building of a temporary reserve of 25.000 m3 (8 ha x 0,40 m).

site 2 Timbara : building of 2 wells after geophysical prospection over 10 ha in the dam pit.

site 3 Toueidima : building of 2 wells after geophysical prospection over 10 ha in the dam pit

site 4 Ameira : supplying of water by tank-wagon from PK 109 at Mogta Lehjar 780 m3)

site 5 Zmailatt : supplying of water by tank-wagon from Bassi Nguiddi (730 m3)

site 6 Moudi Founti : building of a temporary reserve of 600 m3

site 7 Oudei Chrak : building of a temporary reserve of 25,000 m3 (after temporary repair of the present dam).

site 8 Lehneikatt : building of a temporary reserve of 200,000 m3

site 9 Aaguelem : building of a temporary reserve of 13,000 m3

site 10 Toueiz Krett Tagatt : building of a temporary reserve of 100,000 m3

site 11 Mint Aounou : use of the Aneikat reserve

site 12 Lemsoudou : drilling of a 20 m deep well downstream the projected dam after geophysical prospection over 200 ha

site 13 Boudjounged : building of temporary reserve of 800,000 m3

site 14 Irekeya - Oudei Lafkarine : supplying by tank-wagon from the Ouad Amour reserve

site 15 Boussoueilif : drilling of a well at 20 m depth downstream the projected dam after geophysical prospection over 200 ha.

The other prospections and drillings mentioned in the text can be undertaken under a complementary scheme of hydraulic equipment.

REPUBLIQUE ISLAMIQUE DE MAURITANIE

Ministère du Développement Rural

RECLAMATION AND CONSTRUCTION OF 15 DAMS IN THE BRAKNA & GORGOL REGIONS

STUDIES FINANCED BY USAID

CONTRACT N° AID 682 - C O - P M & R - 80-01

PROJECT : E B U 2

TECHNICAL STUDIES

GENERAL REPORT

F. - SOIL SURVEY

B. P. 321
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JULY 1980

SOIL SURVEY

OF 15 BASINS IN THE

BRAKNA AND GORGOL REGIONS

SONADER

USAID

February 1981

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SOIL SURVEY OF 15 BASINS IN THE BRAKNA AND GORGOL REGIONS

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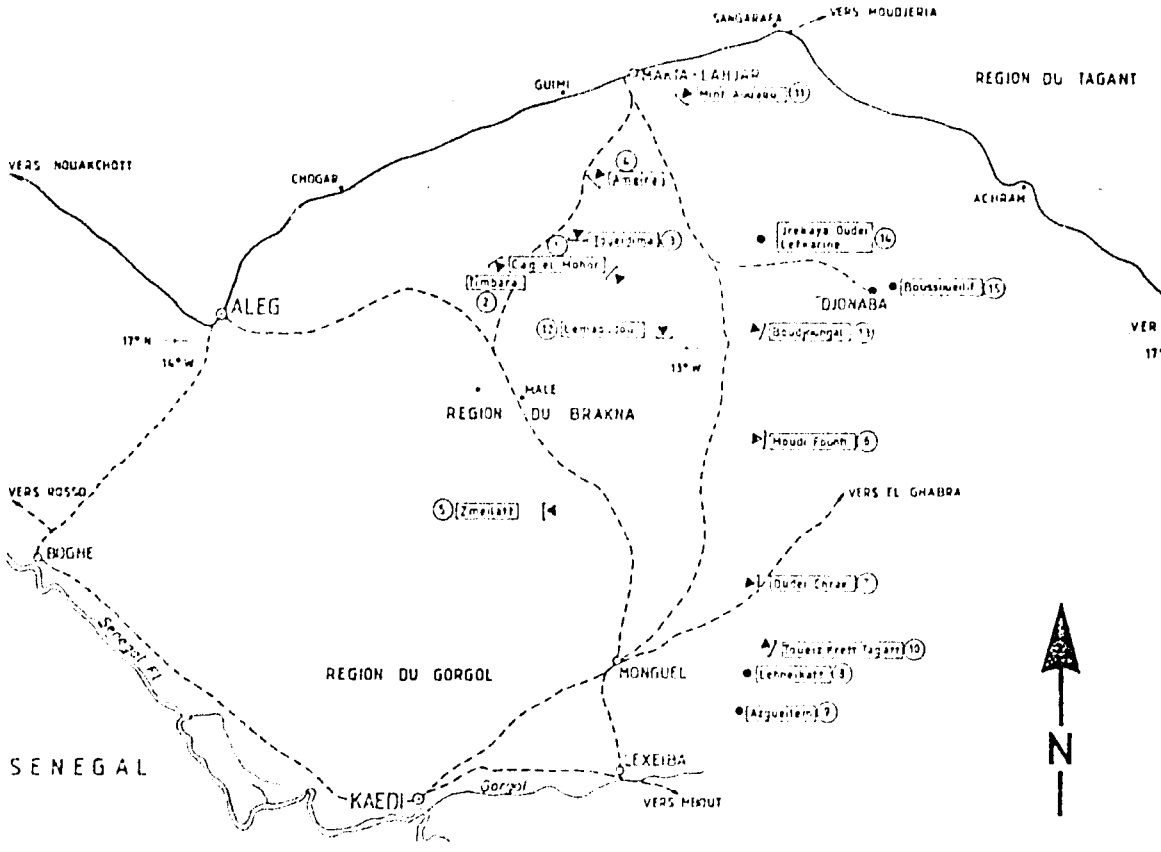

⊙	CHEF LIEU DE REGION		REGIONAL CAPITAL
○	CHEF LIEU DE DEPARTEMENT		MAIN VILLAGE
•	AGGLOMERATION		OTHER VILLAGES
———	ROUTE GOUDRONNEE		HIGHWAY
- - - -	PISTE PRINCIPALE		MAIN TRACK
▶]	BARRAGE EXISTANT		EXISTING DAM
●	SITE AMENAGEABLE		SITE FOR RECLAMATION / CONSTRUCTION

0 5 10 20 30 40 50km

SO.NA.DE.R.

ETUDE D'EXECUTION DE 15 BARRAGES DANS LES REGIONS DU BRAKNA ET DU GORGOL LOCALISATION DE CUVETTES

RECLAMATION AND CONSTRUCTION OF 15 DAMS IN THE BRAKNA AND GORGOL REGIONS

1. Introduction

Following the study of the preselection of 30 dam sites in the Brakna and Gorgol region (Islamic Republic Mauritanie), some 15 sites have been retained for furthermore detailed studies.

These sites are:

Cag el Mohor (5)	EBU-01
Timbara (6)	EBU-02
Toueidima (7)	EBU-03
Ameira (8)	EBU-04
Zmeilatt (11)	EBU-05
Moudi Founti (12)	EBU-06
Oudei Chrak (14)	EBU-07
Lehneikatt (15)	EBU-08
Azgueilem (16)	EBU-09
Toueiz Krett Tagatt (17)	EBU-10
Mint Aouaou (19)	EBU-11
Lemaoudou (22)	EBU-12
Boujoungal (24)	EBU-13
Jrekaya Oudei Lefkarine (25)	EBU-14
Boussoueilif (28)	EBU-15

The number in brackets correspond with those of the preselection study.

The location of the site appears on the map.

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2. Terms of Reference - Field Work and Methods

2.1 Terms of Reference

2.1.1 Description of Two Soil Profiles of 1.5 m Depth at Each Site

2.1.2 Soil Sampling for Laboratory Analyses

2.1.3 Laboratory Analyses:

a) particle size distribution

b) pH

c) conductivity (in correlation with chloride content)

d) chemical analyses including organic carbon, nitrogen, available phosphate and potassium

e) measurements of permeability in the laboratory to be correlated with at least one percolation test in the field per site

2.2 Field Work

The survey was carried out by two pedologists of SONADER during the month of April 1980, while laboratory analyses on 113 soil samples were carried out from June 1980 until February 1981 by the National Laboratory for Soil and Water Analyses (LANASOL) in Nouakchott.

Unforeseen difficulties with water retention (pF) analyses delayed the completion of the soil report.

The survey methods in the field were the following:

a) systematic study of topographic drawings of the dam basins as far as these were available

b) siting of soil profiles where the soils are representative and topographically, depending on the maximum level of innundation. In each case a profile was sited in the lowest area and on the edge of the basin

c) reference points were placed in order to localize the exact sites

d) test pits were dug up to 1.5 m depth or up to rock at shallower depth

e) detailed soil descriptions were made according to the "Guidelines for Soil Profile Description - Land and Water Development Division - FAO

f) taking of soil samples at a rate of one sample of each described horizon, with a minimum of three samples per profile in some cases included underlying weathered rock

Infiltration rates were measured at some 10 sites according to a rapid method of the Rural Engineering Department of the Louvain University (Belgium).

This method entails measurement of the decreasing water level in an augerhole with diameter D starting after the soil has been saturated. Plotting is done on semilogarithmic paper with the time t on the abcis and on the ordinate the logarithm of the equation ((Yo + D/4) / (Y + D/4)) where Yo represents the initial level at the time to and Y the level at the time t. An estimation of the permeability K in cm/sec is given by the equation

K = 1.15 R tan x, where x represents the angle between the plotted curve and the x-axis.

This method which works well in homogeneous soils with equal distribution of clay, silt and sand, did not give the expected results, because the soils were very dry and required very much water before saturation or because of deep cracks.

The use of a double ring infiltrometer was not possible owing to lack of water in this dry area.

2.3 Laboratory Analyses

Laboratory methods have been adjusted by LANOSOL. Analyses on the samples which have been crushed and sieved (2 mm) include:

2.3.1 Physical Analyses

- particle size distribution of all samples by sieving for the coarse fraction (0.05 mm - 2.0 mm) and with the pipette method for the fine fraction
- permeability according to the Henin method
- pF curves; at pF 3 and pF 4.2 with pressure plate apparatus
- residual humidity

2.3.2 Chemical Analyses

- conductivity equivalent at 25°C taken of the extract of the 1 : 5 solution
- pH (H_2O and KCl)
- total carbon (Walkley and Black)
- P_2O_5 (Olsen)
- Available K_2O after removal of exchangeable K
- total Ca (calcimeter of Bernard)
- cation exchange capacity (of the two upper samples of each test pit only) according to the following method: saturation with calcium chloride 1N buffered at pH 7.0 (ratio soil: solution = 1 : 25). The Ca ions are replaced by KNO_3 1 at pH 7.0 and then measured by complexometry

- exchangeable cations (Na, K, Ca, Mg) of the two upper samples of each test pit only; replacement of the cations by ammonium acetate; determination of Na and K ions by flame photometer; Mg and Ca by complexometry.

Further some 15 samples were analysed for soluble cations in the extract of the 1 : 25 solution. The results of the analyses appear in the annex of the French report.

3. The Results of Previous Studies of the Soils in the Region

3.1 Studies by ORSTOM (1960)

As mentioned already in the agropedological preselection study (SONADER, 1978), the soils of some basins of the Brakna and Gorgol have already been studied by Gavaud (ORSTOM, 1960: Etudes pédologiques des cuvettes du Cercle du Brakna - Centre de pédologie de Dakar - Hann).

The analytical data of the soils of following basins appear in Table 1: Dionaba, Gadel, Wadi Ketchi, Wadi Gelouar, Male, Choggar, Sangarara and Guimi. The data are useful to compare with the results of the present study.

Three main types of soil have been distinguished

- brown subarid soils (corresponding in the old classification with the brown soils,except the brown soils "tersifiés")
- brown soils with vertic characteristics (previously brown soils "tersifiés")
- hydromorphic soils.

Each analysed characteristic has three values in Table 1: the first is the minimal value; the second is the mean value calculated for a variable number of samples (8 to 63), the third is the maximum value at two depths: from the surface and at about 50 cm.

3.2 Interpretation

3.2.1 Particle Size Distribution

For each group the data are rather variable but for each given profile the soils are uniform in the first 50 cm. The hydromorphic soils and the brown soils with vertic characteristics are comparable, with a mean clay content of about 45 - 50 %, a low silt content and a low coarse sand content. The brown soils have much more fine sand (50 %) and have relatively little clay (25 %).

