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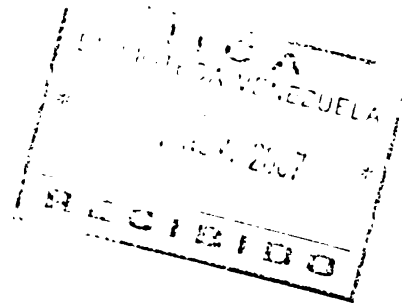

THE OPERATION OF THE DRAINAGE SYSTEM IN THE BLACK RIVER UPPER MORASS PROJECT

by

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1. Introduction

From the hydrological point of view there are two types of soil in the area: the mineral soil made up of clay sandy clay and sandy clay loam with a low infiltration rate and consequently a high runoff potential and the peat soil with a high water absorption potential and a low run off potential.

A set of open drains and three (3) pump stations are to be established in the Project to remove the excess of overland flow during the rainy season and to evacuate the subsurface water from internal drainage and blue holes during the dry period.

The objective of the management of water resources of the area should be to provide the most suitable water relations for optimum agricultural production within the framework of a soil and water conservation policy. The water level in the drains should permit the maintenance of the depth of the water table required by the crop planted in a particular field.

Every drain should be provided at its outlet with a check drain having sluice gates to control the water surface level in the drain.

When there is much surface flow the gates should permit water to flow to the Black River, but in the dry season the gates should stop the flow and raise the water level high enough to facilitate subsurface flow into the fields.

In the soil, water flows from a point of high potential to a point of low potential. If the potential in the drain is higher than the potential in the field, water will flow from the drain into the field. If the potential in the soil is higher than in the drain,

water will flow into the drain. At the present time the latter situation is taking place in the Project area and the peat soil is losing water.

2. Evaluation of the Capacity of Drains

According to the typical drain cross section Figure 1, and using the Manning's Formula for the steady state flow in open channels the drain hydraulic characteristics have been computed and they are presented in the tables in Appendix 1.

The following expressions have been used:

Manning's Formula:

$$Q = \frac{1}{N} \; Ah \; \$ \; 2/3 \quad 1\tfrac{1}{2} \qquad \text{(International System)}$$

$$Q = \frac{1.486}{N} \; Ah \quad R \; 2/3 \quad 1\tfrac{1}{2} \qquad \text{(English System)}$$

Where:

Q = Water discharge (cubic feet per second CFS or cubic meter per second M^3/S)

N = Roughness coefficient, for a clay soil, uniform channel

N = 0.030, because drains should be kept without vegetation to take care of heavy flood during rainy season.

Ah = Hydraulic section (square feet (Ft2) or square meters (M^2)

bh = Hydraulic bottom width (feet)(ft) or meters (m)

dh = Hydraulic depth (feet) (ft) or meters (m)

m = Side slope of the drain; m = 2 for every drain

R = Hydraulic radius (Feet) (ft) or meters (m)

$$R = \frac{Ah}{Ph}$$

Ph = Hydraulic Perimeter (Feet) (ft) or meters (m)

$$P_h = b_h + 2\, d_n\, (1 + m^2)0.5$$

1 = Longitudinal slope of the drain

The values of b_h, d_h and I are given for the different stations of every drain and its capacity computed accordingly. Beside the hydraulic data and based on Figure I the top width and the area taken by every drain have been computed too, in order to know the acreage taken by the drainage system.

The following expressions have been used:

Where:

ba = bottom width (Feet) (Ft)
da = Depth of the drain (Feet) (Ft)
Area lost = (Top width) (Length of drain)

Table I shows that the drainage system has taken 184 acres (74 Ha) or 1.6% of the intensive study area and the maximum capacity at the Grass River Pumping Station is 6054 cfs. The 16 pumps working simultaneously take away only 1600 cfs. This means that the drain is four times oversized.

3. Drainage Organisation

To accomplished the objectives of the drainage system, Figure 2, the latter could be subdivided in three (3) sectors (A, B and C), each sector under the management of a drainage operator.

Drainage Sector A

Drains: AD; AD-2; AD-2A; AD-2B; AD-1; AD-3;
ID; ID-1; ID-2; ID-3; ID-2A; ID-2B

Drainage Sector B

Drains: 2D; 2D-1; 2D-1D, 2D-1B; 2D-1B1; 2D-1A; 2D-1A1; 2D-1A2

Drainage Sector C

Drains: 2D-2; 2D-3; 2D-4; BD;BD1

TABLE 1 Characteristics of Drains in BRUMDEC Project

Drain	Length Maximum Feet	Meters	CFS	Capacity M^3/s	Area Acres	Lost Has
AD	3700	1128	6054	171.5	15.03	6.0864
AD-2	4291.2	1308.29	191	5.41	5.24	2.1207
AD-2A	4760	1451.22	49	1.40	3.19	1.2916
AD-2B	4774	1455.49	159	4.50	3.70	1.4994
AD-1	950.5	289.79	26	0.73	0.61	0.2473
AD-3	1317.6	401.71	60	1.71	0.96	0.3905
ID	19352	5900	1910	54.10	29.32	11.8682
ID-1	5975	1821.65	113	3.21	4.59	1.8567
ID-2	2680	817	97	2.76	1.97	0.7970
ID-3	5525.5	1684.6	137	3.87	4.37	1.7677
ID-2A	2000	610	74	2.09	1.47	0.5948
ID-2B	18423	542	74	2.09	1.33	0.5390
2D	8841.3	2695.52	1483	42.01	16.74	6.7759
2D-1	16400	5000	801	22.68	23.16	9.3752
2D-ID	4515	1376.5	84	2.43	3.42	1.3847
2D-IB	10354.1	3156.74	273	7.74	8.23	3.3315
2D-IBI	6762.8	2061.83	51	1.45	4.40	1.7804
2D-IA	6093.4	1857.7	165	4.68	4.92	1.9933
2D-IAI	6166.8	1880.12	75	2.11	4.69	1.8978
2D-IA2	5000.0	1524.39	73	2.08	3.45	1.3981
2D-2	10940.9	3335.64	227	6.43	11.72	4.7567
2D-3	10970	3344.51	65	1.84	7.86	3.1811
2D-4	7123	2171.68	46	1.29	4.86	1.9680
BD	13294	4053	461	13.05	13.01	5.2675
BD-1	7842.5	2391	34	0.95	5.65	2.2879
Total					183.89	74.4574

[illegible]

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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3-1 Specific Duties of a Drainage Operator

- to keep the water level in the drains at a given depth in conjunction with the required ground water level for the established crop in the type of soil. To do this, he has to keep records of the relationship between the drain water surface and the water levels in the observation wells:
- to control the flow towards the pump station.
- to keep the drains working at full capacity; to do this he has to keep records of the siltation in the drains, and arrange for mineral and vegetable material to be removed from the drains as often as necessary.
- to keep the culverts working at full capacity
- to prepare the programme and the budget for the maintenance of the drains of his sector

  The programme of the maintenance should include the length of drains to be redressed, the type of machine needed, the cost per hour, the number of working hours needed, the specifications of the cross-section of the drain at every station, the volume of earth to be taken out.
- to supervise the maintenance work in drains and related structures.
- to work very closely with the Agronomists and follow the drainage requirements of the crop pattern for every season.
- to work very closely with the pump station supervisors to know the pump stations working conditions

  The Drainage Operator works directly under the Superintendent of Irrigation - Drainage and Roads.
  For carrying out the physical work in the drainage sector, the drainage operator should have labourers working with him.
- to identify the areas in the mineral soil where internal drainage is needed.

4 Maintenance of the Drainage System

At the present time the drains are covered with vegetation that needs to be removed to give the drains the capacity of carrying the excess of water during the rainy season. The resistance of vegetation to flow will increase the Manning's roughness coefficient, reduce the velocity of water flow and increase the water depth. At the beginning of the rainy season the drains should be free of vegetation which could be removed mechanically or by hand labour or by placing sea cows in the drains.

As far as silting is concerned there is no problem of maintenance initially because the drains have been designed with an additional depth of 0.304m (1.0 ft) in the main drains and 0.152m (0.5 ft) in the secondary drains.

When the water management in drains will take place, siltation will increase, records of siltation should be kept to programme the frequency of cleaning and reshaping the cross-section of drains. Culverts should receive maintenance as often as necessary and their working conditions should be observed frequently.

5 The Pump Stations

The excess of water is taken out to the sea through the Black River by three (3) pump stations at Grass River, Island River and New River. In the Grass River Station there are sixteen (16) pumps each having a capacity of 2.83 m^3/s 100 cubic feet per second (100 cfs).

In the Island River there will be eight (8) pumps with a capacity of 100 cfs each and in the New River there will be 4 pumps, 2 with a capacity of 2.83 m^3/s (100 cfs) and 2 with a capacity of 1.42 m^3/s (50 cfs).

The water resources management should be such that pumping hours are minimized to reduce the cost of operation, but the pumps and engines should always be in good working conditions to avoid the damage of flooding.

