DESIGN OF FIELD DRAINAGE AND FLOOD CONTROL STRUCTURES FOR MBIABET TRIBUTARY SWAMPS

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ABSTRACT

Tributary swamps were identified in northern Akwa Ibom State in which agricultural development was serious constrained by imperfect drainage and high flood water level in them. Drainage design used 5 years rainfall return period with the rainfall duration frequency computed for N – consecutive – day rainfall using Gumbel Extreme Value (GEV) plotted on Gringerton position. The case of Mbiabet subcatchment swamp was designed for by sub-dividing it into 10 smaller subcatchments areas to be drained and using rational formula to computerize computed together with the excavation costs of such volumes. The project had a low financial rate of return that would be improved by good water management.

Keywords: tributary swamp, imperfect drainage, drainage design, rainfall - frequency – duration, Rational formula, internal-rate-of-return.

INTRODUCTION

A feasibility report of Akwa Ibom State Government shows that improvement in agricultural production to attain a higher internal rate of return would require 100 percent increase in culturable area for both vegetables and perennial tree corps, coupled with a restriction of subsistence rice farming from rainfed to a more efficient productive form. The need for development of more swamp land is rife when it is observed that of the 261030 population on the tributary catchments area only 0.5 percent are rice – farmers[1].

farmers involved in the rice scheme within the inland basin of Enyong Creek in Akwa Ibom have often complained of not having adequate land for rice cultivation arising from high level of swamp inundation and the erosive force of the flow velocity in the swamps at few weeks after rice seedling transplant. Thus, development of the northern Akwa Ibom swamps is constrained by (1) high flood stage along the river and in the adjoining swamps beyond safe submergence levels for sustainable rice production, (2) imperfect drainage of runoff and (3) poor seasonally submerged access to the swamps. Flooding may be due to any or a combination of the following causes: Rainfall – runoff from upland pounding on lowland floodplains and from rivers in all swamps; backwater afflux at the downstream confluences causing tributary river to back-up into the low-laying areas or wetland along the reach of the river,

dense vegetation and other conveyance barriers on the swamps resisting free outflow water, and depression storage on the swamps that attenuates flooding.

Agronomic practices aimed at alleviating these problems have proved inconclusive as a solution without hydraulic structure; for even if the deepwater species of rice were used the problem would not be deterred, because of the concomitant factors of differential and variable level of inundation, swamp attenuation, very fast and fluctuating flow velocity that uproots transplants or lodges the young plants, inflicting hazards on yield as well experienced in 1993[2]. Therefore the availability of land in these swamps seriously depends on the provision of flow regulation infrastructures to control flow depth and speed and these structures must be suitable for through – drainage of the upland runoff and for stemming the high backwater flooding from the causal river, Enyong Creek.

Thus the objective of this paper is to design such structures for use on the wetland and control water level for sustained rice production.

Tributary Swamp Scheme Design Features

In quite a number of areas tributary swamps were found, apart from the areas along the rivers afflicted by seasonal flooding here the upper end of these areas were at a higher level than the maximum water level these portions of the swamps tended to be less affected by severe inundation during the wet season; the were quickly receded to steady flood imperfect drainage and were identified to include A- Nkari, B- (Itu South), E-(Igwu) and H-(Idim Ibom) swamps (Fig 1). These were the tributary swamps found along the tributaries to the main rivers Enyong creek and Ikpa River. Their slopes were generally more pronounced (between 2-6%) and their width limiting. Some of them were delineated from the severely inundate margin by their slope. Drainage was restricted due to natural sills or constricted drainage conditions caused water levels to form a restriction for agricultural development.

The tributary swamps scheme would have a layout characterized by a central drain (the main drain) which would evacuate excess water resulting from rainfall-runoff from the upland. For those tributary swamps which bordered on the areas afflicted by high water levels in the rivers, a protection dam would be constructed. The dam would be equipped by a number of sluice gates to allow drainage proceed by gravity if the water levels outside the dam were sufficiently low. However, that the improved drainage may likely cause water levels in the protected swamp to drop, thereby reducing water level so much that it would be less favourable to cultivate rice. Therefore, to avoid these adverse conditions, bund would be constructed around the farm plots to conserve the water-level for rice cultivation.