Table 1

Characteristics of soils of 8 basins in the Brakna region

ORSTOM 1960

	P.S.D.				Organic matter				Exchange complex meq/100 g soil									
	C (0 2u)	S (2-50u)	FS (50-200u)	CS (200-2000u)	O.M. %	C %o	N %o	C/N	Ca	Mg	K	Na	S	T	Sat. %	pH	EC umhos 1:5	K cm/h
Surface (1)	18	3	8	7	0,14	1,5	0,3	3,9	1,9	1,6	0,2	0,1	4,0	7	35	4,4	31	0,5
	44	15	35	15	0,90	5,1	0,7	6,5	9,9	5,4	1,0	0,3	16,5	21	80	5,4	48	1,4
	70	30	69	29	3,8	20,8	21,0	9,7	19,0	11,6	1,7	1,0	32,0	38	100	6,5	75	4,0
50 cm	17	4	7	5	0,25	1,2	0,2	3,0	4,8	2,2	0,05	0,1	7,2	9,5	46	5,3	24	
	45	16	30	11	0,50	2,7	0,4	5,8	13,3	7,5	0,9	1,2	22,5	24,6	90	6,7	152	
	71	24	46	24	0,80	4,2	0,5	9,1	23,4	13,9	2,0	3,9	40,0	38,0	100	7,7	580	
Surface (2)	34	6	15	6	0,3	1,7	0,3	5	3,2	0,8	0,4	0,1	12	16	67	4,6	31	
	48	15	35	10	0,7	3,5	0,5	7,4	16,6	6,9	0,9	1,1	25	26	95	6,3	58	2,5
	62	40	52	17	1,9	9,6	1,6	12,5	52,0	22,0	2,7	3,2	60	41	100	7,7	163	
50 cm	36	4	21		0,3	1,7	0,3	5	9,9	3,7	0,4	0,3	17	19	72			
	51	16	32	9,2	0,6	3,1	0,4	7,2	20,3	7,8	0,7	4,2	33	31	99	7,0	197	
	63	30	60		0,8	4,2	0,6	8,8	29,0	12,2	1,2	9,9	47	45	100			
Surface (3)	7	2	36	6	0,3	1,2	0,2	4,0	1,7	0,8	0,2	0,1	3,0	3,6	80	5,3	31	1,5
	27	13	51	16	0,6	3,2	0,4	7,6	9,3	4,6	0,5	1,9	17	17	95	6,2	45	2,5
	44	35	72	32	1,0	6,3	0,9	11,8	22,0	10,5	1,2	17,6	41	36	100	7,9	160	3,9
50 cm	7	3	40	8	0,3	1,4	0,2	5,7	3,6	1,8	0,2	0,1	5,8	7,0	87	5,7	31	
	26	11	51	14	0,5	2,6	0,5	7,5	10,5	4,2	0,4	1,9	17	17	99	6,8	200	
	41	25	67	20	0,7	3,7	1,5	8,6	16,5	6,8	0,6	9,0	31	28	100	7,4	755	

1) Hydromorphic soil
2) Brown sub-arid vertic soil
3) Brown sub-arid soil

Table from:
" Plan Directeur pour le Développement Rurale de la Région du Tagant
SONADER/GTZ 1979.

3.2.2 Organic Matter

All soils are characterised by a low organic matter content in the topsoil; but organic matter is well humified with a mean C/N ratio of about 7 and well distributed throughout the profile, because at 50 cm, organic matter content is still about 0.5 %. This uniform organic matter distribution associated with good humification is one of the main properties of the brown soils.

The soils which are subject to periodic flooding have the highest organic matter content.

3.2.3 pH

The hydromorphic soils are somewhat acid near the surface (mean pH of 5.4); the other soils are almost neutral (pH 6.2 to 6.3). At depth, mean values are neutral (6.7 to 7.0) for all soils. The highest values correspond with the horizons with high sodium content, but the pH always remains below 8.

3.2.4 Exchange Complex

The brown soils with vertic characteristics are most well supplied with cations, in particular with calcium. Mean values of total exchangeable cations range from 16 (hydromorphic soils) to 25 (brown vertic soils) near the surface. This indicates a favourable equilibrium in relation to the clay and silt content. The sum of the cations rises slightly with increasing depth for the hydromorphic soils and the brown vertic soils but for the brown soils, values are uniform throughout the profile. Always calcium is the dominant cation, but the hydromorphic soils have an unfavourably low ratio of Ca/Mg of less than 2.

All brown soils are generally better supplied with sodium than with potassium. Sometimes the exchangeable sodium content relative to the exchange capacity indicates light alkalisation (Na/CEC more than 15 %).

Base saturation is high and with mean values over 80 %. The soils with the lowest base saturation are the hydromorphic soils.

On the whole these soils are characterised by a high chemical fertility in spite of unfavourable ratios of cations of some exceptions with a high sodium or magnesium content.

3.2.5 Electrical Conductivity

The conductivity has been determined of the 1.5 extract at 25°C. Generally it increases with increasing depth. Although the mean values for most soils are below the critical value of 400 micromhos, at depth some values are higher. The highest values occur for the brown soils. Salinity at moderate depth can therefore not be excluded, particularly in the basin of Choggar.

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3.2.6 Permeability

This concerns the coefficient K of Darcy, expressed in cm/hr and measured in the laboratory under a constant head. Overall the soils are slowly permeable. The slowest permeability occurs in the hydromorphic soils.

3.2.7 Conclusions

The two main limiting factors are in the first place the low organic matter content of all soils and in the second place the excess of exchangeable sodium or of soluble salts in some of the soils.

3.3 Other Studies: Achram - Diouk Zone (1978-79)

For the Study "Developpement Rural de la Région du Tagant-Plan Directeur" carried out for SONADER in 1978-79, some observations were made with borings in test pits in the basin upstream of the Gorgol Blanc. This zone borders on the survey area and belongs to the same landform, the "Aftout" the peneplain which extends west of the cliffs of the Tagant and the Assaba, up to Aleg in the west and Monguel and M'Bout in the south.

The samples which were taken during this study have been analysed by LANOSOL and the results presented in Table 2 and 3 have been taken from the above mentioned report.

Profiles 14 and 15 in the French edition of the report are alluvia; profile 14 is situated on the floodplain of the Gorgol Blanc at the intersection with the road Aleg Kiffa. This is a hydromorphic soil with pseudogley overlying uniform alluvia, while profile 15 is situated in the basin of the Achram dam. This soil is a poorly developed alluvium overlying uniform materials.

The profiles 16, 17, 22 and 25 are all brown sub-arid soils which are characteristic for interfluves and regs. These soils are characterized by a gravelly surface (without gravel and stones in the soil profile). Also typical are: very little textural differentiation (the texture consists of equal amounts of clay, silt and sand throughout the profile) and a very clear structural differentiation between the topsoil and the massive underlying horizon.

These chemically rich soils are cultivated in winter, where it is possible to retain water by building bunds.

They show many characteristics which are similar to the soil profiles of the present study described hereafter.

Table 2

Achram-Djouk Zone (Reg soils) - Basin upstream of the Gorgol Blanc

PROFILE		17			16			25			22	
DEPTH		0	20	70	0	25	75	0	30	70	0	50
		10 cm	30 cm	80 cm	10 cm	35 cm	85 cm	10 cm	40 cm	80 cm	10 cm	60 cm
Clay	0 - 2 u	25,8	32,8	29,5	37,5	37,0	39,6	36,0	40,0	40,5	25,5	34,0
Fine silt	2 - 20 u	19,8	14,3	10,3	15,5	19,5	15,0	14,5	13,8	14,5	19,0	24,3
Silt	20 - 50 u	11,1	9,5	6,2	10,0	9,0	8,7	10,0	8,1	4,4	16,2	14,1
Fine sand	50 - 200 u	32,6	34,2	42,5	25,5	24,6	28,2	28,6	27,3	28,3	30,8	23,2
Coarse sand	200 -2000 u	7,3	6,0	8,4	7,9	6,4	6,0	7,1	7,3	8,3	5,7	2,7
Carbon %		0,29	0,17	0,17	0,20	0,20	0,12	0,20	0,17	0,18	0,46	0,17
Organic matter %	0,50	0,29	0,29	0,34	0,34	0,21	0,34	0,29	0,31	0,80	0,29	
pH (H_2O)		9,0	8,9	9,0	7,6	8,3	8,0	7,7	8,5	8,3	6,5	7,8
pH (KCl)		7,4	7,5	7,7	6,0	7,0	6,7	6,1	7,2	7,1	5,1	6,2
P_2O_5 available ‰		0,004	0		0,01	0	0	0	0	0	0,02	0
K available ‰		0,32	0,21		0,45	0,28	0,30	0,37	0,21		0,35	0,21
Ca CO_3 free %					0,25	0,75	0,62	0,50	1,37	0,62	0,37	0,50
Ca		21,5	18,2		13,9	19,3	20,8	12,3	15,3	20,0	5,7	8,3
Mg exchangeable		3,6	3,6		4,6	3,4	2,6	5,6	6,7	1,8	6,3	6,8
Na meq/100 g		1,1	7,1		0,4	1,0	1,2	0,3	2,1	0,5	0,1	0,5
K		0,8	0,6		1,1	0,7	0,7	0,9	0,6	2,5	0,9	0,5
S meq/100 g		26,9	29,5		20,0	24,4	25,3	19,1	24,3	24,8	13,1	16,1
CEC meq/100 g		26,3						19,3	23,0	23,0	13,0	17,1
Sat. %		100						99	100	103	100	94
CE micromhos/cm 1/5		103	477	622	55	154	226	65	284	338	48	64

Source: Plan Directeur Tagant, 1979.

Table 3

Achram-Diouk Zone (alluvial soils) - Basin upstream of the Gorgol Blanc

PROFILE		14				15	
DEPTH		0	1,5	45	100	0	50
		1,5 cm	10 cm	55 cm	110 cm	10 cm	60 cm
Clay	0 - 2 u	44,8	42,0	22,2	14,3	32,3	33,0
Fine silt	2 - 20 u	12,8	10,5	3,5	0,8	27,0	26,5
Silt	20 - 50 u	10,6	9,4	4,0	2,0	23,1	20,2
Fine sand	50 - 200 u	26,4	31,5	64,0	80,9	13,5	16,9
Coarse sand	200 - 2000 u	3,5	3,8	55,3	1,2	0,9	0,5
Carbon %		0,63	0,34	0,10	0,05	0,26	0,23
Organic matter %		1,09	0,5	0,17	0,09	0,45	0,40
pH (H_2O)		6,7	6,4	7,2	9,3	6,8	8,0
pH (KCL)		5,4	4,9	5,6	8,1	5,5	6,5
P_2O_5 available %o		0,06	0,04	0,004	0	0,06	0,03
K available %o		0,52	0,38	0,20		0,34	0,21
$CaCO_3$ free %							
Ca		9,3	8,7	6,1		12,3	15,3
Mg exchangeable		6,2	5,0	3,7		6,1	5,8
Na meq/100 g		0,13	0,11	0,10		0,13	0,26
K		1,3	1,0	0,5		0,9	0,6
S meq/100 g		16,9	15,8	10,4		19,4	21,9
CEC meq/100 g			16,2			19,2	
Sat. %			97,5			10,0	
EC micromhos/cm 1/5		60	34	50	827	52	63

Source: Plan Directeur Tagant - 1979.

4. Description of the Soils of the Basins

EBU-01

CAG EL MOHOR

Coordinates: 17° 10' N
13° 13' W

Catchment area: Tributary on the left bank of the Wadi Katchi (West Diakatouba, mentioned on the IGN map NE-28-XI, West Tembara)

General description of the site

The basin is situated in an area with poor access, in the river bed of an important tributary of the Wadi Katchi. The alluvial plain is more than one kilometre wide and relatively wooded. Dominant trees are Acacia flava and raddiana, Balanites aegyptiaca, Ziziphus, Boscia senegalensis and Bauhinia rufescens. No trees are higher than 3-5 m. Going upstream isolated Anogeissus leiocarpus also occur.

The soils are of little depth. They have developed in loamy sand materials of alluvial origin with a high content of quartzitic gravel and stones as well as lime concretions. The soil overlies soft fissured rock, calcareous grit, sericitic schist and biotite which breaks easily into small plates. Pockets with soft lime may occupy a considerable volume. This rock changes at great depth which can be observed in wells upstream of the destroyed dike, where water pockets in rock fissures between 8 and 15 m depth occur. The yield and storage are minimal. The water table is discontinous which is shown by the different water levels in each well (8-13 m).
The examined soils are of low quality.

Height of mean water level	101.00 m	
Inundated area at water level of	101.00 m	56 ha
	100.50 m	26 ha
Described profiles:	PB 15 height 100.29 m	
	PB 16 heigth 100.00 m	
	(next to reference point A)	

Detailed descriptions of these and all following profiles mentioned, as well as the analyses appear in the French version of the report.

Interpretation

The soils of the alluvial plain are restricted because:

- they are shallow
- they are very gravelly
- they have a low water holding capacity because of their sandy texture.

They are only marginally suitable for recession irrigation because of their fertility as well as of their physical properties.

EBU-02

TIMBARA BASIN

Coordinates: 17° 08' N
13° 22' W

Catchment area: Tributary on the left bank of the Wadi Katchi (IGN sheet NE-28-XI: West Izmana)

General description of the site

The basin is situated above a series of dunes which crosses the wadi and where the dam has been constructed. The actual system is still working but allows only a minor area to be cultivated.