For the operation and maintenance of the engines and pumps a well equipped workshop, a specialized mechanic and a stock of spare parts are required. Pumps and engines should be serviced according to manufacture's recommendations.

RECOMMENDATIONS FOR THE OPERATION AND MAINTENANCE OF THE DRAINAGE SYSTEM IN BRUMDEC'S PROJECT

1 The Irrigation - Drainage and Roads Engineer should be employed by BRUMDEC before the end of the construction of the drains, roads and dykes, because he should work with the Supervisors from the Consultants. (Harza Overseas Engineering Company and Hue Lyew Chin) and from the National Development Agency (NDA) to follow the construction modifications, the material used, the verification of the specifications, the hourly yield of the heavy equipment (draglines, back-hoes, scrapers, tractors etc) the fuel and oil consumption of the equipment, pumps and engines. He will need to be familiar with the equipment used to verify the specifications and the performance of machines. He will need to be familiar with the soil (mineral and organic), with the water resources and with the general environment of the area in order to plan a rational optimum programme of water resources usage in the Project.

2 Employ the three (3) drainage operators and train them in the basic principles of irrigation, drainage, soil-water-plant relationship, precipitation, surface runoff, water table position, flow through media, survey and water control. Then show them their field responsibilities and the water level management in the drainage sector.

3 To avoid water desorption from the peat soil, the water level in the drains should be kept at least at the design water surface. (The capillarity height could take care of the 1.5 feet freebord).

4 At the end of April and at the end of September the drains should be kept free of vegetation to give them the design capacity to carry away the surface water excess.

5 Records of water levels, of drains water surface levels, of volume of water pumped, of hours of work of every pump in each pump station and of silting in the canals, should be kept to have the basic information to plan the management of the water resources for the Project.

6 For the time being silting is not a problem in the drains because the original design has given them 0.304 (1 ft.) and 0.152 m (0.5 ft). Allowance for silting for the main and for the secondary drains, respectively. Besides that as it is shown in Table 1 the drains have been overdesigned.

7 A period of observation under the influence of growing crops is necessary before installing internal drains in the mineral soils. At the present time the mineral soils under sugar cane have a very low infiltration rate and a very bad internal drainage.

8. Check dams should be installed close to the outlet of the drains to control the water level in the drains and consequently the water table in the ground.

9 Pumps should be maintained according to the manufacture's recommendations to get the 25 year lifetime under operation.

APPENDIX I (1)

SECTION CHARACTERISTICS OF DRAIN .ED (S=0.030; Length = 1329± Ft= 405± M; Side Slope=2)

Station	bb		bt		db		dt		Ab		Pb		R		Slope		Velocity		Flow		Freeboard		Silt Zone		Top Width		Area Lost	
0+00																												
	26	7.93	34	7.32	5.8	1.77	6.3	1.92	215	20.27	52	15.81	4.2	1.28	0.00031		2.26	0.69	595	16.82	1.5	0.46	0.5	0.15	65.2	19.86	106317	10047
2+00.9																												
	29	[illegible]	34	6.1	5.9	1.52	6.5	1.68	169	16.87	44	13.52	3.6	1.10	0.00031		2.07	0.63	327	9.21	1.5	0.46	0.5	0.15	58	17.68	80210	8291
4+00.4																												
	[illegible]	[illegible]	32	3.66	4.9	1.22	4.5	1.37	88	8.39	32	9.72	2.8	0.86	0.00029		3.13	0.95	276	7.81	1.5	0.46	0.5	0.15	46	14.02	132881	13000
5+00.9																												
	22	1.66	30	3.05	3.2	0.98	3.7	1.13	59	5.47	26	8.09	2.2	0.68	0.00034		2.46	0.75	144	4.09	1.5	0.46	0.5	0.15	40.8	12.44	233302	12350
7+00.5																												
	6	1.83	4	1.22	2.9	0.92	3.5	1.07	26	2.35	19	5.92	1.9	0.57	0.0031		2.37	0.72	85.63	2.43	1.5	0.46	0.5	0.15	34	10.37	60527	5015
8+00.7																												
	6	1.83	4	1.22	3.0	0.92	3.5	1.07	26	2.35	19	5.92	1.9	0.57	0.00047		1.84	0.56	59	1.66	1.5	0.46	0.5	0.15	34	10.37	68214	6702
10+00.2																												

Area Lost = 579451 Ft^2= 13.7825 Acres=5.536 Ha.

SECTION CHARACTERISTICS OF DRAIN EC-1 (S=0.030; Length = 7842.5 Ft=2391 M; Side Slope =2)

0+0																												
	6	1.83	4	1.22	3	0.92	3.5	1.07	26	2.35	19	5.92	1.86	0.57	0.00025		1.18	0.36	43	1.21	1.5	0.46	0.5	0.15	34	10.37	137972	12827
2+0.8																												
	4	1.22	2	0.61	2.8	0.87	2.7	0.82	18	1.72	14	4.22	1.34	0.41	0.00132		2.90	0.87	81	1.24	1.5	0.46	0.5	0.15	28.8	8.78	95930	5126
4+0																												
	4	1.22	2	0.61	1.6	0.49	2.1	0.64	12	1.07	11	3.40	1.03	0.31	0.00132		1.67	0.51	39	0.58	1.5	0.46	0.5	0.15	26.4	8.05	92282	4766
5+0.5																												

Area Lost=246184 Ft^2=5.6516 Acres = 2.2791 Ha.

bb=Hydraulic bottom width
bt=Bottom width
db=Hydraulic depth
dt=Depth
Ab=Hydraulic Section
Pb=Hydraulic Perimeter
R. Hydraulic Radius

APPENDIX I (2)

DESIGN CHARACTERISTICS OF DRAIN 1D (Follows Smith River, n = 0.030; Length 19352 ft=5900 metres; side slope =2)

Station	bh		bo		dn		da		Ah		Ph		R		Slope		Velocity		FLOW		FREEBOARD		SILT HEIGHT		TOP WIDTH		AREA LOST	
	Ft	M	Ft	M	Ft	M	Ft	M	Ft^2	M^2	Ft	M	Ft	M	Ft/Ft		FPS	M/S	Ft^3/S	M^3/S	Ft	M	Ft	M	Ft	M	Ft^2	M^2
0+00																												
	32	9.756	28	8.536	4	2.439	9.0	2.744	384	35.69	67.77	20.66	5.667	1.727	0.021		4.972	1.516	1910	54.10	1.5	0.46	1	0.305	80	24.39	14[illegible]0	1326.[illegible]
2+00																												
	32	9.756	28	8.536	5.8	1.768	9.2	2.803	392.88	32.80	55.25	16.84	6.326	1.947	0.021		5.185	1.580	1901	53.86	1.5	0.46	2.4	0.732	76.3	23.41	[illegible]	[illegible]
35+12																												
"	32	9.756	28	8.536	7.2	2.195	9.2	2.803	334.38	31.05	64.20	19.57	5.20	1.586	0.0002		2.172	0.662	702	19.89	1.5	0.46	1.0	0.305	76.8	23.41	[illegible]	[illegible]
55+10																												
	32	9.756	28	8.536	7.0	2.134	9.0	2.439	322	29.93	63.30	19.30	5.087	1.551	0.0002		2.073	0.632	668	18.91	1.5	0.46	1.0	0.305	76.0	23.17	[illegible]	[illegible]
75+50																												
	32	9.756	28	8.536	7.0	2.134	9.0	2.439	322	29.93	63.30	19.30	5.087	1.551	0.00022		2.171	0.662	699	19.81	1.5	0.46	1.0	0.305	76.0	23.17	[illegible]	[illegible]
111+25																												
	24	7.317	20	6.097	5.6	1.707	6.6	2.012	245.52	22.82	49.04	14.95	5.210	1.589	0.00066		3.934	1.199	939	26.61	1.5	0.46	1.0	0.305	62.4	19.02	[illegible]	[illegible]
127+00																												
	24	7.317	20	6.097	5.2	1.585	6.2	1.890	201.68	18.74	47.25	14.40	4.268	1.301	0.00065		3.916	1.194	675	19.11	1.5	0.46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
155+13.-																												
	10	3.049	6	1.829	4.2	1.280	5.2	1.585	77.28	7.18	28.75	8.76	2.685	0.817	0.00083		2.752	0.839	213	6.02	1.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
183+07																												
	10	3.049	6	1.829	3.4	1.036	4.4	1.341	57.12	5.31	25.20	7.68	2.267	0.691	0.00083		2.46	0.750	141	3.98	1.5	[illegible]	[illegible]	[illegible]	39.6	12.07	4+513	[illegible]
191+42																												

bh- Hydraulic bottom width
bo- bottom width
dh-Hydraulic depth
dn-depth
Ah-Hydraulic section
Ph-Hydraulic Perimeter
R-Hydraulic Radius