Also, the upland runoff may throw unwanted water and sediments deposits to the bottomland unless flow control is so provided for. Te bottomland would be protected from unwanted deposit by constructing interception drains along swamps to channel (route) surface runoff from the uplands in a safe way into the main (control) drain.

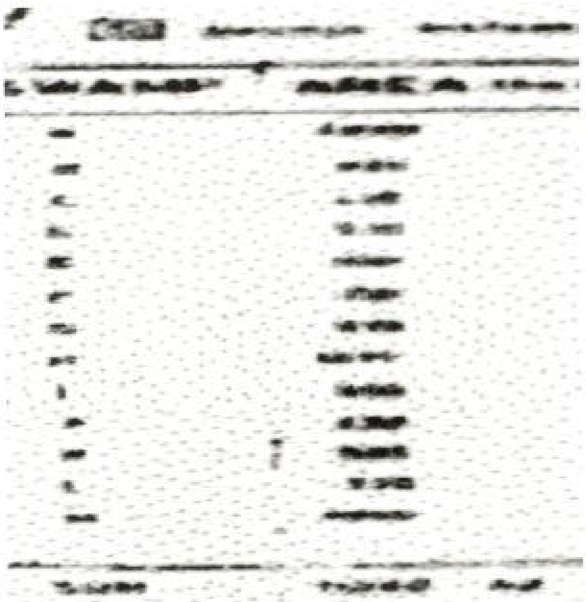
Design Objectives for Tributary Swamp Scheme: The objective of the tributary swamps scheme was to increase surface area available for agricultural production in the swamps by improving drainage and subsequently lowering the water levels in the swamps. The design for Mbiabet (H) swamp scheme where experiments Government Rice Farm (GRF) project is imperiled is given here. Other areas found suitable such as A and E require embankment which design is not considered here.

METHODS

The designs of the water ways were made taking into account their use in either drainage or subsequent gravity irrigation. Thereafter estimate of the bill of quantities for the drainage for the drainage work was made. The approach for this was as follows. With 1:20,000 aerial photographs (courtesy[1]) and sterecope, boundaries of the catchments and swamp areas were delineated. Maps were then produced to indicate catchments, swamps, natural drains and relevant elevations. Thereafter, the catchments was divided into subcatchments and used for stepwise calculation of the design discharge. The rational method was applied as quite suitable for small catchments. Design discharges with a return period of 5-years were carried out (see rainfall duration frequency).

The Manning formula[3] was applied for the calculation of the rain dimensions using roughness factors of 30 (see canal roughness coefficient later) and the side slope of the canal was take at 1/15 vertical/horizontal (V/H) (see canal geometry and side slope). An overall drain slope that is parallel to the overall catchments swamp slope was estimated at 0.0004m/m from the map. When the above slope was used for higher discharges, velocities of

Table 1: Component Swamps in the study area



around 1ms-[1] were obtained, while for lower discharges velocities of 0.6ms-[1] were obtained. Therefore, the velocity of 1m-[1] was acceptable for the design.

Drains were only designed for those areas where drainage was required to improve conditions upstream or where agricultural activities were taking place at the time of study. Those included Mbiabet swamp (H2) where government stallholder swamp rice farming pilot project was having water-level problems (Fig.1, Table 1). In calculating the lengths of drains and volume of excavation per sub-catchments, it was noted that sub-catchments generally contained a number of natural drains which originated in other catchments before flowing into the main drains. For each of those drains the design discharge was established together with its lengths. Then the cross sections were calculated to get the necessary volume of excavation.