The wadi drains a zone with regs in its upper course and steep river bank on the right side. Both areas have been covered by a veneer of sand. Being an important zone with wells in Wadi Katchi (water level between 3 and 4 m in April) it supplies the population as well as cattle with water. The site has been inhabited since ancient times; pieces of old pottery cover the dune on the left bank.

The soils which are situated 250 m upstream of the dam are cultivated and regularly covered with soil from the wells, of which about 15 are used every year.

The vegetation is very open and comprises Balanites, Boscia and Acacia shrubs.

The soils which are situated upstream of the basin and which are presently cultivated were formerly cultivated in winter, making use of run-off water which was retained by bunds.

Because no topographic survey has been carried out in this basin the areal extent is not known.

Height of the overflow:	10.00 m
Described profiles:	PB 13 at 10.40 m (950 m upstream of the overflow)
	PB 14 at 9.85 m (150 m upstream of the drainage works)

Interpretation

The soils of the Timbara Basin are mainly brown sub-arid soils with good structure, good drainage, moderate fertility. They do not have major limitations for recession irrigation. The soils immediately above the dike are subject to frequent alteration and renewal because of the intensive exploitation of the water table and well digging. This is the only place with permanent water and good yield in an area of some 20 sq.km.

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TOULIDIMA BASIN

Coordinates: 17° 14' N
13° 13' W

Catchment area: Tributary right bank of Wadi Diakatouba (down stream of Cag el Mohor) which is a tributary of the left bank of Wadi Katchi

General description of the site

This basin collects run-off from a catchment area with a reduced surface, mainly consisting of gravelly regs and rocky banks. An estimated area of 20 ha is cultivated behind a modern dam which is in need of repair.

A series of wells upstream of the drainage works was dug to make use of the ground water at 4.30 m in a small area, yielding little. The whole area is ploughed and in places covered by sorghum stubble.

A topographic survey of the area has not been carried out. With the aid of a brief survey of the cultivated area (30 cm below the overflow) it was possible to estimate the areal extent at some 20 ha.

Described profiles: PB 17 height: 75 cm below the level of the overflow; 160 m upstream the drainage works

PB 18 height: 52 cm below the level of the overflow; about 80 m upstream of the overflow on the right bank at the end of the cultivated zone

Interpretation

The soils of this basin are of limited depth and gravelly because of their position high in the catchment. Annual sedimentation of fine materials behind the dam increases the soil depth by some 15 cm in the center of the basin.

In testpit PB 17 the soil is compacted. This phenomenon occurs in particular in basins which are subject to long periods of annual flooding. In compacted soils the permeability and percoation of water is reduced. This is reflected by pseudogley which occurs near the surface in PB 17.

The chemical fertility of the soils is satisfactory. Profile PB 17 even shows the highest levels of P_2O_5 and K_2O in the study area: 46 and 603 ppm in the top soil.

The underlying rock which is highly weathered contains like the adjacent Cag el Mohor basin a very high proportion of powdery lime of which the origin is not known.

The soils of this basin are moderately to marginally suitable for recession irrigation. The main limitations are:

- shallow depth
- a high proportion of gravel
- compaction

122

AMEIRA BASIN

Coordinates: 17° 18' N
13° 10' W

Catchment area: Tributary right bank of the Wadi Katchi

General description of the site

The wadi which is only vaguely demarcated in the landscape by a narrow band of vegetation (Acacia flava, Balanites aegyptiaca) drains a catchment which is constituted of gravelly regs with a very gentle gradient.

A traditional dike marks the axis of the future dam; the edge of the basin is not visible in the terrain. This zone has no water points.

Height of mean water level:	101.80 m
Inundated area:	142 ha at a level of 101.80 m 96 ha at a level of 101.30 m
Described profiles:	PB 19 height 99.80 m PB 20 height 99.98 m

Interpretation

The alluvial soils of the basin comprise about 1/3 of the total extent (PB 19). They are deep, well structured, with a satisfactory fertility level and a texture with equal amounts of clay, silt and sand. They have a good moisture retention capacity. They are good agricultural soils for recession irrigation and cultivation during the winter season - without important limitations.

The soils of the regs (PB 20) comprise 2/3rds of the inundated area. These are moderately deep and gravelly on the surface but without gravel in the profile. The pH is high in the topsoil as well as in the subsoil (8.5). The high conductivity indicates a salinity hazard. These soils are marginal for agriculture.

EBU - 05

ZMEILATT BASIN

Coordinates: 16° 41' N
13° 15' W

Catchment area: Tributary left bank of Wadi Gellouar (tributary of the Senegal river) of which the run-off only reaches the river in years with exceptional rainfall

General description of the site

The dam site (with a modern dam which was destroyed in 1978) is situated at the height of a natural sill in the axis of a quarzitic outcrop on both banks of the wadi.

Upstream the basin has a gentle and constant slope and is well wooded. The soils, developed in medium textured slightly calcareous alluvium, are uniform over a large area which extends several kilometres upstream from the site of the dam and is several hundred metres wide.

Rounded hills where quartzites, laterites and schists outcrop, border the alluvial plain.

The vegetation which is particularly dense along the numerous gullies which form the riverbed, carry several tree specimens of 10 - 20 m height (Anogeissus leiocarpus, Mytragina inermis) are equally distributed:

Acacia (several species)
Ziziphus sp.
Combretum sp.
Boscia senegalensis
Balanites aegyptiaca

The ground cover comprises amongst other Corchorus olitorius and Cenchrus biflorus.

The basin is cultivated on an area of several hectares immediately upstream of the destroyed dam. Because there is no permanent water point, there is no village or habitation in this area. Some low yielding wells 6 km upstream allow water supply for some herds a few months after winter. The nearest perennial well is situated at Bassi Nguidi, 20 km distant.

Height of the mean water level:	7.50 m
Inundated surface at 7.50 m level:	52 ha
at 7.00 m level:	22 ha

Described Profiles: PB 11 height 7.50 m
PB 12 height 7.30 m

Interpretation

Two types of soil can be clearly distinguished. In the first place the alluvial soils which cover the greater part. They are uniform and have developed in fine textured materials (B 11). The soils are regularly submerged by run-off from an active catchment area which has probably a high run-off coefficient. They are compact and slightly alkaline at depth. Such soils are moderately to marginally suitable for agriculture with a poor structure as their main limitation which reduces the infiltration rate. They are in places densely covered by trees.

In the second place there are soils developed in colluvium (PB 12). These represent only a small strip bordering the alluvial plains. These soils, particularly near the dam, are preferred for cultivation.

The texture is light, they are permeable and easier to work, although their fertility is less. They have no important limitations.

EBU - 06

MOUDI FOUNTI BASIN

Coordinates: 16° 48' N
12° 50' W

Catchment area: Tributary right bank of the Gorgol Blanc

General description of the site

The basin is enclosed between two flat regs and is covered by a veneer of sand on the right bank and the left bank.

A destroyed traditional dam marks the site of the axis of the future works.

Part of the basin is covered by eaolian sandy sediments of variable thickness.

The examined soils are heterogeneous and of alluvial origin. They overlie strongly weathered schistlike rock.

A water table close to the surface supplies water for areas with settlement on the left bank.

Part of the basin is cultivated for sorghum and niébé.

Height of the mean water level:	9.50 m
Inundated area:	80 ha at 9.50 m level 30 ha at 9.00 m level
Described profiles:	PB 9 height 9.50 m PB 10 height 8.10 m
Altitude:	about 50 m a.m.s.l.

Interpretation

The soils of this basin are on the whole good agricultural soils with good water retention capacity, relatively rich in organic matter, P_2O_5 and K_2O and with a texture with equal clay silt and sand distribution. There are no particular limitations apart from some zones which are covered by a layer of sand of more than 10 - 15 cm thickness.

EBU - 07

OUDEI CHRAK BASIN

Coordinates: 16° 34' N
12° 50' W

Catchment area: Tributary right bank of the Gorgol Blanc

General description of the site

The basin is situated between two regs with little slope in which the water percolates to the ground water table.

The edges are not clear. A destroyed dike demarcates a natural sill which continues on the left bank as a quartzitic outcrop and on the right bank as an outcrop of sericitic schist.

In places, the natural vegetation is very dense. It is concentrated in the lowest area, demarcating the zone of run-off.

Species include:

- Balanites aegyptiaca
- Dalbergia melanoxylon (Ebony)
- Ziziphus sp.
- Combretum aculeatum (concentrated in the low parts of the wadi)
- Acacia senegal
- Acacia flava (growing in lines in the regs)
- Acacia seyal (in parts which are temporary flooded)

The grasses are perennial and were not identified during the study.

The soils are on the whole agriculturally marginal. Their main restriction is limited depth.

To cultivate this basin which presently lies fallow, it will be necessary to clear the vegetation. Apart from the Gorgol valley, this is the most important wooded area in the region.

Height of the mean water level:		8.00 m
Inundated area:	At 8 m level	210 ha
	at 7 m level	100 ha
Described profiles:	PB 5 height	6.60 m
	PB 6 height	5.80 m
Altitude:		about 40 m a.m.s.l.

Interpretation

The texture consists of equal amounts of clay, silt and sand size particles and the soils are on the whole permeable. Residual moisture is still present 7 months after winter, in the soil (PB 6) as well as in the weathered rock (PB 5).

The exchange complex is well saturated, with more than 80 % calcium, while the reaction is close to neutral and even slightly acid at depth (PB 6). The chemical fertility is satisfactory. The main limitation is the shallow depth of the soils which fringe the alluvia, which themselves are deep, well drained and well aerated.

EBJ - 08

LEHNEIKATT BASIN

Coordinates: 16° 24' N
12° 51' W

Catchment area: Tributary right bank of the Gorgol Blanc

General description of the site

The Lehneikatt Basin is one of the largest of the inventory. Bounded by a natural sil in a straight line with a rock outcrop, the inundated plain at maximal height of 9.75 m covers about 750 ha. The Wadi Bokkoul flows over the natural sil.

Lengthwise the slope of the basin is very gentle (about 0.8 ‰) and run-off is slow, which favours the infiltration of precipitation.

Vegetation has been cleared over a large part of the zone to allow for agriculture.

In general the examined soils show a beginning of alkalisation.

The distribution of the different soil types follows a sequence which is transversal on the direction of the flow of the wadi: well developed soils with distinct horizons occur around the basin, and poorly developed soils occupy the central part, where sediments are finer textured.

On part of the area sorghum is growing.

Height of the mean level: 9.75 m

Inundated area: at 9.75 m level 750 ha
at 8.75 m level 370 ha

Described profiles: PB 3 height 7.95 m
PB 4 height 7.45 m

Altitude: about 40 m a.m.s.l.

Interpretation

The main limitation of these soils is the danger of alkalisation. This process is already clearly indicated in profile PB 4 where the prismatic structure, which is typical of sodic soils, has developed.

Limitations which are induced by alkalisation are:

- slow permeability
- poor workability
- slow internal drainage

- restricted root development
- high pH (8 to 9 in two cases)
- clogging up of the soil pores (which is caused by peptisation of the clay fraction)

AZGUEILEM BASIN

Coordinates: 16° 19' N
12° 53' W

Catchment area: Tributary right bank of the Gorgol Blanc; tendency of silting up

General description of the site

Wadi Azgueilem flows through an area which is more or less covered by sand and passes a succession of sils which create scattered zones where the water stagnates. This occurs annually for periods of different duration. It allows infiltration of a major part of the run-off which creates temporary high water tables and constitutes the main supply of water in the region. The succession of sils also creates possibilities for agriculture, there where flooding takes place and sufficient water can infiltrate.

The dam site is situated between low dunes on the left bank and gravelly regs on the right bank. The rest of an old traditional dam has been used to establish bench marks. The axis of the projected works had to be shifted 600 m upstream of the bench marks after it was found that the soils were not suitable for recession irrigation (PB 7).

The soils which can be cultivated, are situated in a narrow strip of 50 - 100 m wide on both sides of the river bed.

Those soils which have developed in stable sands on the left bank are of no interest for recession irrigation because they are too rapidly permeable and have a low water retention capacity.

Height of the mean water level: 11.00 m

Inundated surface: at the 11.00 m level 45 ha
at the 10.50 m level 24 ha

Described profiles: PB 7 height 10.30 m
PB 8 height 9.80 m

Altitude: about 25 m a.m.s.l.

The described profiles have been sited downstream from the projected works. This was carried out before it was known that these soils were not suitable for irrigation.

Interpretation

The soils profiles are not representative for the soils. PB 7 in particular is developed in very sandy soils totally unsuitable for irrigation.

PB 8 represents a type of soil developed in heterogeneous alluvia with a fine textured topsoil up to 50 cm, then 20 cm coarse textured, and from 70 cm fine textured again. This stratification clearly reveals the different phases of sedimentation.