Area Lost = 1277204 ft^2=27.32 acres = 11.0632 Ha

APPENDIX I (3)

DESIGN CHARACTERISTICS OF DRAIN ID -1 (S=0.030; Length = 5975 Ft = 1821.65 M; Side Slope =2)

Sides	Bo		ba		do		dn		Fb		H		Slope	Velocity		Flow		Freeboard		Silt Zone		Top Width		Area Lost	
	Ft	M	Ft	M	Ft	M	Ft	M	Ft^2	M^2	Ft	M	Ft	M		Ft/s	M/S	Cfs	M^3/S	Ft	M	Ft	M	Ft	M	Ft^2	M^2
0.2																										
	4	1.22	2	0.61	3.8	1.16	4.3	1.31	44.08	4.10	20.99	6.40	2.10	0.64	0.030	2.565	0.782	113.31	3.21	1.5	0.46	0.5	0.152	35.2	10.73	58060	5394.44
=3																										
	4	1.22	2	0.61	3.8	1.16	4.3	1.31	44.08	4.10	20.99	6.40	2.10	0.64	0.000581	1.97	0.60	84.34	2.46	1.5	0.46	0.5	0.152	35.2	10.73	45640	4240.47
=2																										
	4	1.22	2	0.61	3.2	0.98	3.7	1.13	33.28	3.09	18.31	5.58	1.88	0.55	0.000581	1.77	0.539	60.95	1.67	1.5	0.46	0.5	0.152	32.4	10.00	42610	3958.84
=2																										
	4	1.22	2	0.61	2.4	0.73	2.9	0.88	21.12	1.96	14.73	4.49	1.44	0.44	0.000581	1.51	0.46	31.77	0.90	1.5	0.46	0.5	0.152	29.6	9.02	39720	3691.08
=75																										

Area Lost = 197780 Ft=4.59 acres = 1.8567 Ha

DESIGN CHARACTERISTICS OF DRAIN ID -2 (S=0.030; Length = 2680 Ft=817 M; Side Slope=2)

0																										
	4	1.22	2	0.61	3.0	0.915	3.5	3.067	30	2.79	17.416	5.31	1.72	0.52	0.00213	3.25	0.99	97.43	2.76	1.5	0.46	0.5	0.152	32	9.76	48000	4460.16
=0																										
	4	1.22	2	0.61	3.0	0.915	3.5	3.067	30	2.79	17.416	5.31	1.72	0.52	0.00213	3.25	0.99	97.43	2.76	1.5	0.46	0.5	0.152	32	9.76	37760	3509.79
=80																										

Area Lost = 85760 Ft=1.97=0.7970 Ha

APPENDIX I (i)

DESIGN CHARACTERISTICS OF DRAIN LD-3 (n=0.030; Length = 5525.5 Ft=1684.6 M Side Slope =2)

Station	bb		Bw		db		da		Ab		Pb		B		Slope	Velocity	Flow	Freeboard		Side Slope		Top Width		Area Lost	
	Ft	M	Ft	M	Ft	M	Ft	M	Ft^2	M^2	Ft	M	Ft	M		Fps m/	cfs	M^3/S	Ft	M	Ft	M	Ft	M	Ft^2	M^2
0+00																										
	4	1.22	2	0.61	4.2	1.28	4.7	1.43	32.08	4.84	22.70	6.95	2.30	0.70	0.000052	2.62	0.80	336.6	9.53	1.5	0.46	0.5	0.152	36.8	11.22	67178.4	6243.35
10+21.5																										
	4	1.22	2	0.61	4.2	1.28	4.7	1.43	32.08	4.84	22.70	6.95	2.30	0.70	0.000151	1.61	0.49	83.66	2.37	1.5	0.46	0.5	0.152	36.8	11.22	43221.6	4016.86
20+00																										
	4	1.22	2	0.61	3.4	1.04	3.9	1.19	26.72	3.41	19.20	5.85	1.90	0.58	0.000352	1.81	0.83	51.80	1.47	1.5	0.46	0.5	0.152	31.6	9.63	76805.8	7136.00
27+21.5																										

Area Lost = 191219.8 Ft^2=4.37 Acres = 1.7677 Ha

DESIGN CHARACTERISTICS OF DRAIN AD-1 (n=0.030; Length = 950.5 Ft= 289.79 M Side Slope =2)

0+00																										
	4	1.22	2	0.61	2.0	0.61	2.5	0.76	16	1.49	12.94	3.95	1.25	0.38	0.0008	1.61	0.49	25.77	0.73	1.5	0.46	0.5	0.152	25	8.54	26614	
9+50.5																										

Area Lost = 26614 Ft^2=0.61 Acres = 1.2473 Ha

DESIGN CHARACTERISTICS OF DRAIN AD-3 (n=0.030; Length 1317.6 Ft= 401.71 M; Side Slope = 2)

0+00																										
	5	1.829	4	1.22	3.0	0.915	3.5	1.067	36	3.35	19.42	5.92	1.87	0.57	0.0005	1.67	0.51	60.4	1.71	1.5	0.46	0.5	0.152	31.89	9.72		
13+17.6																										

Area Lost = 42918 Ft^2=0.96 Acres = 0.3905 Ha

APPENDIX I (5)

DESIGN CHARACTERISTICS OF DRAIN ED-2A (S=0.030; Length = 2000 Ft=610M Side Slope = 2)

Station	bh Ft	bh M	bm Ft	bm M	dh Ft	dh M	dm Ft	dm M	Ah Ft²	Ah M²	Ph Ft	Ph M	R Ft	R M	Slope	Velocity Fps	Velocity M/S	Flow cfs	Flow m³/s	Freeboard Ft	Freeboard M	Silt Zone Ft	Silt Zone M	Top Width Ft	Top Width M	Area Lost Ft²	Area Lost M²
0+0																											
	4	1.22	2	0.61	3	0.915	3.5	1.067	30	2.79	17.416	5.31	1.72	0.52	0.0012	2.46	0.75	73.78	2.09	1.5	0.46	0.5	0.152	32	9.76	48000	4457.96
2+0																											

Area lost = 48000 Ft=1.47 acres=0.5948 Ha

DESIGN CHARACTERISTICS OF DRAIN ED-2B (S=0.030; Length =1842.3=562 M; Side Slope=2)

0+0																											
	4	1.22	2	0.61	3	0.915	3.5	1.067	30	2.79	17.416	5.31	1.72	0.52	0.0012	2.46	0.75	73.78	2.09	1.5	0.46	0.5	0.152	32	9.76	48000	4457.96
15+0																											
	4	1.22	2	0.61	2.8	0.85	3.3	1.01	26.88	2.50	16.52	5.04	1.63	0.50	0.00081	1.28	0.38	33.54	0.95	1.5	0.46	0.5	0.152	29.2	8.90	9995.16	928.7
18+2.3																											

Area lost = 57995 Ft=1.33 acres = 0.5390 Ha

bh=Hydraulic bottom width
bm=bottom width
dh=Hydraulic depth
dm=depth
Ah=Hydraulic section
Ph=Hydraulic Perimeter
R=Hydraulic Radius

APPENDIX I (6)

DESIGN CHARACTERISTICS OF DRAIN 2D (Follows Elm River; S=0.030; Length =5341.3 Ft = 2698.32 m ; side slope = 2)

Stations	bt		bm		db		dm		At		Pb		R		Slope	Velocity	
	Ft	M	Ft	M	Ft	M	Ft	M	Ft^2	M^2	Ft	M	Ft	M		Fps	M/S
0+00																	
	125	38.11	119	36.29	7.4	2.26	8.4	2.561	1034.52	96.14	138.09	42.09	6.54	1.995	0.0000685	1.434	0.437
8+41.6																	
	83	24.39	76	23.17	6.0	1.829	7.0	2.134	552	51.30	126.83	38.67	5.166	1.575	0.00007	1.238	0.378
22+16.6																	
	35	10.67	29	8.84	4.0	1.22	5.0	1.524	172	15.99	52.89	16.12	3.25	0.992	0.000381	2.122	0.647
27+21.2																	
	22	6.71	18	5.49	3.2	0.98	4.2	1.280	90.88	8.45	36.31	11.07	2.503	0.763	0.00121	3.175	0.968
32 +41.3																	

Hydraulic bottom width

Geometric width

Top hydraulic depth

Geometric

Hydraulic Section

Hydraulic Perimeter

Hydraulic Radius

Area Lost = 729094.8 Ft^2=16.74 Acres = 6.7759 Has.