Design of Waterways

Waterway may be designed for irrigation or for drainage. Both have separate or specific criteria. The values for these criteria were established for the canals used here. The general design principles were as follows:

Hydraulic Formulae

Flow Formula: For the flow of the canal section, the flow was considered as uniform, and the manning –Stickler formula was applied[4]: i.e.

$$V = K * R^{2/3} I^{1/2} \qquad (1)$$

Where $R = AP^{-1}$, $A = (b + mh)h$; $P = b + 2h(m^2 + 1)^{1/2}$

$$Q = V * A \qquad (2)$$

$$B = m * h \qquad (3)$$

(See notations for symbols meaning)

Roughness Coefficient: This could be affected by many factors, namely; roughness, irregularity of the canal surface alignment, the amount of vegetation in the canals, and the sediment transported in the water. in the design for drainage and irrigation canals in the northern Akwa Ibom Swamps, the following roughness coefficients (Table 2) were maintained for both drainage and irrigation canal.

Table 2: Stickler roughness Coefficient ($K_m = 1/n$) for Earthen Canals

Design discharge, $m^3 s^{-1}$	$K_m, (m^{1/3} s^{-1})$
Q >10	45
5 <Q < 10	42.5
1 < Q < 5	40
Q < 1	35

Sources: Pitchel (1994). Personal communication

Maximum Velocity

The maximum allowable velocity is the average flow velocity will not cause erosion of canal surface. The USCS[5] has established values for these velocities differentiating between sediment-laden flow (S>20000 ppm) and considered free. When Diversion River is used to Sep up the irrigation water where it is necessary a sediment trap should be applied to reduce the sediment load so as to consider it as free. If the drainage water from upland flow is sediment-laden it will be indicated in the sediment load in the river.

For the tributary swamps, suspended solids were found to be lea than 1000ppm [1,6]. For instance, at Ibiaku Ikot Esifa in swamp H, Nkana in swamp D, and Okoroma in swamp E,
the suspended solid were $350mgl^{-1}$ (350ppm), $400mgl^{-1}$ (240ppm) respectively, noting that the irrigation water (or drainage water in the swamps) were sediment-free by FAO standards[7]. A number of data wee required to obtain an estimate of the maximum allowable velocity (V_{max}). These included the Vmax should not exceed $0.6ms^{-1}$.

Earthen Canal: (i) canal cross section: the trapezoidal form of earthen canals discharges up to 0.5 approaches an ideal cross-section. For larger canals the design velocity are greater than the maximum allowable velocity. The ration of bottom width/water stage (b/h) up to 10 and higher were used where applicable. (ii) Lined canals: In localities were conditions such as unsuitable topography, unsuitable or higher land pressure prevents the use of on lined canals and lined canals will be used.

Types of Lining

In the concept of development in Akwa Ibom State swamps, two lining are recommended. These are concrete and stone masonry. These are suitable for all purpose except for the improvement of bank stability. They are available and in some cases near the construction site. The type and thickness of lining are classified in Table 3.

Table 3: Type and Thickness of Lining

Type of Lining	Minimum Thickness (m)
Stone masonry	0.30
Plain concrete for $Q<6m^3 S^{-1}$	0.08
Plain concrete for $Q>6m^3 S^{-1}$	0.10
Reinforce concrete (rk)	0.08
Compacted soil cement	0.10 - 0.15

Compiled from various sources [4,8]

Roughness Coefficient, K

The recommended stickler roughness coefficient, K, for the different linings are shown below[9,3,4]. The lining used to protect the transition from a structure into an earthen embankment would have the same value as the earthen embankment.

Table 4: Stickler Roughness Coefficient for Different Lining

Types of lining	K manning
Stone masonry	60
Concrete	70
Earthen	35-45

Table 5: Canal Design Characteristics

Discharge, $m^3 s^{-1}$	Side slope	Ratio b/h	Roughness coefficient, km
0.15 – 1.00	1.0	1.0 – 1.5	35
1.00 – 1.50	1.0	1.5 – 1.8	40
1.50 – 5.00	1.5	1.8 – 1.9	40
5.00 – 10.00	1.5	1.9 – 3.9	42
10.00 – 10.00	2.0	3.9 – 9.0	45

Composed from [4,10,11]

Canals would be excavated in well compacted soils or constructed in situ in tiff clay loam or cohesive sandy clay that correspond to any of the symbols CL, SC or SM. In the subject area of Enyong creek, there were no coarse textured soils throughout the profile (Table 6). The coarse layers were either overlain or underlain by finer, less permeable layers[1]. These were therefore suitable for swamp rice cultivation and for canal construction.