The pH is neutral; a lower saturation of the exchange complex in the topsoil corresponds with a slightly lower pH (6.2). The organic matter content is relatively high (0.6 to 1.0 %) throughout the profile and corresponds with dark chromas. The chemical composition shows a satisfactory fertility of all alluvial soils, which show here a tendency of hydromorphy.

TOUEIZ KRETT - TAGATT BASIN

Coordinates: 16° 27' N
12° 49' W

Catchment area: Tributary right bank of the Gorgol Blanc

General description of the site

The basin is situated between two rock out-crops with quartz and at the base of the outcrop often sericitic schist.

The soils are partly alluvial sandy loam bordering the wadi bed and partly colluvium of variable thickness and overlying a strongly weathered schist-like rock. These soils are of little interest for agriculture.

Height of the mean water level: 9.75 m

Inundated area: at the 9.75 m level about 90 ha
at the 8.75 m level about 50 ha

Described profiles: PB 1 height 7.45 m
PB 2 height 8.50 m

Altitude: about 40 m a.m.s.l.

Interpretation

The particle-size distribution of the studied profiles does not show variations within the profile (40 - 50 % fine particles in PB 1, 35 % in PB 2) and in the texture, clay, silt and sand are equally divided.

The exchange complex is mainly saturated with calcium (more than 65 %) and the cation exchange capacity is fairly high. The chemical fertility is adequate. The permeability is moderate.

The most important limitation is the depth of the soil, which affects also the capacity to retain water in the soil.

MINT AOUAOU/HNEIKATT BASIN

Coordinates: 17° 27' N
12° 59' W

Catchment area: Wadi El Hneikatt ends without further drainage in the Maghta Lahjar basin 12 km to the west

General description of the site

The basin is an extensive zone of sedimentation which is bordered in the west and north by rock outcrops about 15 m high. An already ancient dam (El Hneikatt) closes the main outlet in the north-west of the basin while the new work will close the south-west outlet. This outlet serves actually as natural overflow, discharging excess water.

Annually, the basin is intensively cultivated over practically its whole arable extent. The water table is shallow (3 to 4 m) near the dam. Downstream of the dam a small grove of palms is developing.

Wadi Hneikatt is a major tributary of the Maghta Lahjar basin where an area of 500-600 ha is cultivated annually.

Height of the mean water level: 99.00 m

Inundated area: 210 ha at the 99.00 m level
120 ha at the 98.50 m level

Described profiles: PB 29 at a height of 97.40 m
PB 30 at a height of 98.20 m

Altitude: about 70 m a.m.s.l.

Interpretation

The soils of the basin constitute the best arable soils which were examined during the survey. They have no limitations; a texture with equal amounts of clay, silt and sand; an excellent structure and a satisfactory chemical fertility.

Next to these soils, there are also soils of less quality (PB 29). They are alkaline with a pH of 9 from 50 cm depth and they have a less favourable structure. These limitations are, however, not so serious that they restrict crop growth, since they are mostly below the root zone.

LEMAOUDOU BASIN

Coordinates: 17° 01' N
13° 02' W

Catchment area: Endoreic drainage; run-off infiltrates and disappears in dunes downstream of the sill which marks the place of the future works.

General description of the site

The basin which drains run-off water from the adjacent regs is bounded downstream by a sill where it runs through a series of dunes with east-west orientation. Upstream, the boundaries are not clear because farmers have built bunds to catch run-off. Cultivation during winter on run-off and recession irrigation are both practiced.

A natural pool is formed in the eastern part of the basin after water recession. This indicates restricted drainage in this zone. The vegetation is characterised by the presence of typical invader colonies of Calotropis procera. Capparis decidua, Acacia flava and Ziziphus also appear in the basin and on the adjacent slopes. A traditional dam which is strongly damaged and a natural rocky sil allow recession irrigation of a small area, while the regs bordering the basin are intensively cultivated in winter. An important zone with recession irrigation is also situated downstream of the sil, between the dunes.

Immediately upstream of the sil is an important zone with wells which permanently supply grazing cattle with water (depth in April 3.40 m)

Height of the mean water table 39.80 m

Inundated area: 120 ha at the 99.80 m level
70 ha at the 99.30 m level

Described profiles: PB 21 height 102.80 m
PB 22 height 98.60 m

Altitude: about 80 a.m.s.l.

Interpretation

The soils of the basin and the adjacent slopes which are cultivated in winter (PB 21) are of moderate potential and have no serious limitations.

Hydromorphic soils occupy the larger portion of the basin. Sedimentation is still taking place. These soils are deep with a moderate available water capacity, no salinity, neutral pH, moderately saturated exchange complex, relatively high organic matter content and available potassium.

BOUDJOUNGAL BASIN

Coordinates: 17° 01' N
12° 53' W

Catchment area: Endoreic drainage; part of the run-off infiltrates and percolates in the dunes bordering the basin in the south.

General description

The basin partly drains a zone of gently sloping regs situated in the north and east, and partly a series of dunes in the south. Two traditional dams have been constructed at 300 m distance; the eldest, upstream, has been ruined, while the more recent one has been rebuilt in 1979 on the axis of the old works. Since that year, the basin has been cultivated again.

A school on the left bank is the only stone building. A cemented well of 20 m with low yield between the dunes and several wells of 10 m in the small palm groves next to the dunes have water of the aquifer between schists and muscovite.

The water in the wells has risen about 1 m after the construction of the traditional dam. The soils of the basin are very good agricultural soils because they are well drained, have a good structure and a texture with equal amounts of clay, silt and sand.

Height of the mean water level: 99.00 m

Inundated area: 140 ha at the 99.00 m level
110 ha at the 97.70 m level

Altitude: about 80 m a.m.s.l.

Interpretation

Like in Lemaoudou, it is difficult to establish the edge of the basin because upstream, bunds have been constructed in order to catch run-off during the winter when crops are cultivated.

The soils are of alluvial origin; they are deep, well drained, well structured and friable (PB 24). The fertility level and water holding capacity are satisfactory. Along the edge of the basin (PB 23), the pH is over 8 in the subsoil which is only a minor limitation. PB 24 represents a very good agricultural soil in this region.

EBU-14

JREKAYA OUDEI LEFKARINE

Coordinates: 17° 11' N
12° 49' W

Catchment area: Tributary right bank of Wadi Amour ending endoreic in the depression of Tamourt Gadel. The run-off could reach the Gorgol Blanc in years of exceptional precipitation.

General description of the site

The wadi drains a catchment area consisting of rocky hills with rather steep slopes. The alluvial plain is fairly narrow and incised by a well demarcated river bed. The shrub vegetation fringing the river bed comprises: Balanites aegyptiaca, Acacia flava and raddiana, Capparis decidua and few Calotropis procera.

The terrain which is fairly flat can be used for winter crops utilising run-off of the downstream slopes by means of bunds around the lands.

The site of the future works is situated between two rock outcrops which are several metres higher than the plain.

Height of the mean water level: 95.00 m

Inundated area: 53 ha at the 95.00 m level
32 ha at the 94,50 m level

Described profiles: PB 25 at 93.50 m
PB 26 at 95.00 m

Altitude: about 95 m a.m.s.l.

Interpretation

The brown sub-arid soils represented by PB 26 constitute the greater part of the soils of the alluvial plain. Both for recession irrigation and cultivation during winter, these soils have no limitations. They are deep, well structured in the topsoil, chemically favourable, and have a good water capacity available within rooting depth.

B1

BOUSSOUEILIF BASIN

Coordinates: 17° 07' N
12° 34' W

Catchment area: Tributary right bank of the Gorgol Blanc

General description of the site

The basin is situated at some kilometres east of the main village of the "arrondissement" Djonaba. It is a depression between dunes which drains a weakly defined catchment comprising for the greater part more or less fixed dunes. A zone of gravelly regs occupies part of the basin on the left bank. A network of more of less deep drainage channels demarcates the zone of run-off. The micro-relief is very uneven, demarcating shrubs which have disappeared and an overburden of sand of variable thickness.

The trees are stunted: Acacia raddiana and flava, several Balanites aegyptiaca. Shrubs include the species Indigofera oblongifolia and few Capparis decidua as well as Calotropis procera.

The basin is bordered by an outlet running through the series of dunes in southern direction, and demarcated by a destroyed traditional dam.

Height of the mean water level: 97.00 m

Inundated area: 52 ha at the 97.00 m level
42 ha at the 96.00 m level

Described profile: PB 27 at 95.00 m
PB 28 at 95.40 m

Altitude: about 65 m a.m.s.l.

Interpretation

The soils of the Boussoueilif basin are of very little agricultural interest for recession irrigation:

- either they have very high pH values (PB 27) associated with a poor structure and high sodium concentrations
- or they have a texture which is too light (PB 28) and an available moisture capacity which is too low.

Elsewhere, a large part of the flooded basin consists of loose sand and gravelly regs which are not suitable for all crops. As most of the area is marginal for cropping, it is recommended for grazing with recession irrigation.

REPUBLIQUE ISLAMIQUE DE MAURITANIE

Ministere du Developpement Rural

RECLAMATION AND CONSTRUCTION OF 15 DAMS IN THE BRAKNA & GORGOL REGIONS

STUDIES FINANCED BY USAID

CONTRACT N° AID 682 - C O - P M & R - 80-01

PROJECT : E B U 2

TECHNICAL STUDIES

GENERAL REPORT

G. TECHNICAL COMPUTATIONS

B. P. 321
NOUAKCHOTT

JULY 1980

1251

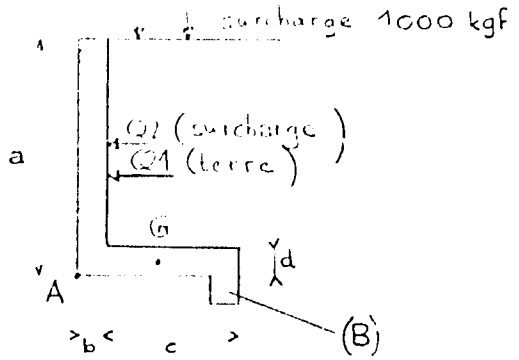
SONADER USAID

STABILITY OF RETAINING WALLS

140

A. PRINCIPE DU CALCUL .

Les murs envisagés sont tous du type suivant :



La bêche (B) est incluse pour assurer la stabilité au glissement , et ses dimensions figurent sur les plans de chaque ouvrage . Cependant , par mesure de simplification , son poids n'est pas pris en compte dans les calculs .

Nous avons fait les hypotheses suivantes , correspondant aux caractéristiques moyennes des dols rencontrés :

- angle du talus naturel : = 32° , d'où $tg^2(-)=0,31$
- poids volumique de la terre : 2025 kgf/m^3
- poids volumique du béton : 2500 kgf/m^3

Les calculs sont faits pour une tranche de 1 m delarge .

1. Sécurité au renversement .

Les moments sont calculés par rapport au point A .

1.1 Moment de renversement :

Il est composé des moments de la poussée de la terre Q1 et de la poussée Q2 résultant d'une surcharge de 1 tonne .

$Q1 = 0,31 \times 2025 \times a^2/2$

$Q2 = 0,31 \times 1000 \times a$

D'où le moment de renversement par rapport à A :

$M_A^R = Q1 \times a/3 + Q2 \times a/2$

1.2 Moment stabilisant :

C'est le moment des forces verticales :

$P1 = a \times b \times 2500$

$P2 = (a-d) \times c \times 2025$

$P3 = d \times c \times 2500$

D'où la résultante des forces verticales :

$P = P1 + P2 + P3$

et le moment stabilisant par rapport à A :

$M_A^S = P1 \times b/2 + (P2+P3)(b + c/2)$

1.3 Coefficient de sécurité au renversement :

C'est le rapport $cR = M_A^S / M_A^R$

Ce rapport doit rester supérieur à 2 .

2. <u>Sécurité au glissement</u> :

C'est le rapport $cG = (Q1 + Q2) / (P1 + P2 + P3)$

Ce rapport doit rester inférieur à 0,35 , valeur acceptable grâce à la bêche et à la présence du déversoir en butée .

3. <u>Excentricité</u> :

C'est la distance entre le centre de gravité G de la semelle et la résultante des forces verticales :

$e = (b + c)/2 - M_A^S / P$

Cette valeur doit être inférieure à (b+c)/6 (règle du tiers central) .

4. Pression au sol maximum :

C'est la pression au droit du point A .

4.1 Moment total par rapport à G :

$$M_G = M_A^R + e \times P$$

4.2 Pression au sol au point A :

$$p_A = P / (b + c) + 6 \times M_G / (b + c)^2$$

Cette valeur devra rester inférieure à 3 kgf/cm^2 , valeur maximum admissible pour l'argile compacte humide .

B. CALCULS .

Les calculs ont été effectués pour 5 murs parmi les plus importants , à l'aide d'un programme sur calculateur HP 41 C . Les résultats figurent sur les fiches ci-jointes .