Flow		Freeboard		Silt		Top Width		Area Lost	
cfs	M^3/S	Ft.	M	Ft	M	Ft	M	Ft^2	M^2
1193	42.01	1.5	0.46	2.0	0.305	169.6	51.69	2419e3.8	2247
685	19.39	1.5	0.46	2.0	0.305	129	39.32	2.0e000.0	2324
365	10.35	1.5	0.46	2.0	0.305	65	19.82	170e85	1e2e5
289	8.18	1.5	0.46	2.0	0.305	50.8	15.49	16e706	1e4e6

DESIGN CHARACTERISTICS OF DRAIN ZD-1 (N=0.030; Length = 16400 Ft= 5000 M; side slope = 2)

STATION	bb		bm		db		da		Ab		Pb		R		Slope	Velocity		Flow		Freeboard		Silt Size		Top Width		Area Lost	
	Ft	M	Ft	M	Ft	M	Ft	M	Ft^2	M^2	Ft	M	Ft	M		FPS	M/S	CFS	M/S	Ft	M	Ft	M	Ft	M	Ft^2	M^2
0+0																												
	90	15.24	46	14.02	6.6	2.012	7.6	2.317	417.12	38.77	79.52	24.24	5.245	1.60	0.00015	1.83	0.585	801	22.68	1.5	0.46	0.5	0.152	92.4	28.17	297304	27625
8+0																												
	90	15.24	46	14.02	6.6	1.829	7.6	2.134	372	34.57	76.83	23.42	4.841	1.476	0.00015	1.76	0.529	656	18.29	1.5	0.46	0.5	0.152	90.2	27.43	190197	17676
16+0																												
	90	6.19	16	4.88	4.8	1.463	5.8	1.768	142.08	13.20	41.47	12.64	3.426	1.044	0.00080	3.38	1.029	479	13.58	1.5	0.46	0.5	0.152	33.2	16.83	261345	24289
24+0																												
	90	6.19	16	4.88	4.6	1.402	5.6	1.707	134.32	12.48	40.57	12.37	3.313	1.010	0.00080	3.32	1.007	444	12.57	1.5	0.46	0.5	0.152	32.4	16.59	124483	11570
32+0																												
	12	3.66	8	2.44	4.0	1.22	5.0	1.524	80	7.43	29.59	9.11	2.676	0.816	0.00205	4.32	1.318	346	9.79	1.5	0.46	0.5	0.152	31	13.41	135	12
40+0																												
	12	3.66	8	2.44	3.8	1.16	4.8	1.463	76.68	6.92	28.99	8.84	2.569	0.783	0.00205	4.29	1.282	313	8.87	1.5	0.46	0.5	0.152	30.2			
48+0																												

DESIGN CHARACTERISTICS OF DRAIN AD (N=0.030; Length = 3700 Ft=1128 M, side slope = 2)

Station	bb		bm		db		da		Ab		Pb		R		Slope	Velocity		Flow		Freeboard		Silt Size		Top Width		Area Lost	
	Ft	M	Ft	M	Ft	M	Ft	M	Ft^2	M^2	Ft	M	Ft	M		FPS	M/S	CFS	M/S	Ft	M	Ft	M	Ft	M	Ft^2	M^2
0+0																												
	125	38.11	121	36.89	9	2.439	9	2.744	1128	104.81	160.78	49.02	7.014	2.139	0.00085	5.366	1.636	6054	171.5	1.5	0.46	1.0	0.305	137	41.96	654000	60765.31
37+0																												

bb=Hydraulic bottom width
bm=Bottom width
db=Hydraulic Depth
da=Depth
Ab=Hydraulic Section

Pb=Hydraulic Perimeter
R= Hydraulic Radius

Area lost in DRAIN ZD-1 =1008771 Ft^2=23.158 acres = 9.3732 Ha.
Area lost in DRAIN AD = 654900 Ft^2 = 15.03% Acres = 6.260 Ha.

APPENDIX I (f)

DESIGN CHARACTERISTICS OF DRAIN AD-2 (N=0.030; Length = 4291.2 Ft = 1308.29 M; Side Slope=2)

Station	b1		b2		d3		d4		A3		P3		R		Slope	Velocity		Flow		Freeboard		Side Cote		Top Width		Area Lost	
	Ft	M	Ft	M	Ft	M	Ft	M	Ft^2	M^2	Ft	M	Ft	M		Fps	M/S	Cfs	M^3/S	Ft	M	Ft	M	Ft	M	Ft^2	M^2
0+00																												
	2	6.56	16	4.88	5.4	1.65	5.9	1.80	166.32	15.46	44.15	13.46	3.772	1.15	0.00009	1.15	0.35	101	5.41	1.5	0.46	0.5	0.152	55.6	16.95	77840	7234.20
12+00																												
	10	9.13	16	5.27	5.0	1.52	5.5	1.68	140	13.01	43.36	12.70	3.49	1.06	0.00009	1.08	0.33	151	6.29	1.5	0.46	0.5	0.152	52	15.84	150362	13972.36
24+00.2																												

Area lost = 228122 Ft^2 = 5.24 Acres = 2.1217 Ha

DESIGN CHARACTERISTICS OF DRAIN AD-2A (n=.030; Length = 4769 Ft=1451.22 M; Side Slope =2)

0+00																												
	4	1.22	2	0.61	2.6	0.79	3.1	0.95	23.12	2.15	13.63	4.77	1.68	0.45	0.00111	2.13	0.65	59	1.40	1.5	0.46	0.5	0.152	30.4	9.27	72200	6710.24
23+75																												
	4	1.22	2	0.61	2.0	0.61	2.5	0.76	16	1.49	12.04	3.95	1.25	0.38	0.00111	1.90	0.58	37	0.86	1.5	0.46	0.5	0.152	28	8.54	66780	6206.32
47+63																												

Area lost 138945 Ft^2 = 3.19 Acres =1.2916 Ha

DESIGN CHARACTERISTICS OF DRAIN AD-2B (N=0.030; Length = 4774 Ft= 1455.49 M; Side Slope = 2)

0+00																												
	6	1.83	4	1.22	4.2	1.28	4.7	1.43	60.48	5.62	24.78	7.55	2.43	0.74	0.00085	2.62	0.80	159	4.5	1.5	0.46	0.5	0.152	39.8	11.93	44000		
11+35																												
	4	1.22	2	0.61	3.4	1.04	3.9	1.19	36.72	3.41	19.20	5.85	1.90	0.58	0.00085	2.23	0.68	82	2.32	1.5	0.46	0.5	0.152	32	9.6	25000	2322.5	
35+00																												
	4	1.22	2	0.61	3.0	0.91	3.5	1.07	30	2.79	17.42	5.31	1.71	0.51	0.00085	2.10	0.64	63	1.79	1.5	0.46	0.5	0.152					6677.71
47+67.4																												

Area lost = 161339 Ft^2 = 3.70 Acres = 1.4994 Ha

b1=Hydraulic bottom width; **b2**=bottom width

d3=Hydraulic depth; **d4**=depth

A3=Hydraulic Section; **P3**= Hydraulic Perimeter

R= Hydraulic Radius

APPENDIX I (9)

DESIGN CHARACTERISTICS OF DRAIN ZD-1A2 (N=0.030; Length=5000 Ft=1524.384; Side Slope = Z)

Station	bh		ba		dh	da	Ah	Ph	R	Slope	Velocity	Flow	Freeboard		Silt Zone		Top Width	Area Lost	
0+0																			
	8	1.82	4	1.22	2.4	0.73	2.9	0.88	27.65	2.57	16.73	5.10	1.64	0.50	0.0015	2.66	0.81	73	2.08	1.5	0.46	0.5	0.152	31.6	9.63	91840	8516.73
25+0																											
	4	1.22	2	0.61	2.0	0.61	2.5	0.76	16	1.49	12.94	3.95	1.25	0.38	0.0015	2.23	0.68	36	1.01	1.5	0.46	0.5	0.152	28	8.54	58800	5464.68
50+2																											

Area Lost = 150440 Ft^2=3.45 Acres = 1.3981 Ha

DESIGN CHARACTERISTICS OF DRAIN ZD-1B (N=0.030; Length = 10354.1 Ft=3156.74 M; Side Slope=Z)

0+0																											
	6	1.83	4	1.22	4.4	1.34	4.9	1.49	79.52	7.39	25.68	7.83	3.08	0.94	0.0011	3.31	1.01	275	7.74	1.5	0.46	0.5	0.152	39.6	12.07	112560	10458.85
24+52																											
	6	1.83	4	1.22	3.8	1.16	4.3	1.31	51.68	4.80	22.99	7.01	2.23	0.68	0.0011	2.79	0.85	144	4.08	1.5	0.46	0.5	0.152	37.20	11.34	94530	9161.71
52+0																											
	5	1.83	4	1.22	3.0	0.91	3.5	1.07	36	3.35	19.42	5.92	1.87	0.57	0.00179	3.18	0.97	115	3.25	1.5	0.46	0.5	0.152	34.0	10.37	36918	3453.81
65+56.7																											
	4	1.22	2	0.61	2.8	0.85	3.3	1.01	26.88	2.50	16.52	5.04	1.64	0.50	0.00179	2.92	0.89	79	2.23	1.5	0.46	0.5	0.152	31.2	9.51	69055	6417.75
85+0																											
	4	1.22	2	0.61	1.6	0.49	2.1	0.64	11.52	1.07	11.16	3.40	1.02	0.31	0.0045	3.35	1.02	38	1.09	1.5	0.46	0.5	0.152	26.4	8.05	41028	3813.03
103+54.1																											