Canal Curvature: For earthen canals, allowable curvature depends on: Size and capacity of the canals; types of soil; and flow velocity. The minimum radius of curvature measured with reference to the canal centre line will be 8 times the design a water surface width [4,10,11,12,13]. Lining is known to reduce the minimum radius. This is considered of the radius becomes too wide to fit in the local topography. Lining should extend at least 4 times the water depth beyond the curve. For a lined canal the minimum canal curve would be as follows:

3 times surface width for discharge of $0.6 m^3 s^{-1}$ up to 4 times surface width for discharge of $10 m^3 s^{-1}$. Total lining = (rc + 2 x 4d) 2, where rc is radius of curvature, and d is water width.

Table 6: Summary of Clay content in the upper 50cm of soils in wetlands of Enyong creek in Akwa Ibom State

Area	Clay Content range, %	Mean	Texture Class
Wetlands	5.4 – 88.8	30.5	SCL,C SL
Creek wetland	8.8 – 80.2	38.9	LS,SCL,C

AKADEP[1]

Freeboard for Lined Canals

Lining of the entire freeboard is not necessary in lined canals. The benefit of this principle is a considerable reduction of cost of constriction especially where larger sections are involved. Table 7 shows the freeboard allowance in discharge-carrying canals. Using these principles, specific values were made for drainage and for irrigation systems;

Table 7: freeboard for lined canals

Discharge Q $m^3 s^{-1}$	Lining (m)	Freeboard (m)
< 1.5	0.20	0.50
1.5-5.0	0.25	0.60
5.0-10.0	0.30	0.75
10.0-15.0	0.4	0.85
>15.0	0.50	1.00

Source: [4,8,11].

Design for Drainage System

The drainage system aimed at evacuating excess runoff water and keeping water level below a certain level. For the cultivation of rice, use was made of surface drainage system. This served to evacuate excess rainfall as well as the water that were to be removed from the field as a result of cropping practice. It was noted from AKADEP[1] report that the risk of Stalinization were absent in the study area. Therefore design of drainage for the additional purpose of keeping ground water below a certain level was not needed here. The determinant factor in this drainage design was the water-level in the field, hence the maximum rainfall causing excessive rise of water level.

Allowable Water Depth

To drain of flood water completely has not always been economically feasible, hence the drainage system design allow for certain submergence for a certain period of time. For this system, rice cultivation was in focus. The allowable periods and their subsequent influence in the rice yield are known to differ greatly according to crop stage.

Table 8: Submergence of Rice in clear Water and % Decease in Rate of Yield

Growth	Level of Submergence	% Decrease in rate of yield under days of flooding			
		1-2	3-4	4-5	>7
At 20 days after transplanting	Completely	10	20	30	35
At young panicle formation	i) Partly	10	30	65	95-100
	ii) Completely	25	45	80	80-100
At heading	Completely	15	25	30	70
At ripening	Completely	0	15	20	20

From Table 8, it was clear that young plants would be less susceptible to damage by submergence but were easily submerged and for longer period than the taller plants at panicle formation. Thus, the most critical period was the first month after transplanting short straw varieties which would eventually grow to 1 m were found not to experience a substantial reduction of yield under a 3-8 days submergence provided water depth did not exceed 20cm. for the traditional long straw varieties, which tolerated water depth, this was about 40cm.

If a normal water depth in the field is assumed at 100m for rainfall condition in the month of transplanting, while 200mm is an acceptable depth to flooding, it follows that 100mm can be used in the field. This helped in determining the design discharge of drainage module.

Rainfall Intensity- Duration - Frequency Relationship

Rainfall frequencies for consecutive day rainfall over periods of a day and longer were estimated by fitting extreme value distributions to the data at Uyo given in Tables 9, 10, 11. The general extreme value type (iii) (Gumbel Extreme Value)[4] distribution was found to best fit the data particularly in the tail. The results are presented in Table 11.