STABILITE DES MURS DE SOUTENEMENT

Date du calcul : 6/80 Fait par : F. Stejlan

Site : Lehnalrath Référence plan :

A. DONNEES :

Angle du talus naturel : 32 °

Poids spécifique de la terre : 2025 kgf/m^3

Poids spécifique du béton : 2500 kgf/m^3

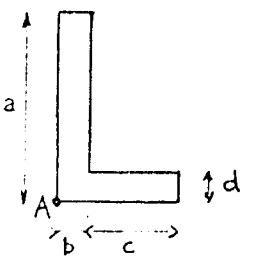
Cotes :

a = 5,2 m

b = 0,4 m

c = 2,3 m

d = 0,5 m



B. RESULTATS :

1. Moment de renversement M_A^R = 18735 kgf.m

   Moment stabilisant M_A^S = 39426 kgf.m

   Sécurité au renversement cR = 2,10

2. Poussée horizontale totale Q = 10 009 kgf

   Force verticale totale P = 29 965 kgf

   Sécurité au glissement cG = 0,33

3. Excentricité e = 0,034 m

4. Pression au sol maximum = 2,74 kgf/cm^2

STABILITE DES MURS DE SOUTENEMENT

Date du calcul : 6/80 Fait par : F. Stephan

Site : Arguillon - aval Référence plan :

A. DONNEES :

Angle du talus naturel : 32 °

Poids spécifique de la terre : 2025 kgf/m^3

Poids spécifique du béton : 2500 kgf/m^3

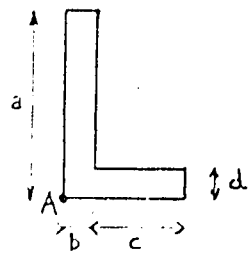
Cotes :

a = 4,5 m

b = 0,4 m

c = 2,0 m

d = 0,5 m



B. RESULTATS :

1. Moment de renversement M_A^R = 12560 kgf.m

   Moment stabilisant M_A^S = 27080 kgf.m

   Sécurité au renversement cR = 2,15

2. Poussée horizontale totale Q = 7682 kgf

   Force verticale totale P = 23200 kgf

   Sécurité au glissement cG = 0,33

3. Excentricité e = 0,033 m

4. Pression au sol maximum = 2,35 kgf/cm^2

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STABILITE DES MURS DE SOUTENEMENT

Date du calcul : 6/80 Fait par : F. Skyhan

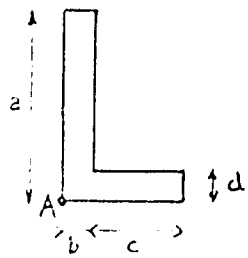
Site : Arguillon - amont Référence plan :

A. DONNEES :

Angle du talus naturel : 32 °
Poids spécifique de la terre : 2025 kgf/m^3
Poids spécifique du béton : 2500 kgf/m^3

Cotes :

a = 3,1 m
b = 0,4 m
c = 1,3 m
d = 0,5 m



B. RESULTATS :

1. Moment de renversement M_A^R = 4565 kgf.m
   Moment stabilisant M_A^S = 9512 kgf.m
   Sécurité au renversement cR = 2,08

2. Poussée horizontale totale Q = 3942 kgf
   Force verticale totale P = 11569 kgf
   Sécurité au glissement cG = 0,34

3. Excentricité e = 0,028 m

4. Pression au sol maximum = 1,69 kgf/cm^2

STABILITE DES MURS DE SOUTENEMENT

Date du calcul : 6/80 Fait par : F. Stephan

Site : Bordjomgad. centre Référence plan :

A. DONNEES :

Angle du talus naturel : 32 °

Poids spécifique de la terre : 1025 kgf/m^3

Poids spécifique du béton : 2500 kgf/m^3

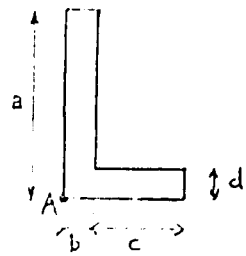
Cotes :

a = 4,35 m

b = 0,4 m

c = 2,0 m

d = 0,5 m



B. RESULTATS :

1. Moment de renversement M_A^R = 11442 kgf.m

Moment stabilisant M_A^S = 26199 kgf.m

Sécurité au renversement cR = 2,29

2. Poussée horizontale totale Q = 7223 kgf

Force verticale totale P = 22442 kgf

Sécurité au glissement cG = 0,32

3. Excentricité e = 0,033 m

4. Pression au sol maximum = 2,20 kgf/cm^2

STABILITE DES MURS DE SOUTENEMENT

Date du calcul : 6/80 Fait par : F. Stephan

Site : Boudjoungal amont / kwal Référence plan :

A. DONNEES :

Angle du talus naturel : 32 °

Poids spécifique de la terre : 2025 kgf/m^3

Poids spécifique du béton : 2500 kgf/m^3

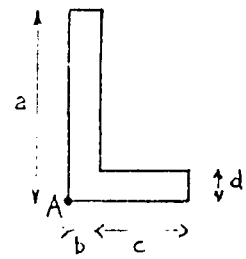
Cotes :

a = 3,6 m

b = 0,4 m

c = 1,5 m

d = 0,5 m



B. RESULTATS :

1. Moment de renversement M_A^R = 6829 kgf.m

   Moment stabilisant M_A^S = 13704 kgf.m

   Sécurité au renversement cR = 2,01

2. Poussée horizontale totale Q = 5138 kgf

   Force verticale totale P = 14891 kgf

   Sécurité au glissement cG = 0,34

3. Excentricité e = 0,030 m

4. Pression au sol maximum = 1,99 kgf/cm^2

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COMPUTATION OF DURATION FOR PARTYING

1 .. BARRAGE DE CAG EL MOHOR

TABLE DE VIDANGE

$Q = m.S.\sqrt{2gh}$

$m = 0.65$ (CONCRETE TABLE 148)

$\phi = 350$

COTE (m)	VOLUME A VIDANGER (m³)	h (m)	Q (m³/s)	T. de VIDANGE (jour)
101.50	383.500	1.25	0.310	14,33
101.00	203 687	0.75	0.240	24,16
100.50	62 875	0.25	0,139	29,41
100.00				

J.

4 -. BARRAGE DE AMEIRA

TEMPS DE VIDANGE

$Q = m.s.\sqrt{2gh}$

$m = 0.74$ (CONGRESTES TABLE 148)

$\phi = 300$

COTE (m)	VOLUME A VIDANGER (m³)	h (m)	Q (m³/s)	T. de Vidange (jour) (cumul)
100.80				
100.50	135 350	1.15	0.248	6,81
100.00	164.650	0.75	0.201	15,80
99.50	37.075	0.25	0,116	19,51

5 -. BARRAGE DE ZMEILATT

TEMPS DE VIDANGE

$Q = m.S.\sqrt{2gh}$

$m = 0.60$ (CONDITIONS TRACE 148)

$\phi = 250$

COTE (m)	VOLUME A VIDANGER (m³)	h (m)	Q (m³/s)	T. de Vidange (jour)
7.50				
	196.562	1.25	0.146	15,60
7.00				
	63.250	0.75	0,113	22,08
6.50				
	3 625	0.25	0,065	22.72
6.00				

6 - BARRAGE DE MOUDI FOUNTI

TEMPS DE VIDANGE

$Q = m \cdot S \cdot \sqrt{2gh}$

$m = 0.80$ (LENCASTRE TABLE 148)

$\phi = 300$

COTE (m)	VOLUME A VIDANGER (m³)	h (m)	Q (m³/s)	T. de VIDANGE (jour)
9.50				
9.00	287.425	1,25	0.280	11,88
8.50	119.425	0.75	0.217	18,25
8.00	54.250	0.25	0.125	23,27

7 - BARRAGE DE OUDEI CHRAK

TEMPS DE VIDANGE

$Q = m \cdot S \cdot \sqrt{2gh}$

$m = 0.62$ (CONCISTRES TABLE 148)

$\phi = 500$

COTE (m)	VOLUME A VIDANGER (m³)	h (m)	Q (m³/s)	T. de VIDANG. (jours)
8.00				
	901.000			
7.50		2.75	0,894	11,66
	619.813			
7.00		2.25	0,809	20,53
	405.625			
6.50		1.75	0,713	27,11
	236.750			
6.00		1.25	0,603	31,66
	106.562			
5.50		0.75	0,467	34.3
	29 000			
5.00		0.25	0,270	35,54

8 .. BARRAGE DE LEHNEIKATT

TEMPS DE VIDANGE

$Q = m \cdot S \cdot \sqrt{2gh}$

$m = 0.68$ (LORENTZ TABLE 148)

$\phi = 700$

COTE (m)	VOLUME A VIDANGER - (m^3)	h (m)	Q (m^3/s)	T. de VIDANG (jours)
9.75				
9.00	2.759.375	2,63	1,880	16,39
8.50	1.760.000	2,25	1,739	28,71
8.00	1.122.812	1,75	1,533	37,18
7.50	658.438	1,25	1,296	43,06
7.00	360.750	0,75	1,004	46,87
6.5	101437	0.25	0.580	48.90

9 -. BARRAGE DE AZGUEILEM

TEMPS DE VIDANGE

$Q = m.s.\sqrt{2gh}$

$m = 0.77$ (LENCASTRE TABLE 148)

$\phi = 200$

COTE (m)	VOLUME A VIDANGER - (m^3)	h (m)	q (m^3/s)	T. de VIDANG. (jour)
11.00	181.35	1,75	0,142	14,81
10.50	86.400	1,25	0.120	23,15
10.00	23.400	0,75	0,093	26,82
9.50	6.250	0,25	0.054	28,17
9.00				

10 -. BARRAGE DE TOUEIZE GRETT TAGATT

TEMPS DE VIDANGE

$Q = m \cdot S \cdot \sqrt{2gh}$

$m = 0{,}60$ (CONCASTRE TABLE 148)

$\phi = 400$

COTE (m)	VOLUME A VIDANGER (m³)	h (m)	(m³/s)	T DE VIDANGE (heure)
9,75				
9,50	110.750	2,875	0,566	2,26
9,00	357.687	2,75	0,554	9,74
8,50	258.250	2,25	0,501	15,71
8,00	171.625	1,75	0.442	20,20
7,50	102,375	1,25	0,373	23,37
7,00	47,875	0,75	0,289	25,29
6,50	11,437	0,25	0,167	26,08
6,00				

11 -: BARRAGE DE MINT AOUAOU

TEMPS DE VIDANGE

$Q = m.s.\sqrt{2gh}$

$m = 0.69$ (LINCASTRE TABLE 148)

$\phi = 600$

COTE	VOLUME A VIDANGER - (m^3)	h (m)	Q (m^3/s)	T. de vidange (jours)
99,00			1,143	16.706
98,50	1650 000	1,75	~~0,777~~	~~24,27~~
98,00	900 000	1.25	0,966 ~~0,657~~	27,49
97,50	400 000	0.75	0,748	33,67
97,00	100.000	0.25	0,432	36,35

12 -. BARRAGE DE LEMAOUDOU

TEMPS DE VIDANGE

$Q = m.s.\sqrt{2gh}$

$m = 0,66$ (LENCASTRE TABLE 148)

$\phi = 400$

COTE (m)	VOLUME A VIDANGER - (m³)	h (m)	Q (m³/s)	T. de VIDANG (jour)
99,80				
99,50	340.000	1,45	0,442	8,90
99,00	335.675	0,95	0.358	19,75
98,50	74.585	0,45	0,246	23,25
98,30	0			

13 .. BARRAGE DE BOUDJOUNGAL

TEMPS DE VIDANGE

$Q = m.S.\sqrt{2gh}$

$m = 0.64$ (CONCENTRE TABLE 143)

$\phi = 500$

COTE (m)	VOLUME A VIDANGER (m³)	h (m)	Q (m³/s)	T. de VIDANG. (jour)
99,00				
	600.000	1,75	0,786	9,43
98,50				
	480.000	1,25	0,622	18,36
98,00				
	300.000	0,75	0,482	25.56
97,50				
	140.000	0,25	0.278	31,38
97,00				

14 .. BARRAGE DE JREKAYA OUDEI LEFKARINE

TABLE DE VIDANGE

$Q = m \cdot S \cdot \sqrt{2gh}$

$m = 0,58$ (LOUCASTRE TABLE 148)

$\phi = 250$

COTE (m)	VOLUME A VIDANGER (m³)	h (m)	Q (m³/s)	T. de VIDANG. (jour)
95,00				
	216.562	2,25	0,189	13,25
94,50				
	117.000	1,75	0,167	21,37
94,00				
	47.875	1,25	0,141	25,30
93,50				
	21.500	0,75	0,109	27,58
93,00				
	6.875	0,25	0,063	28,84
92,50				

15 - BARRAGE DE BOUSSOUEILIF

TEMPS DE VIDANGE

$Q = m.S.\sqrt{2gh}$

$m = 0,60$ (CONSTRUCTEUR TABLE 143)