Area Lost = 358471 Ft^2=8.23 Acres = 3.3315 Ha

APPENDIX I (10)

DESIGN CHARACTERISTICS OF DRAIN ED-1B1 (N=0.030; Length = 6702.8 Ft=2061.85 M; Side Slope = Z)

0+0																									
	4	1.22	2	0.61	2.4	0.73	2.9	0.88	21.12	1.96	14.73	4.49	1.44	0.44	0.00148	2.43	0.74	51	1.45	1.5	0.46	0.5	0.152	29.6	9.02	79115	7352.68
25+72.8																											
	4	1.22	2	0.61	2.0	0.61	2.5	0.76	16	1.49	12.94	3.95	1.25	0.38	0.00269	2.98	0.91	48	1.36	1.5	0.46	0.5	0.152	28	8.54	42202	3922.08
61+60																											
	4	1.22	2	0.61	1.8	0.55	2.3	0.70	11.66	1.08	12.05	3.67	0.95	0.29	0.00269	2.49	0.76	29	0.82	1.5	0.46	0.5	0.152	27.2	8.29	70252	6529.01
67+62.8																											

Area Lost = 191569 Ft^2=4.40 Acres = 1.7804 Ha

APPENDIX I (11)

DESIGN CHARACTERISTICS OF DRAIN ZD-1D (n=0.030; Length = 4515 Ft=1376.5 M; Side Slope = 2)

Section	Tb		Ta		Td		Tc		Ad		Pc		B		Slope	Velocity		Flow		Freeboard		Silt Zone		Top Width		Area Sect	
	Ft	M	Ft	M	Ft	M	Ft	M	Ft^2	M^2	Ft	M	Ft	M		Fps	M/S	cfs	M^3/S	Ft	M	Ft	M	Ft	M	Ft^2	M^2
ZD																												
-1+00.0	0	1.22	3	0.91	3	0.91	3.5	1.07	30	2.79	17.4	5.3	1.74	0.53	0.00332	2.85	0.87	85	2.41	1.5	0.46	0.5	0.152	33	10.06	354.304	32.917
	Area Lost = 1.0000 Ft^2=0.02 Acres = 1.9047 Ha																											
	DESIGN CHARACTERISTICS OF DRAIN ZD -1A (n=0.030; Length =6093.4 Ft=1857.7 M; Side Slope = 2)																											
0+00																												
	0	1.83	8	2.44	3.4	1.04	3.9	1.19	57.12	5.31	25.4	7.74	2.26	0.69	0.00106	2.79	0.85	165	4.68	1.5	0.46	0.5	0.152	39.6	12.07	5.630	0.523
13+03.8																												
	6	1.53	6	1.22	3.0	0.91	3.5	1.07	36	3.35	19.4	5.92	1.87	0.57	0.00106	2.46	0.75	89	2.52	1.5	0.46	0.5	0.152	34.0	10.37	7.467	0.693
14+23.8																												
	9	1.83	6	1.22	3.0	0.91	3.5	1.07	36	3.35	19.4	5.92	1.87	0.57	0.00106	2.46	0.75	89	2.52	1.5	0.46	0.5	0.152	34.0	10.37	7.467	0.693
15+23.8																												
	Area Lost = 2.0476 Ft^2=0.02 Acres = 1.9047 Ha																											
	DESIGN CHARACTERISTICS OF DRAIN ZD-1A1 (n=0.030; Length =6166.8 Ft=1880.12 M; Side Slope = 2)																											
0+00																												
	0	2.44	6	1.83	3	0.91	3.5	1.07	42	3.90	21.52	6.53	1.97	0.60	0.00092	1.77	0.54	73	2.11	1.5	0.46	0.5	0.152	36	10.97		
2+00																												
	2	2.44	6	1.83	2.8	0.85	3.3	1.01	38.08	3.54	20.52	6.26	1.87	0.57	0.00092	1.71	0.52	65	1.84	1.5	0.46	0.5	0.152	34				
3+00																												
	4	1.22	2	0.61	2.2	0.67	2.7	0.82	18.48	1.72	13.84	4.22	1.34	0.41	0.00071	2.33	0.71	43	1.22	1.5	0.46	0.5	0.152	29.80	8.75			
4+00.0																												
	Area Lost = 20.4304 Ft^2=0.69 Acres=1.5978 Ha																											

DESIGN CHARACTERISTICS OF DRAIN ZD-2 (S=0.030; Length = 10940.9 Ft=3335.6 M; Side Slope=2)

Station	b1 Ft	b1 M	b2 Ft	b2 M	d1 Ft	d1 M	d2 Ft	d2 M	A Ft²	A M²	P Ft	P M	R Ft	R M	Slope	Velocity Ft/s	Velocity M/S	Flow Cfs	Flow M³/S	Freeboard Ft	Freeboard M	Side Slope Ft	Side Slope M	Top Width Ft	Top Width M	Area Cost Ft²	Area Cost M²
0+00																											
	11	3.37	12	3.66	4.8	1.34	4.9	1.49	100.32	9.32	33.68	10.27	2.98	0.91	0.[illegible]48	2.26	0.69	227	6.43	1.5	0.46	0.5	0.152	47.6	14.51	142779	13267.08
3+00																											
	12	3.66	12	3.66	4.8	1.46	5.2	1.62	103.68	9.64	33.47	10.20	3.12	0.95	0.[illegible]40	2.30	0.70	238	6.37	1.5	0.46	0.5	0.152	47.9	14.72	2[illegible]	2[illegible]3.72
7+00																											
	10	3.05	8	2.44	4.8	1.34	4.9	1.49	82.72	7.69	29.69	9.05	2.79	0.85	0.[illegible]40	1.97	0.60	164	4.61	1.5	0.46	0.5	0.152	43.6	13.29	73[illegible]3	7256.81
11+40.2																											

Area Cost $213[illegible]3 Ft² = 11.72 Acres =4.7567 Ha.

DESIGN CHARACTERISTICS OF DRAIN ZD - 3 (S=0.030; Length =10970 Ft=3344.51 M; Side Slope=2)

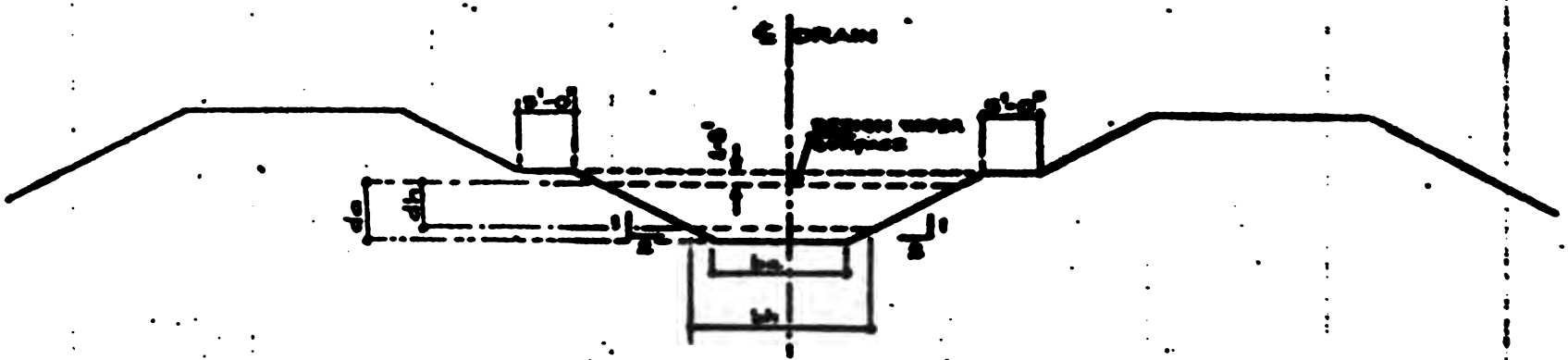
0+00																											
	4	1.22	2	0.61	2.0	0.91	3.5	1.07	30	2.79	17.42	5.31	1.74	0.53	0.[illegible]19	2.16	0.66	65	1.84	1.5	0.46	0.5	0.152	32	9.76	[illegible]00	16716.59
3+00																											
	4	1.22	2	0.61	2.0	0.79	3.1	0.95	23.92	2.22	15.63	4.77	1.54	0.47	0.0[illegible]5	1.85	0.85	35.3	1.00	1.5	0.46	0.5	0.152	30.4	9.27	[illegible]55	35[illegible].28
7+00.2																											