It was observed that the data for shorter duration storms were not available for carrying out frequency analysis, hence the method by Hargreaves[14] were used to get such duration storms at various frequencies for a regions of the world was established by Hargreaves[14] and given by.

$$R = Kt^{0.25}\,T^{0.167} \qquad (4)$$

where R is the amount of rainfall (mm); K is the coefficient for each location or region; t is the storm duration (hrs); T is the return period of frequencies in yeas. The coefficient K relates to the 20 years monthly rainfall in the following manner: $K = K_pP_{05}$ where K_p = location dependence factor; $K_p = 0.08$ for Nigeria; P_{05} value were estimated from the monthly rainfall at catchments apex met stations. (Uyo and Umudike) by fitting extreme value distribution of the data, which gave the following results: $P_{05} = 618$ mm for Uyo and 594mm for Umudike.

Rainfall Duration Frequency

This was used to estimate the design discharge or drainage module of the drainage system using data from Uyo and Umudike as the southern and northern axes of the swamp area respectively. To establish the design drainage module, rainfall duration frequencies (sum of N-day rainfall were established for 1-6 days periods. The observation thus obtained were ranked using Gringorton planting position plotted on Gumbel paper (Gumbel extreme values, GEV)[16]. An interpolation was drawn and rainfall sums for the specific return period for the rainfall periods were established. These values subsequently, were plotted in rainfall duration graphs [16, 4] assuming a normal water depth in the field at 100mm for rainfed conditions in the months of planting; while 200mm was an acceptable depth of flooding it was expected that 100mm will be stored in the field. To determine the drainage module tangent lines were then drawn from the 100mm – point on the rainfall axis. Lines passing through the origin were thereafter drawn paralleled to the tangent lines. This gave the following values (Table 12)

Table 9: Maximum Consecutive N- Day Rainfall at Uyo (unit: mm)

Year	N = 1	N = 2	N = 3	N = 1	N = 5	N = 6
1978	170.3	178.6	179.8	314.6	315.1	323.4
1979	180.5	351.1	421.1	471.1	591.1	614.7
1980	157.3	128.1	191.1	216.3	240.7	246.6
1981	102.4	137.9	139.3	173.2	174.5	163.0
1982	123.0	125.5	130.9	140.5	133.8	139.9
1983	93.6	75.7	93.5	97.1	115.3	80.3
1984	83.0	79.7	112.2	103.1	125.2	99.6
1985	97.7	130.5	136.1	115.1	116.8	87.1
1986	69.0	97.1	158.9	118.4	137.9	139.4
1987	82.8	125.1	94.3	107.4	108.9	128.9
1988	82.7	127.7	141.8	157.5	168.9	170.2
1989	124.2	177.5	199.7	1544.7	319.7	179.2
1990	120.5	136.4	145.9	149.9	111.8	141.9
1991	120.0	121.0	192.8	181.9	203.4	204.5
1992	144.5	149.0	155.7	160.7	171.2	186.2
1993	118.8	120.0	147.0	155.	186.4	189.4
Average	141.3	165.0	165.0	182.3	201.3	193.
Maxi	351.1	421.1	421.1	471.1	591.1	614.7
Mini	75.7	93.5	93.5	97.1	108.9	80.8

Maxi = maximum value, mini = maximum value, N= No of rainfall days

Table 10: Consecutive N-Day Rainfall at Various Exceedance probabilities at Uyo (Unit mm) (N-D Rainfall, mm)

Year	N =1 day	N=2days	N=3days	N=4days	N=5days	N=6days
2	113	127	147	155	164	159
5	142	168	196	222	244	241
10	160	202	238	282	318	314
20	176	241	286	354	411	403
50	196	304	363	473	576	554
100	210	361	434	588	242	700
200	223	428	518	730	957	883

Rainfall depths for various duration and frequencies were calculated using the above relation and are shown in Table 11. These values were used in subsequent analysis for the design of drains.