$\phi = 300$

COTE (m)	VOLUME A VIDANGER (m³)	h (m)	Q (m³/s)	T. de Vidang. (jour)
97,00				
96,50	234.063	2,50	0,297	9,12
96,00	168.562	2,00	0,266	16,46
95,50	112.813	1,50	0,230	22,14
95,00	71.000	1,00	0,188	26.51
94,50	25.125	0.50	0,133	28.70
94,25	0			

SONADER

USAID

STABILITY OF OVERFLOW EMBANKMENT DAMS

163

```
 01*LBL "START"
REG "A=" PROMPT
ARCL X AVIEW STO 00
"M=" PROMPT ARCL X
AVIEW STO 01
"ALFA(GRD)" PROMPT
STO 02 ARCL X AVIEW
"BETA=" PROMPT ARCL X
AVIEW STO 03 RCL 01
1024 RCL 02 * 1 +
RCL 00 1440 MOD
RCL 03 * 1024 RCL 02
MOD + / RCL 01 *
STO 04 "X1=" ARCL X
AVIEW RCL 03 1440 MOD
RCL 01 * 1024 *
STO 05 "Y1=" ARCL X
AVIEW RCL 01 4.5 *
[illegible] MOD
STO 07 RCL 2
RCL 04 RCL 05 -
STO 08 RCL 04 * CHS
RCL 07 + STO 01
"ALFA(GRD)" PROMPT
STO 02 ARCL X AVIEW
X<0 GTO 02

 02*LBL 03
GSB "A=" PROMPT
ARCL X AVIEW
STO IND 00 [illegible]
"M=" PROMPT ARCL X
AVIEW STO IND 01
[illegible] "ALFA" PROMPT
ARCL X AVIEW
STO IND 02 ISG 03
"BETA=" PROMPT ARCL X
AVIEW STO IND 03
ISG 03 "DATA=" PROMPT
ARCL X AVIEW
STO IND 01 ISG 03
"TF=" PROMPT ARCL X
AVIEW STO IND 03
ISG 03 GTO 02

 121*LBL 0
ADV ADV "TITRE=" ADV
PROMPT ARCL AVIEW
"PRO" PROMPT ARCL X
AVIEW STO 01 "DC=" [illegible]
PROMPT ARCL X AVIEW
STO 06 "EGRI=" PROMPT
```



```
ARCL X AVIEW STO 07
"DRIR=" PROMPT ARCL X
AVIEW STO 08 "CSQT=" [illegible]
PROMPT ARCL X AVIEW
STO 19 "TRAPNI=" [illegible]
PROMPT ARCL X AVIEW
GTO 24

 169*LBL A
0 STO 17 STO 18 ADV
ASV "K=" PROMPT
ARCL X AVIEW STO 11
X12 RCL 04 X12 1 +
* RCL 01 X12 - SQRT
CHS RCL 08 RCL 01 *
- RCL 08 X12 1 + /
STO 12 RCL 04 *
RCL 01 * STO 13 RCL 01
RCL 04 STO 05

 195*LBL 01
RCL 50 RCL 04 STO 09

 203*LBL 02
RCL IND 07 RCL 05
X<0? GTO 03 2 STO 03
[illegible] GTO 02 "ERR.1"
PROMPT

 213*LBL 03
RCL 05 ADV 07 RCL 05
X<0 GTO 04 [illegible]
[illegible]
ST- 05 [illegible] GTO 03

 220*LBL 04
RCL 05 [illegible] 2 / -
[illegible] X<0 GTO 15 STO 15
CHS STO 14 [illegible] ENTER↑
X<0 GTO 14 ABS
ENTER↑ X<0 49 ST- 15
RCL 09 X<Y? - X<Y?
RCL 12 - X<Y? / ABS
STO 18 RCL 03 5 +
RCL IND X STO 16
RCL 15 X<0? 0 STO 15
RCL 14 [illegible] *
RCL 15 RCL 07 * +
RCL 16 RCL 03 * +
RCL 03 < ? RCL 16 STO
```



```
* ADV "T=" ARCL X
AVIEW ST+ 17 LASTX /
RCL 05 RCL 15 * -
RCL 08 COS * "H="
ARCL X AVIEW ST+ 19
[illegible] GTO 05 RCL 04
[illegible] GTO 01

 305*LBL 05
RCL 05 X<0 47 RCL 05
X<0 49 X<=Y? GTO 06
RCL 04 20 / ST- 05
GTO 05

 317*LBL 06
ADV "ST=" ARCL 17
AVIEW "EN=" ARCL 18
AVIEW RCL 13 X<Y
[illegible] RCL 15 - / 18
/ [illegible] RCL 12 RCL 13
/ MIN + RCL 11 *
180 / PI * "L="
ARCL X AVIEW RCL 19 *
RCL 18 RCL 20 * -
RCL 17 / "C=" ARCL X
AVIEW STOP

 360*LBL 47
RCL [illegible] 3 * STO 18
[illegible]

 365*LBL 49
[illegible]

 371*LBL [illegible]
RCH RCL IND 18 *
ISG 18 RCL IND 18 +
RTN

 379*LBL 49
RCL 12 - X↑2 RCL 11
X↑2 X<>Y - X<0?
GTO 45 SQRT RCL 13
X<>Y - RTN

 391*LBL 48
CLX 1 E5 RTN

 393*LBL 50
RCL 02 6 * 20 +
1000 / 21 + STO 03
RTN END
```

M=1,020
H=2,000
ALFA(DEG)37,000
BETA=20,000
X1=0,871
Y1=2,650
N2,SF(25,000

XF=0,500
NREM8=0,086
EXEX3=0,500
NSRT=1,000
BSRT=0,200
EPPR=1,000

XF=1,000
DPEM8=0,000
DPEN8=1,000
NSRT=1,000
BSRT=0,000
EPPR=1,000

XF=1,500
DPEM8=0,000
DPEN8=1,500
NSRT=0,400
BSRT=0,000
EPPR=0,700

XF=2,500
DPEM8=0,000
DPEN8=2,500
NSRT=0,200
BSRT=0,200
EPPR=0,[illegible]

XF=5,000
DPEM8=-0,689
DPEN8=4,413
NSRT=-0,689
BSRT=4,413
EPPR=0,240

MINT DOUTOU NVAL PICL
PA(20,500
BS=1,750
DPMT=2,120
DPPR=1,000
CSA =2,150
TORPMI=0,620

R=2,920

T=-0,384
N=1,266

T=-0,085
N=1,689

T=0,285
N=1,543

T=0,638
N=1,454

T=0,914
N=1,287

T=1,044
N=0,879

T=0,966
N=0,481

T=0,170
N=0,057

ΣT=3,325
ΣN=0,596
L=4,310
c=4,215

R=3,500

T=3,[illegible]
N=1,235

T=0,[illegible]
N=1,412

T=0,756
N=1,276

T=0,842
N=0,935

T=0,767
N=0,652

T=0,414
N=0,278

ΣT=3,493
ΣN=5,047
L=7,223
c=3,022

T=0,374
N=1,172

T=2,675
N=1,276

T=0,053
N=1,183

T=0,087
N=0,762

T=0,543
N=0,422

T=0,127
N=0,075

ΣT=3,378
ΣN=4,815
L=2,712
c=2,619

R=5,000

T=0,571
N=1,862

T=0,018
N=1,030

T=0,055
N=0,073

T=0,[illegible]
N=0,526

T=0,290
N=0,196

ΣT=3,140
ΣN=3,747
L=2,196
c=[illegible]

R=6,[illegible]

T=0,667
N=0,981

T=0,039
N=0,969

T=0,794
N=0,736

T=0,633
N=0,488

T=0,861
N=0,839

ΣT=3,014
ΣN=3,806
L=1,928
c=2,029

R=4,500

T=0,492
N=1,113

T=0,760
N=1,172

T=0,069
N=0,971

T=0,709
N=0,626

T=0,445
N=0,314

ΣT=3,234
ΣN=1,496
L=2,536
c=2,357

165

M=1.580
N=1.259
ALPA(DEG)X3.009
GMA=26.680
XI=1.498
YI=2.546
HB.SEG74.080

T=0.236
N=0.972

T=0.032
N=0.325

T=0.220
N=0.347

T=0.000
N=0.021

T=-0.263
N=0.846

XE=2.500
HF2X8=8.667
HB2X8=8.680
WXUF=0.667
LSUF=0.880
TCOR=0.248

T=0.242
N=0.037

T=-0.116
N=0.097

T=0.473
N=0.693

T=0.173
N=1.079

T=0.583
N=0.667

T=0.583
N=1.177

XE=3.036
HF2X9=0.165
PXF=1.250
XSUF=-0.335
RSU=2.595
TCOR=0.238

T=0.726
N=0.492

T=0.099
N=1.115

T=0.220
N=0.203

T=1.013
N=0.917

XT=3.584
GPLOD=0.800
PXF=0=1.250
TCOR=0.250
RSUT=2.253
GPLOD=0.200

ΣT=2.490
ΣN=3.510
L=5.735
c=4.892

T=0.252
N=0.508

T=0.919
N=0.092

T=0.377
N=0.170

T=0.924
N=0.656

X=1.400
PXF=0.479
GPLOD=1.750
TCOR=0.225
RSUT=2.513
GPLOD=0.250

X=3.100

T=-0.055
N=0.376

ΣT=3.423
ΣN=5.240
L=4.725
c=4.270

T=0.029
N=0.298

T=-0.824
N=0.509

R=0.500

ΣT=3.119
ΣN=5.556
L=4.316
c=4.083

FIND DOUBLE AMOUT MUFI
FLOD=0.500
GP=1.750
TCOR=1.04
GPLOD=1.000
ΣT=1.10
TCOR=0.620

T=0.168
N=0.727

T=0.028
N=0.267

T=0.472
N=0.010

T=0.131
N=0.451

T=0.715
N=0.029

T=0.298
N=0.556

T=0.052
N=0.636

T=0.172
N=0.557

T=0.623
N=0.629

T=0.623
N=0.494

T=0.405
N=0.006

T=0.405
N=0.388

ΣT=3.009
ΣN=3.438
L=4.095
c=4.912

T=0.070
N=0.043

ΣT=2.116
ΣN=2.650
L=3.402
c=4.296

166

DUNLAP

USAID

STABILITY OF CONCRETE DAMS

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50
45
45
40
23
15
8
$\frac{V^2}{2g}$
300
50
75
75
50

BARRAGE DE : MOUDI FOUNTI

CALCUL DES MOMENTS

DESIGNATION	F1 →	Z	M1 ↻	F2 ↓	Z	M2 ↺
POUSSEE HYDRAULIQUE						
$\frac{2.23^2 - 0.15^2}{2}$	2.29					
$2.08 - \left(\frac{2.23 - 0.15}{3(0.15 + 2.23)}\right)(0.15 + 2 \times 2.23) \times 0.5$		1.24	2.84			
MACONNERIES						
2.5 × 0.5 × 2.3				2.88	1.55	4.46
2.0 × 0.45 × 2.3				2.07	1.07	2.21
1.25 × 0.45 × 2.3				1.29	0.62	0.80
0.5 × 0.40 × 2.3				0.46	0.20	0.09
TOTAUX	2.29	1.24	2.84	6.70	1.13	7.56

- COEFFICIENT DE SECURITE

$$\frac{7.56}{2.84} = 2.66$$

CALCUL DES CONTRAINTES RETENUE PLEINE

— Point de passage de la résultante

$$\frac{7.56 - 2.84}{6.70} = 0.70$$

— Excentricité

$$\frac{1.80}{2} - 0.70 = 0.20 < \frac{1.80}{6} = 0.30$$

— Pression moyenne

$$\frac{6.70}{180 \times 100} = 0.372 \text{ Kg/cm}^2$$

— Pression sur l'arête aval

$$0.372 \left(1 + \frac{6 \times 0.20}{1.80}\right) = 0.620 \text{ Kg/cm}^2$$

— Pression sur l'arête amont

$$0.372 \left(1 - \frac{6 \times 0.20}{1.80}\right) = 0.124 \text{ Kg/cm}^2$$

— Glissement

$$\frac{6.84}{7.56} = 0.876 > 0.$$

CALCUL DES CONTRAINTES RETENUE VIDE

— Excentricité

$$\frac{1.80}{2} - 1.13 = -0.23 < \frac{1.80}{6} = 0.30$$

— Pression sur l'arête aval

$$0.372 \left(1 + \frac{6 \times -0.23}{1.80}\right) = 0.087 \text{ Kg/cm}^2$$

— Pression sur l'arête amont

$$0.372 \left(1 - \frac{6 \times -0.23}{1.80}\right) = 0.657 \text{ Kg/cm}^2$$

— Pression sur la base du parafouille

$$\frac{\frac{0.40 + 0.80}{2} \times 1.70 \times 2.30}{40 \times 100} = 0.258 \text{ Kg/cm}^2$$