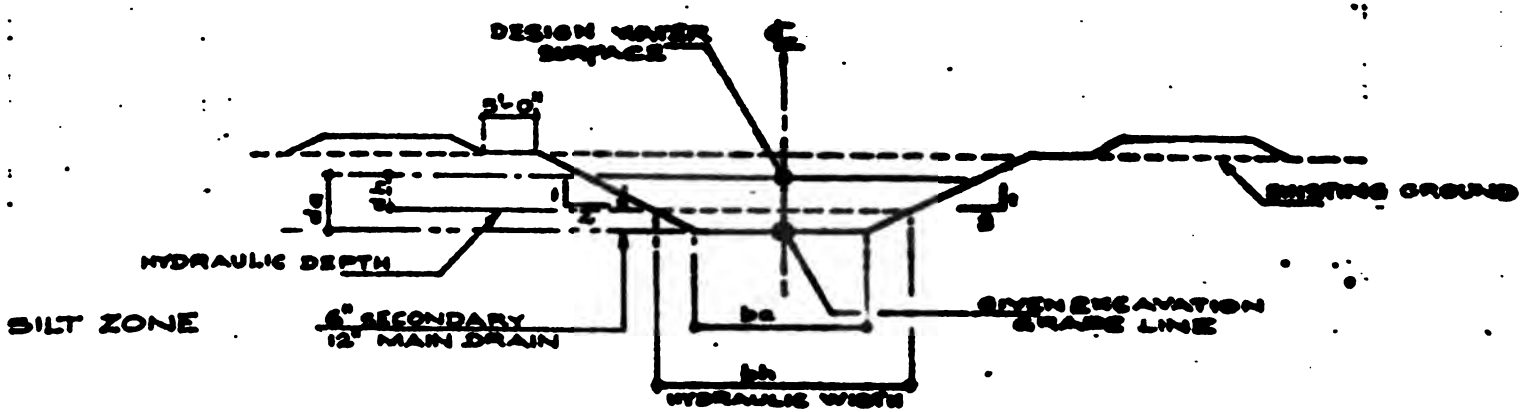
Area Cost $[illegible]255 Ft² = 7.86 Acres=3.1811 Ha.

DESIGN CHARACTERISTICS OF DRAIN ZD-4 (S=0.030; Length = 7123.1 Ft=2171.68 M; Side Slope =2)

0+00																											
	4	1.22	2	0.61	2.0	0.85	3.3	1.01	22.4	2.08	16.42	5.04	1.36	0.41	0.00[illegible]6	2.03	0.62	45.[illegible]	1.29	1.5	0.46	0.5	0.152	31.2	9.[illegible]		
3+00																											
	4	1.22	2	0.61	1.8	0.83	1.9	0.58	9.52	0.88	10.26	3.16	0.92	0.28	0.00427	2.59	0.79	25	0.70	1.5	0.46	0.5	0.152	25.60			
7+23.1																											

Area Cost=$21[illegible]34 Ft² = 4.86 Acres=1.9680 Ha



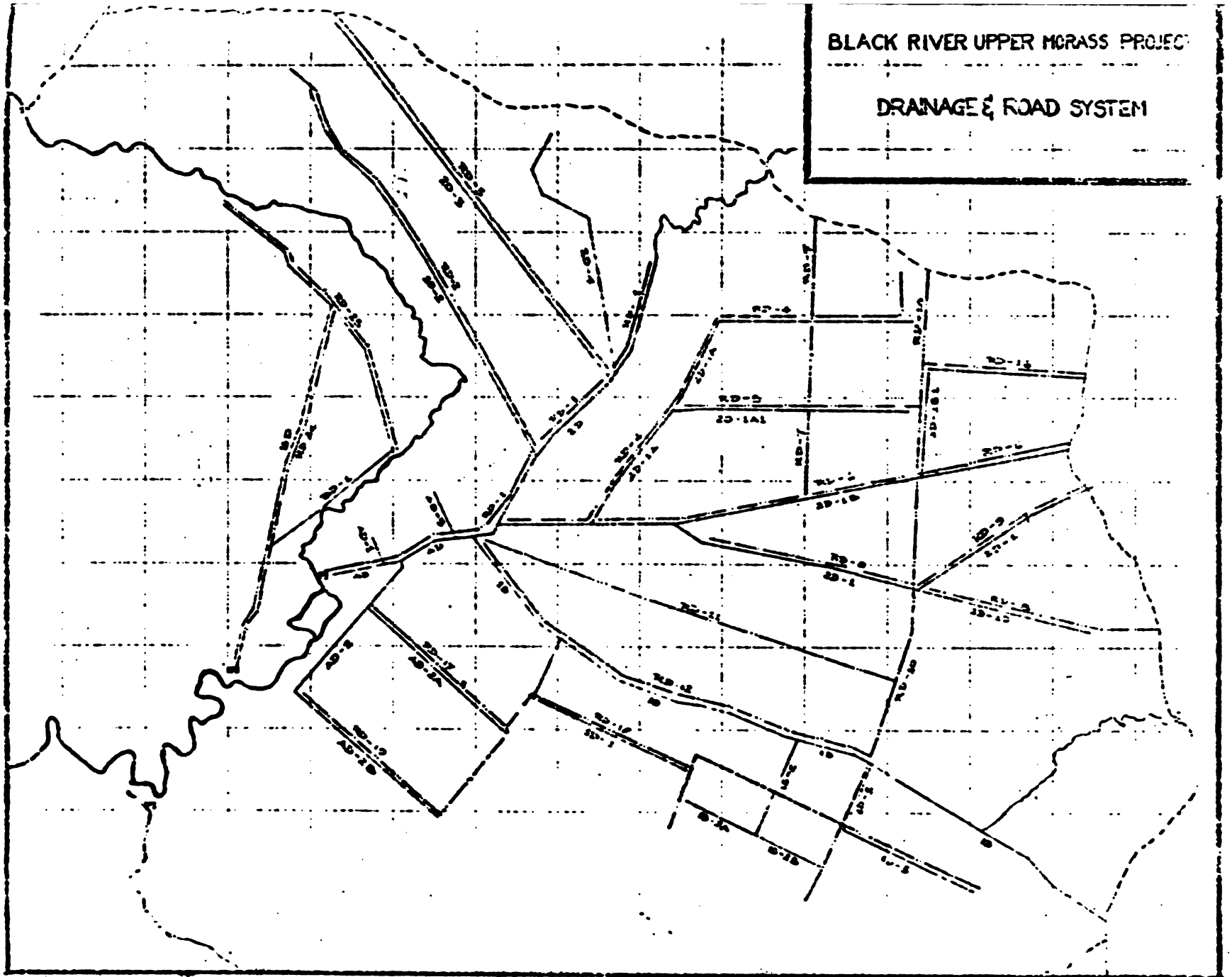


TYPICAL DRAIN SECTION

SOURCE: HARZA OVERSEAS ENGINEERING COMPANY AND NDE LVET! ON, 1977. BLACK RIVER UPPER MODULE FEASIBILITY REPORT. 3 VOLS.

TYPICAL DRAIN SECTION

TYPICAL LAYOUT OF DRAIN IN LOOSE STRATA


BLACK RIVER UPPER MORASS PROJECT
DRAINAGE & ROAD SYSTEM

APPENDIX II

RECOMMEND DEPTH OF THE WATER TABLE FOR MAXIMUM YIELD OF CROPS GROWING IN PEAT SOILS

Crop	Depth of Water Table	
	Feet	Meter
Beans	1.5 - 2	0.45 - 0.61
Cabbage	1.5 - 2	0.45 - 0.61
Carrots	2	0.61
Corn (sweet)	2.0 - 2.5	0.61 - 0.75
Lettuce	2.5 - 3.0	0.75 - 0.90
Onions	2.0 - 2.5	0.61 - 0.75
Peas	1.5 - 2.0	0.45 - 0.61
Potatoes	1.5 - 2.0	0.45 - 0.61
Tomatoes	1.5 - 2.0	0.45 - 0.61

APPENDIX III

RECOMMENDED PARTS FOR THE ENGINE (30" PUMP)