Table 11: Short Duration Storms at Uyo (unit: mm)

Return T (yrs) Rainfall duration (hrs)	2yrs	5yrs	10yrs	20yrs	50yrs	100yrs
0.50	47	54	61	69	80	90
0.75	52	60	68	76	88	99
1.00	56	65	73	81	95	107
1.25	59	68	77	86	100	113
1.50	61	72	80	90	105	118
1.75	64	74	83	94	109	123
2.00	66	77	86	97	113	127
2.25	68	79	89	100	116	130
2.50	71	83	93	105	122	137
3.00	73	85	96	107	125	140
3.25	75	87	97	109	127	143
3.50	76	88	99	111	130	146
3.75	77	90	101	113	132	148
4.00	78	91	103	115	134	151

4.25	80	93	104	117	136	153
4.50	81	94	106	119	138	155
4.75	82	95	107	120	140	157
5.00	83	97	109	122	142	159
5.25	84	98	110	123	144	161
5.50	85	99	111	123	144	161
5.75	86	100	112	126	147	165
6.00	87	101	114	128	149	167
6.20	88	102	115	129	150	168
6.50	89	103	116	130	152	170
6.75	89	104	117	131	153	172
7.00	90	105	118	133	154	173
7.25	91	106	119	134	156	175
7.50	92	107	120	135	157	176
7.75	93	108	121	136	158	178
8.00	93	109	122	137	160	179
24	123	143	61	180	210	236
48	146	170	191	214	250	280
72	162	188	211	237	276	310
96	174	202	221	255	297	333

Calculated using Hargreaves method

Table 12: Drainage Module for Different Return Periods

Return Period (Years)	Drainage Module (mm/day	
	Uyo	Umudike
2	16	12
5	45	34
10	65	53
20	70	

Source: Essien[16]

The 5-year return period is commonly used. Then the drainage discharges of a channel section, sluice or pump were then calculated.

Drainage Design

Drainage design was carried out using the rational method. The method gave the estimate of the peak runoff using the relationship.

$$Q = CiA/360 \quad (5)$$

where, Q is the design flow rate (m^3/s^{-1}), C is the dimensionless runoff coefficient, i is the design rainfall intensity (mm/hr), A is the catchment area (ha). The runoff coefficient C, was taken as 0.4 in the swamp area for drainage design of frequency greater than 1 in 10 years.

Rational method assumes that the runoff rate in a catchment reaches a maximum when the storm duration is equal to the time of concentration. Thus it assumes that the recurrence interval of storm depth (R) and the flow peak were equal. Therefore the design rainfall intensity (i) was derived for the catchment. The time of concentration for the catchment had been estimated by using the Espey Winslow relation, which relations account for the catch characteristics – slope, stream length, land cover and hydraulic efficiency of the drainage structures and has been found to be appropriate for small catchments where overland and channel flow dominate. The relation is given as[17]:

$$t_c = 4.096.\ L^{0.23} S^{-0.25} I^{-0.18} ø^{1.57} \quad (6)$$

where t_c is the time of concentration (min), L is the stream length (m), S is the channel slope (m/m), I is the impervious portion of the catchment (%), ø was taken as 1.3 for each of the subcatchment in the swamps area to account for the low hydraulic efficiency which occurs in the highly vegetated network on the catchment[5]. The storm depth (R) for a given time of concentration and frequency was calculated.

Roughness Coefficient

The recommended Strickler roughness coefficient, K for the drainage canal were based on earthen unlined canals used in which weed growth as expected to be abundant as they would not always be filled with water. These conditions reduced the coefficients for drainage (the same were applicable to irrigation canals) even though regular maintenance was also assumed. Thus, for $h \leq 1.5m$, $K_m = 25$ and for $h > 1.5m$, $K_m = 30$, where h = water depth in canal and K_m = roughness coefficient.

Water Level: Designed water levels in the drains were a function of drain in the system. For the field drains (quaternary and tertiary drains) which were receiving water level in them were (or could be) at ground level in the drainage system, receiving its water from the tertiary system; water levels were determined by the required water levels at tertiary points.

In designing the main drainage system, two conditions were considered:
(1) That for design discharge under normal conditions, water level might rise to the ground level (this was the case at Mbiabet H2 swamps).
(2) That for peak discharge acceptable water depends on flood protection works along drainage canals. (This was the case in Ikpa swamps and not discussed here).
The maximum design water level used as at ground at Mbiabet rice field.