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BARRAGE DE: AZGUEILEM

CALCUL DES MOMENTS

DESIGNATION	F1 →	Z	M1 ↻	F2 ↓	Z	M2 ↺
POUSSEE HYDRAULIQUE						
$\frac{3.00^2 - 0.34^2}{2}$	4.442					
$2.34\left(\frac{3.0-0.34)(0.34+2\times3.0)}{3(0.34+3.0)}\right)+0.5$		1.48	6.574			
MACONNERIES						
0.5 × 3.00 × 2.30				3.45	2.15	7.42
0.5 × 2.50 × 2.30				2.88	1.65	4.75
0.5 × 1.83 × 2.30				2.10	1.15	2.41
0.5 × 1.46 × 2.30				1.33	0.65	0.86
0.4 × 0.5 × 2.30				0.46	0.20	0.09
TOTAUX	4.44	1.48	6.57	10.22	1.52	15.53

COEFFICIENT DE SECURITE

$$\frac{15.53}{6.57} = 2.36$$

CALCUL DES CONTRAINTES RETENUE PLEINE

— Point de passage de la résultante

$$\frac{7.53 - 6.57}{10.22} = 0.88$$

— Excentricité

$$\frac{2.40}{2} - 0.88 = 0.32 < \frac{2.40}{6} = 0.40$$

— Pression moyenne

$$\frac{10.22}{2.40 \times 100} = 0.426 \text{ Kg/cm}^2$$

— Pression sur l'arête amont

$$0.426\left(1 + \frac{6 \times 0.32}{2.40}\right) = 0.767 \text{ Kg/cm}^2$$

— Pression sur l'arête aval

$$0.426\left(1 - \frac{6 \times 0.32}{2.40}\right) = 0.085 \text{ Kg/cm}^2$$

— Glissement

$$\frac{4.26}{10.22} = 0.416 = tg\ 23.05 < tg\ 30°$$

CALCUL DES CONTRAINTES RETENUE VIDE

— Excentricité

$$\frac{2.40}{2} - 1.52 = -0.32$$

— Pression sur l'arête aval

$$0.426\left(1 + \frac{6 \times 0.32}{2.40}\right) = 0.767 \text{ Kg/cm}^2$$

— Pression sur l'arête amont

$$0.426\left(1 - \frac{6 \times 0.32}{2.40}\right) = 0.085 \text{ Kg/cm}^2$$

— Pression réelle sur la base du parafouille

$$\frac{0.4 \times 2.4 \times 1.7 \times 2.300}{40 \times 100} + 0.426 = 1.013 \text{ Kg/cm}^2$$

REPUBLIQUE ISLAMIQUE DE MAURITANIE

Ministère du Développement Rural

RECLAMATION AND CONSTRUCTION OF 15 DAMS IN THE BRAKNA & GORGOL REGIONS

STUDIES FINANCED BY USAID

CONTRACT N° AID 682 - C O - P M & R - 80-01

PROJECT : E B U 2

TECHNICAL STUDIES

GENERAL REPORT

H. STANDARD DRAWINGS

B. P. 321
NOUAKCHOTT

JULY 1980

REPUBLIQUE ISLAMIQUE DE MAURITANIE

MINISTERE DU DEVELOPPEMENT RURAL

SONADER

SOCIETE NATIONALE POUR LE DEVELOPPEMENT RURAL

NOUAKCHOTT BP 321

Contrat USAID

N° AID 682 - CO - PME - 80 - 01

MODIFICATIONS

DATE	OBJET	VISA

ETUDE de 15 BARRAGES dans le BRAKNA et le GORGOL

PIECES COMMUNES

OUVRAGE DE VIDANGE TYPE SUR DIGUE

Etabli par Sce Topo SONADER	ECHELLE	DATE	N° DOSSIER	BARRAGE	PIECE
Vérifié par DET	1:50	JUILLET 80	E B U 2	— —	H

A4

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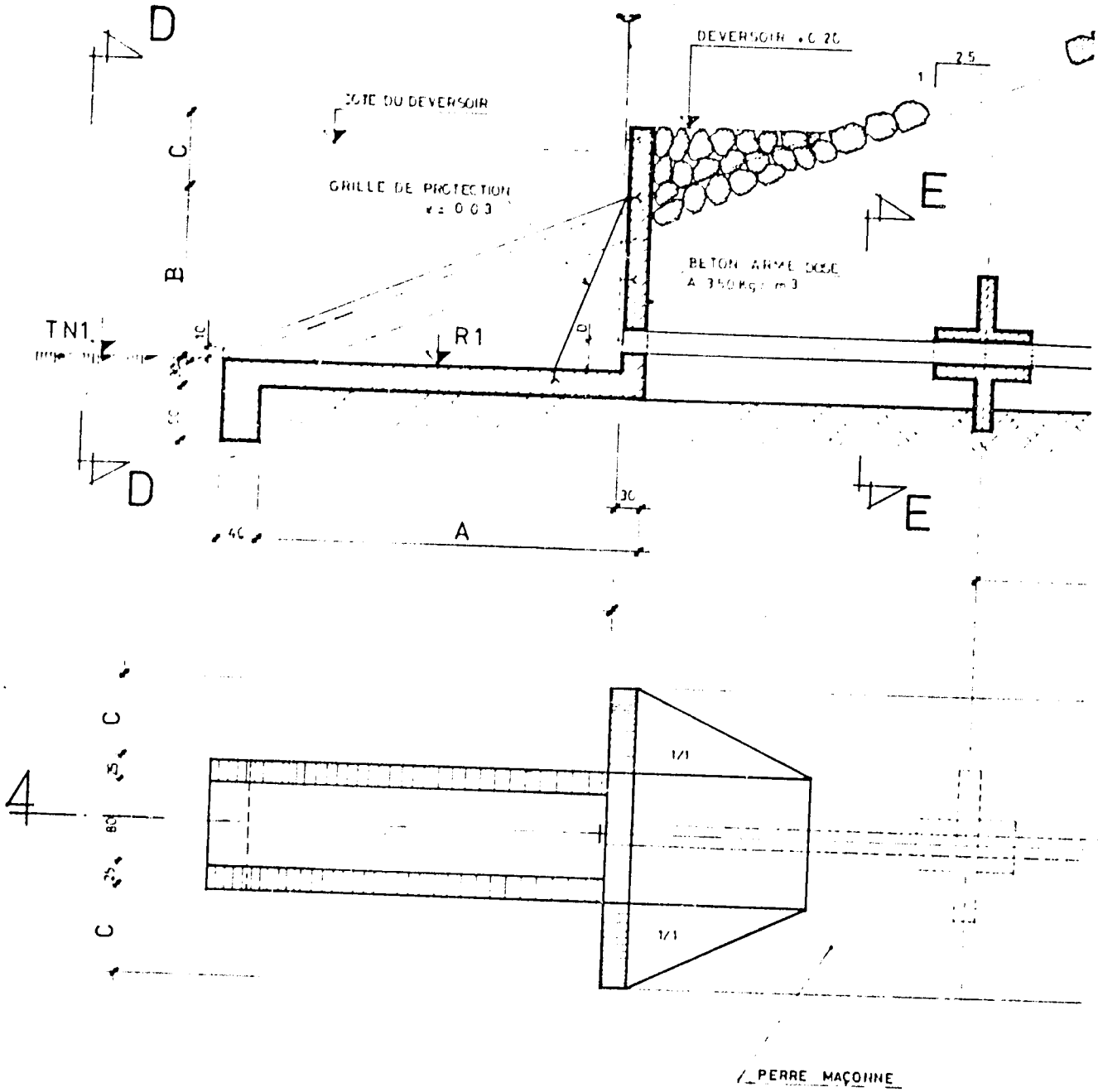
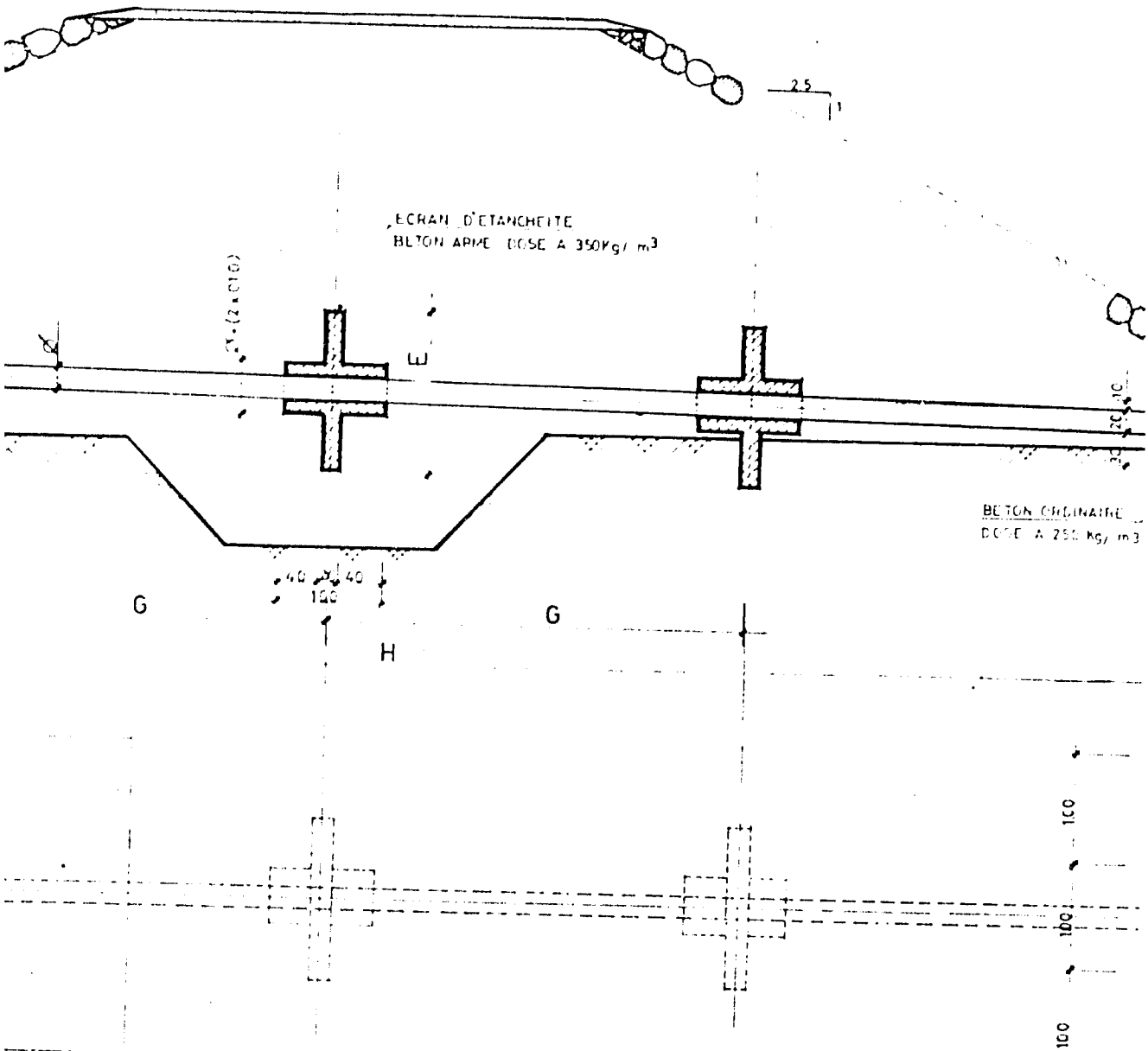
VANNE A GLISSEMENT