2 sets of fan belts

1 set of radiator hoses, clamps and tubing

1 box of 15 amp fuses

1 fuel solenoide

1 safety relay

3 starter solenoide

4 voltage ampmeter

4 water temperature gauge

4 oil pressure gauge

12 fuel filters

12 oil filters

6 air filters

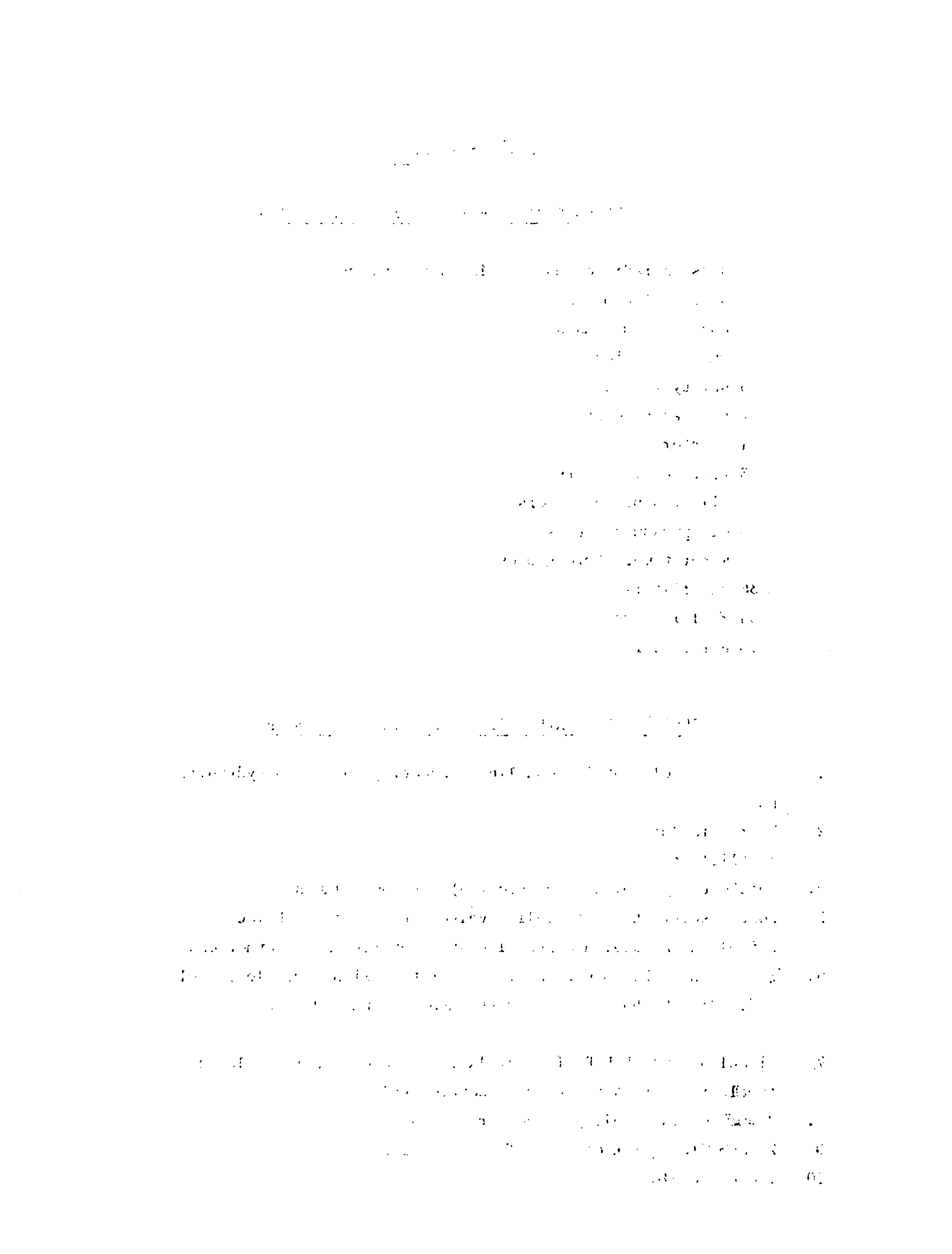
APPENDIX III (cont'd)

RECOMMENDED PARTS FOR THE ENGINE (42" PUMPS)

3 sets of radiator hoses, clamps and tubing
4 sets of fan belts
3 boxes 15 amp fuses
3 fuel solenoids
3 safety relays
2 starter solenoid
1 starter
3 voltage amp meters
3 oil pressure ampmeters
3 oil pressure gauges
36 water temperature gauges
36 oil filters
36 fuel filters
18 air filters

RECOMMENDED PARTS LIST - MAJOR (42" PUMP SIZE)

1. 1 coupling element for coupling connecting engine to hydraulic pump
2. Hydraulic pump
3. 1 relief valve
4. Intake to hydraulic pump (suction) hose and clamps
5. Hose assembly L.P. for relief valve return with push-loc swivel on one end, and push-loc straight fitting on other end
6. ¼" hose assembly H.P 2' H.P. hose fitting with reusable swivel end. 2' H.P. hose fitting with reusable straight end.
7. Miscellaneous ¼" H.P. fitting ¼x 1/8 adaptor fitting male and female from check valve to ¼" control valve
8. 2 each quick coupling, 5100 for return line
9. 2 each 5100 quick coupling for supply line
10. 1 each needle valve



APPENDIX III (cont'd)

11. 1 each 0-3000 P.S.I. pressure gauge
12. 1 each vacuum gauge
13. 1 float for hyd. tank safety
14. 1 each 40' H.P. supply hose with male pipe fitting ends and quick couplings
15. 1 each 40' L.P. return hose with male pipe fitting ends and quick couplings
16. 1 each S/S teflon oil feeder line for pump
17. 1 hydraulic motor
18. 1 propeller
19. 1 each S/S wear ring
20. 1 bottom seal plate
21. 1 Crane seal
22. 6 return line filters
23. 1 box 2¼"x 5/8 bolts and nuts (contains 50)
24. 2 discharge pipe gaskets
25. set pump bowl bearings

RECOMMDNDED PARTS LIST - MAJOR (30" PUMP SIZE)

26. 1 coupling element for coupling connecting engine to hyd. pump.
27. Hyd. pump
28. 1 relief valve
29. Intake to hyd. pump (suction) hose and clamps
30. Hose assembly L.P. for relief valve return with push-loc swivel on one end and push-loc straight fitting on other end
31. ¼" hose assembly H.P., 2'H.P. hose fitting with reusable straight end
32. Miscellaneous ¼" H.P. Fitting ¼x1/8 adaptor fitting male and female, from check valve to ¼" control valve
33. 2 each 5100 quick coupling for supply
34. 2 each quick coupling, 5100 for return line
35. 1 each needle valve
36. 1 each 0-3000 P.S.I. pressure gauge
37. 1 each vacuum gauge
38. 1 float for hyd tank safety

APPENDIX III (cont'd)

39. 1 each 40' H.P. supply hose with male pipe fitting ends and quick couplings
40. 1 each 40' L.P. return hose with male pipe fitting ends and quick couplings
41. 1 each S/S teflon oil feeder line for pump
42. 1 hydraulic motor
43. 1 propeller
44. 1 each S/S wear ring
45. 1 bottom seal plate
46. 1 crane seal
47. 6 return line filters
48. 1 box 2"x½" bolts and nuts (contains 50)
49. 2 discharge pipe gaskets
50. set pump bowl bearings

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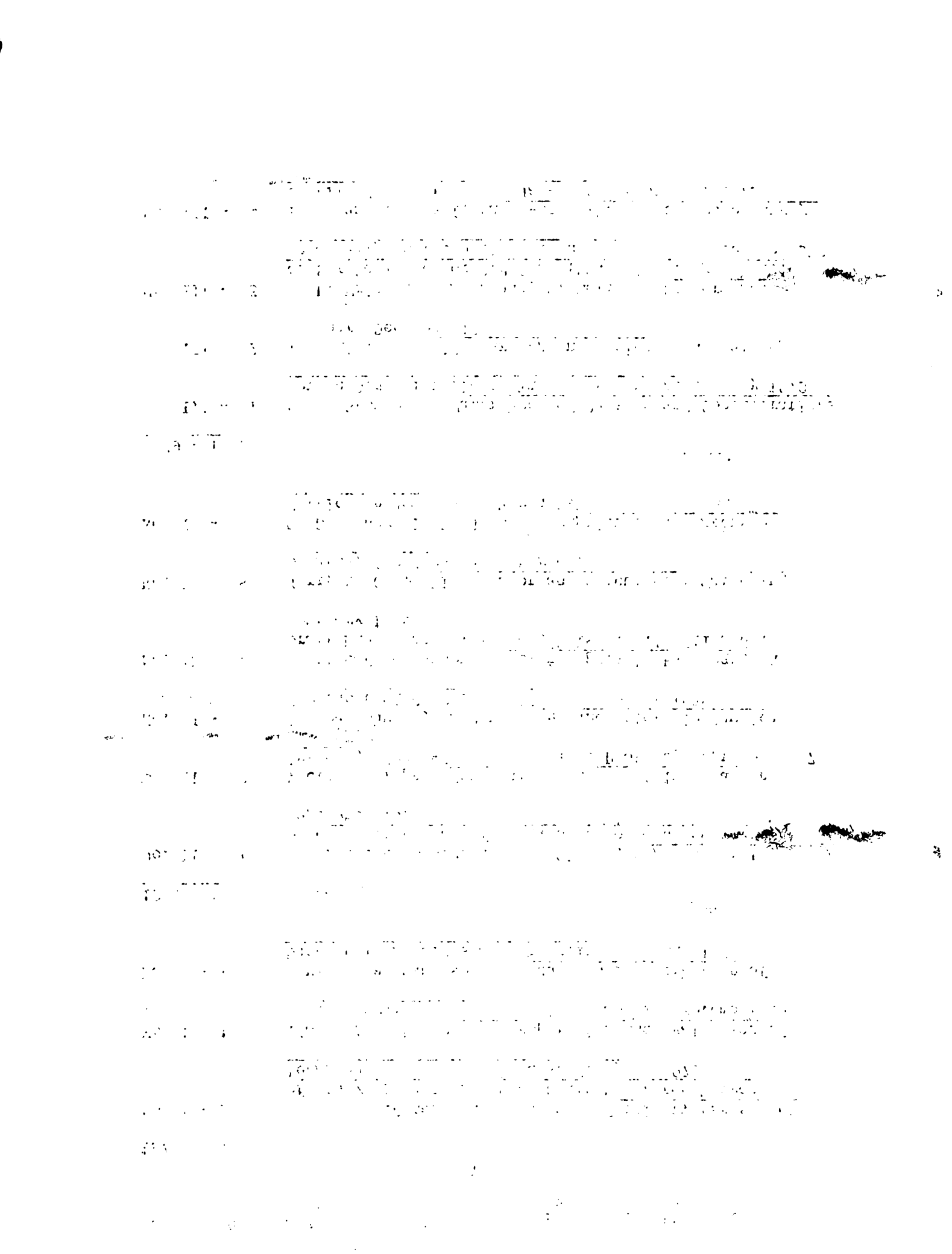