PERRE MAÇONNE

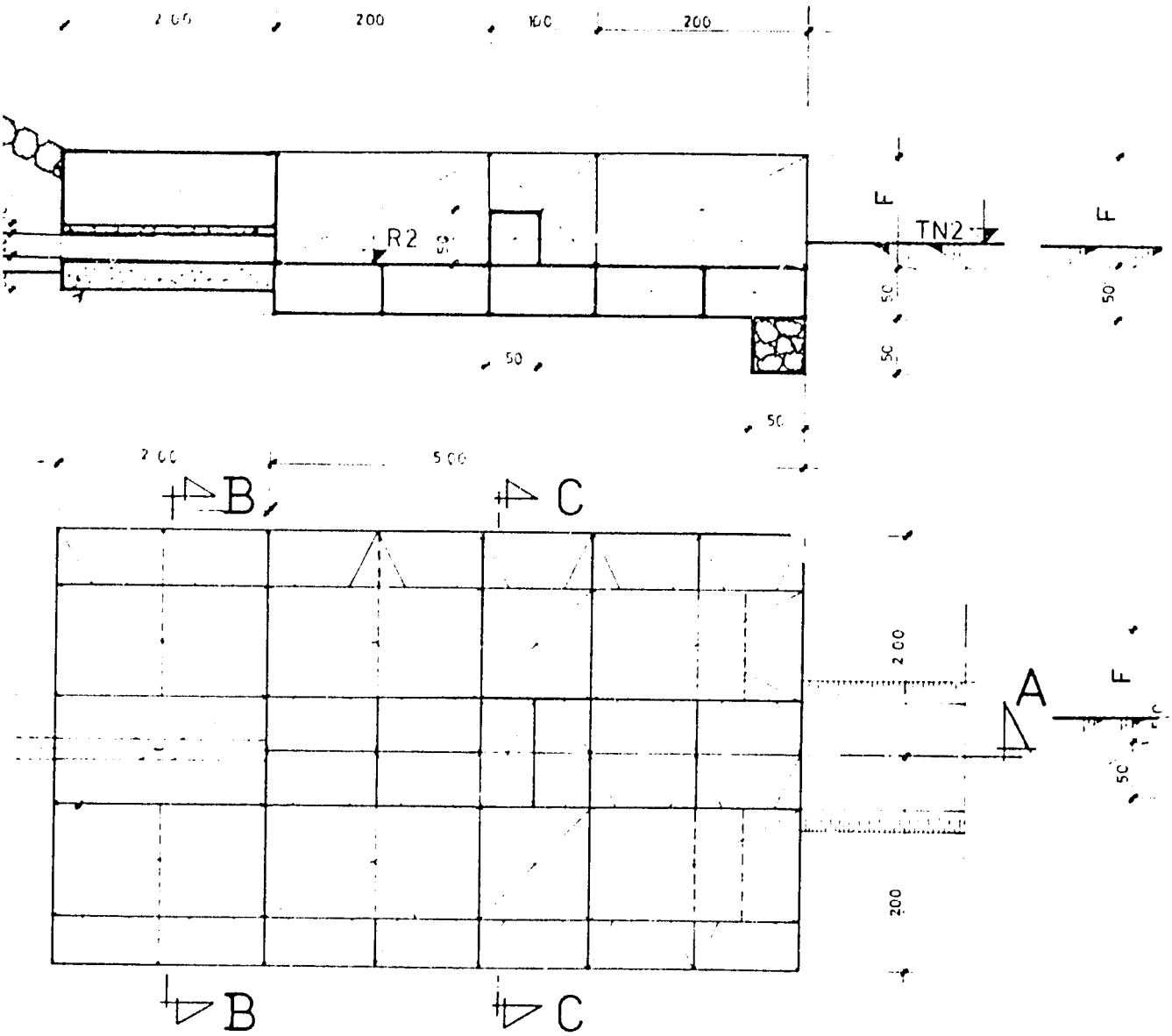
COUPE AA



VUE EN PLAN

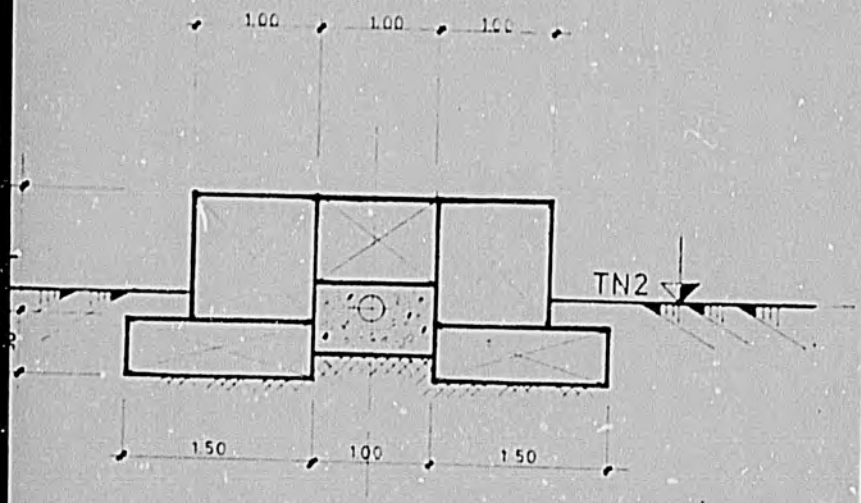
171

1ere SOLUTION DE SORTIE (GABIONS)

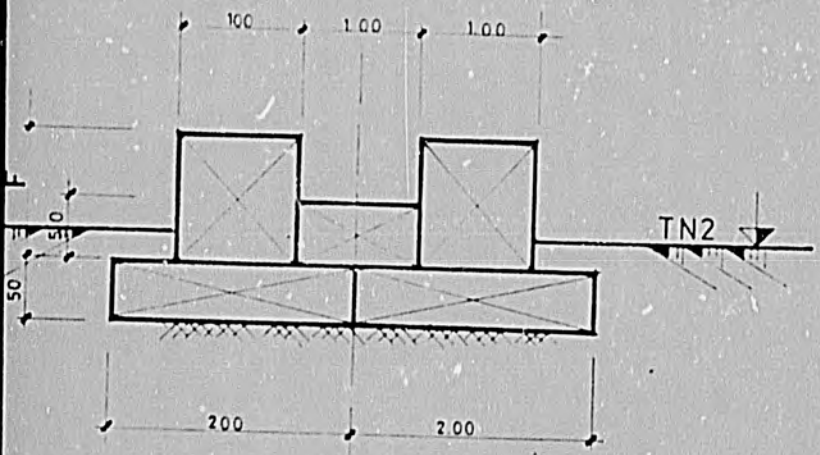


175

COUPE BB

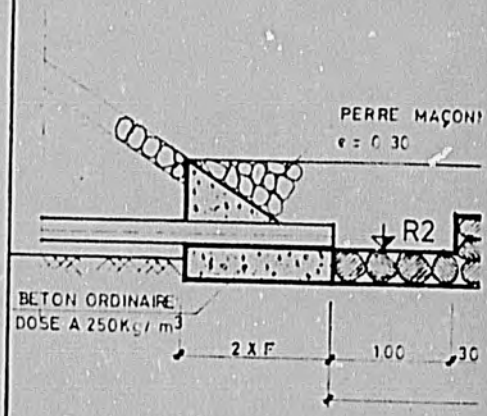


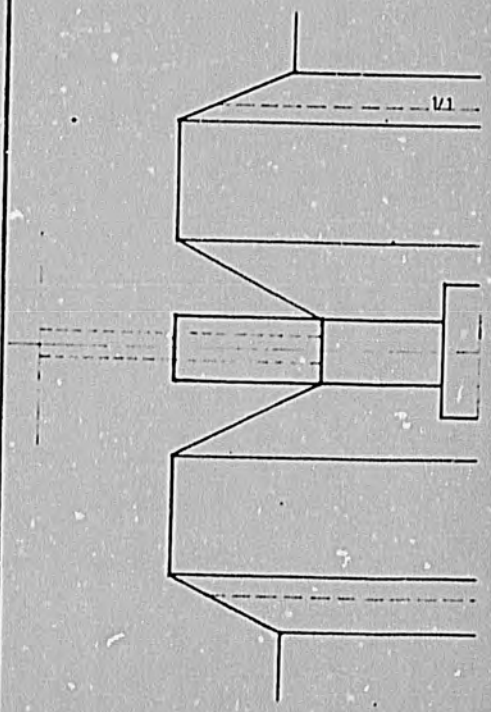
COUPE CC



2eme SOLUTION (SOR

COUPE

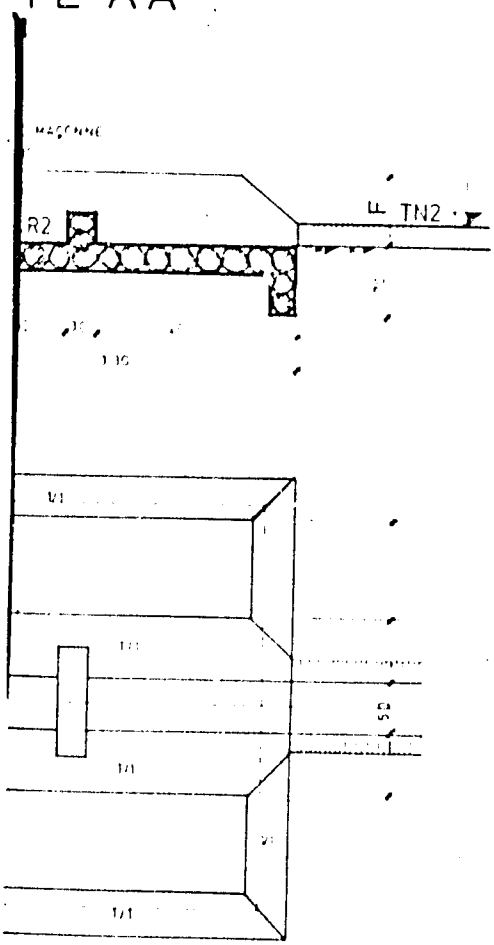




VUE E

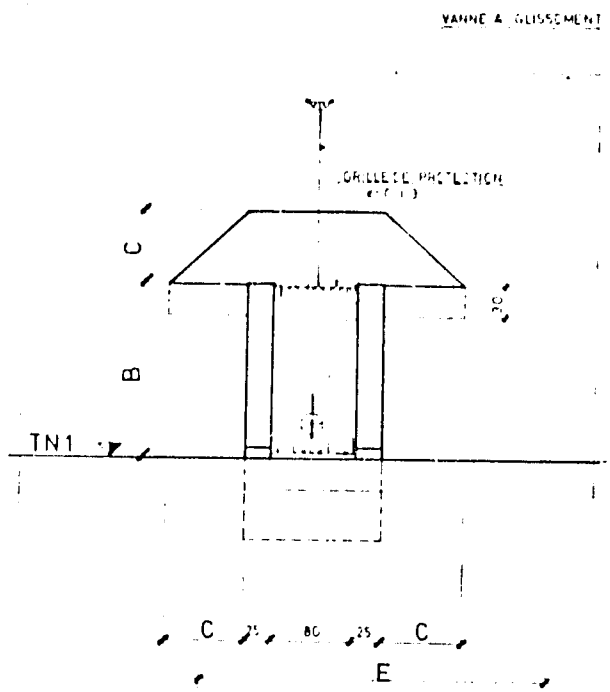
(SORTIE MAÇONNEE)

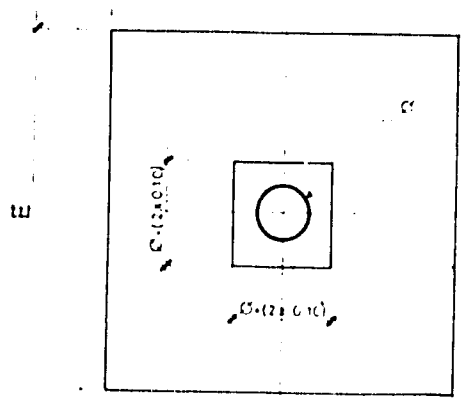
PE A'A'



JE EN PLAN

COUPE DD





COUPE EE ECH. 1/20e

180

N°	DESIGNATION DU BARRAGE	VANNES Ø	TN1	TN2	R1	R2	A	B	C	D	E	F	G	H	COTE DU DEVERSOIR	Nbre d'écrans d'Etanchéité	SORTIE DE VIDANGE
1	CAG EL MOHOR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	TIMBARA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	TOUEDIMA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	AMEIRA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	ZEMEILATT	2.50	6.00	6.00	6.00	5.50	2.90	1.20	0.50	0.25	1.50	0.80	5.00	15.75	7.50	2	MACONNE
6	MOUDI FOUNTI	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	OUDEI CHRACK	5.00	4.90	4.90	4.90	4.10	5.40	2.30	1.00	0.40	1.70	1.00	5.00	21.50	8.00	3	GABION
8	LEHNEIKATT	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	AZGUEILEM	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	TOUEIZ KRETT TAGAT	4.00	6.35	6.35	6.35	5.85	5.90	2.50	1.10	0.35	1.50	1.00	5.00	19.05	9.75 (PHE)	3	GABION
11	MINT ACUADU	6.00	97.00	97.00	97.00	96.50	3.65	1.50	0.60	0.45	1.70	1.20	6.00	17.25	93.00	2	GABION
12	LE MAOUDOU	4.00	98.40	98.40	98.40	97.90	3.65	1.50	0.60	0.35	1.60	1.00	5.00	14.55	100.30	2	GABION
13	BOUDJOUNGAL	5.00	97.00	97.00	97.00	96.40	3.65	1.50	0.60	0.40	1.70	1.00	5.00	21.30	95.00	2	GABION
14	JREKAYA OUDEI LEFKARINE	2.50	92.40	92.40	92.40	91.90	4.65	2.00	0.80	0.25	1.50	1.00	5.00	17.60	95.00	3	MACONNE
15	BOUSSOUEILIF	3.00	94.15	93.75	94.15	93.25	4.80	2.05	1.00	0.30	1.50	1.00	5.00	18.45	97.00	3	MACONNE