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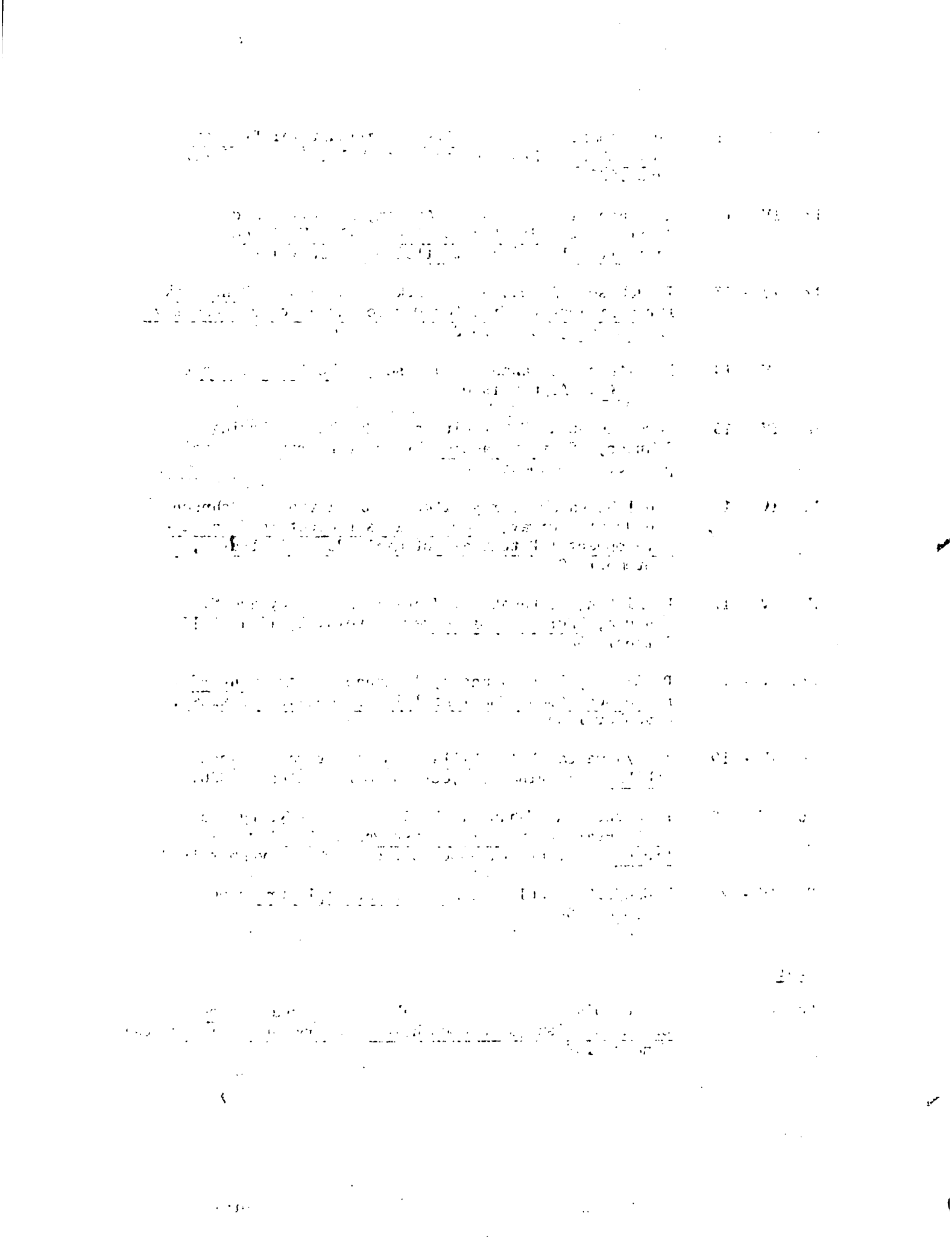

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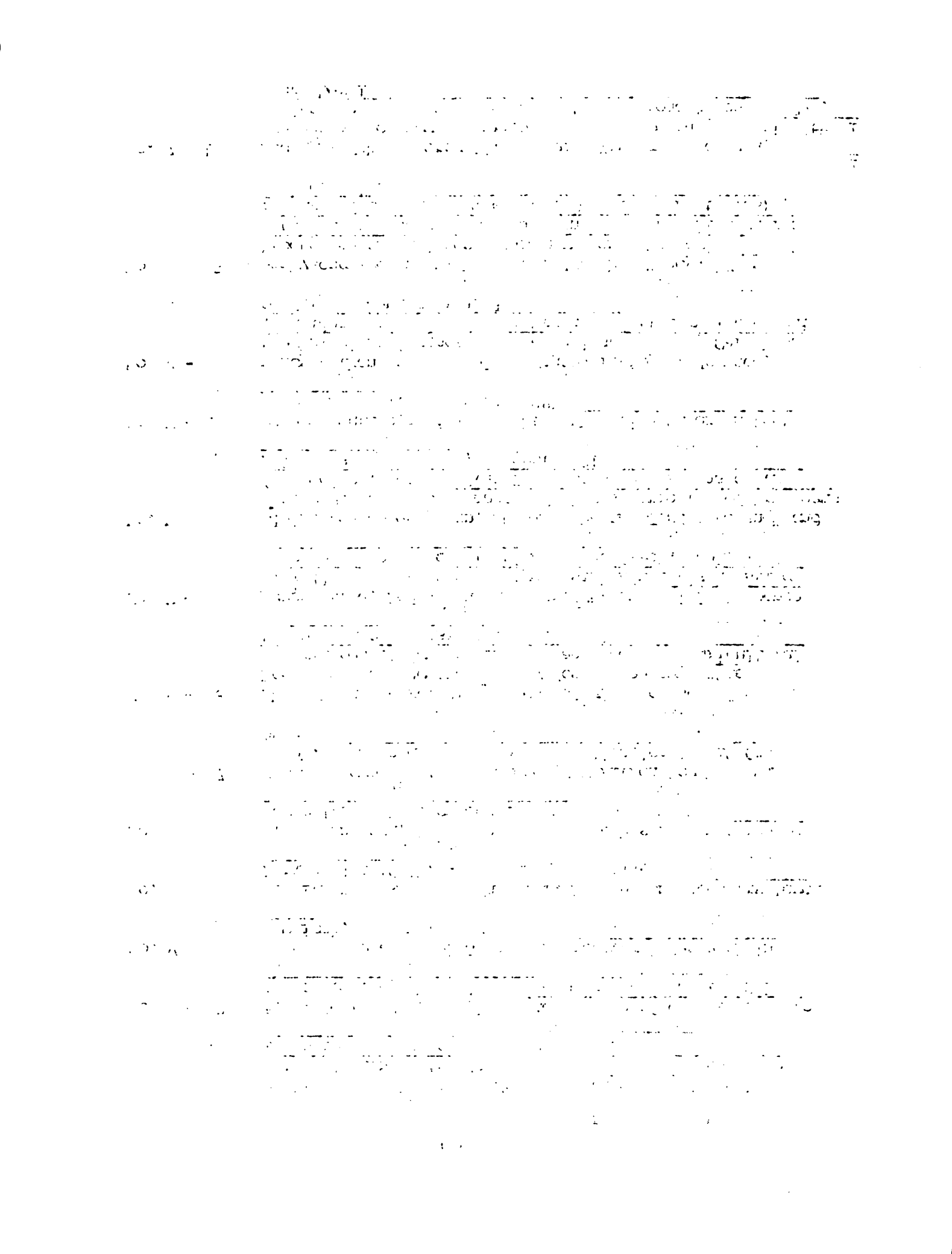

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