Canal Cross Section: Fig.2 typifies a cross – section of a drainage canal without flood protection, while Fig.3 is for drainage canal with flood protection. The former is discussed here.

Geometry and Side Slope: The width/depth (b/h) ratios for smaller secondary drainage canals were taken to be between 1 and 3. The ratio for the larger drainage canals was taken to be 3. The minimum bottom width was 0.03m for tertiary canals and 0.06m for canals of higher order. Side slopes for drainage canals were similar to those for irrigation canals. The steeper slope have the advantage for requiring less land for construction and producing a more concentrated flow at low discharge. The following values were maintained (Table 13).

Table 13: Excavation depth and side slope of canals

Excavation depth, D(m)	Minimum side slope (1:m)
$D \leq 1.0$	1.0
$1.0 < D < 2.0$	1.5
$D \leq 2.0$	2.0

Freeboard: As the maximum design water level was at ground level no other allowance was made for freeboard. However for cases where storm drainage would be conveyed through the drainage system, protection would be provided, then freeboard would be provided in relation to the drainage canal.

Application to Mbiabet Swamp H2

Design discharge for Mbiabet swamp (H2): The Mbiabet (H2) swamp is one of the tributary swamps where improvement of drainage and subsequent lowering of water table (stage) on the swamps (wetlands) was a development option. Calculations were made for drainage improvement system without flood protection. Using Equations 2 and 3 on the subcatchment A – J, the design discharges were made at catchment outlet points on the swamps, numbering M1 to M10 (SeeTable 14). Outlet point M1 situated at the location where the Mbiabet swamp (H2) joined another swamp, Idim Ibom Swamp (H1); Point M9 formed the outlet of a small subcatchment where an irrigation reservior was proposed to be constructed for the Mbiabet irrigation scheme. Mbiabet swamp was sub – divided into sub – catchments A,B,C,D,E,F,G,H,I,J which corresponds with at least one catchment outlet point. These are presented in Fig 3 and Table 14 using the values of storm depth R for each return period as (i) in the Rational formula (Equation 2), the drainage discharges for the subcatchment was made, as presented in Table 14.
The summary of the design discharges Q at catchments on in the subcatchments are a number of natural drains which originate in other catchments before flowing into the main drain. For each of these drains, the design discharges (Q), drains length have been established and cross-sections (A) calculated. The volume (V) of the cross-sections to be excavated out of the soil had been computed (Table 15). A summary is given in Table 16 (see Fig.3) for subcatchments.

Cost of Mbiabet Tributary Swamp Scheme

Mbiabet tributary swamp drainage scheme has a total volume of $750m^3$. At $N500/m^3$, this would cost N387, 034,000. Financial analysis of the Mbiabet tributary swamp project (not attached) showed that financial rate of return including contingencies and maintenance was 1% which was low rate of return.
Consequently, drainage scheme should be subjected to efficient water management scheme and correct economic practices in order to improve on the internal rate of return.

Table 14: Design Discharge at outlet point for Subcatchments of Mbiabet Swamp (H2)

Area, A (ha)	Catchment Length	Slopes, S (m/m)	Q design, m^3s^{-1} at rainfall T (5years.
4030	11200	0.0029	93.5
3288	10000	0.0032	80.3
279	2800	0.0310	12.9
640	5000	0.0177	24.0
2097	8500	0.0039	53.9
486	3600	0.0231	20.4
628	5100	0.0069	20.0
574	5800	0.0019	16.5
99	2000	0.0105	5.1
657	4500	0.0204	25.5

N/B T = Rainfall return period of 5years

Table 15: Calculation of Volumes of Cut for Drain Excavation in Mbiabet (H2) Swamp

Area	Discharge	Length	Slope	B	h	H	v	Crossection	Volume
A	-	-							
B	5	1700	0.0004	2	1.79	2.00	0.60	10.00	17000
	15	1960	0.0004	3	2.71	3.00	0.79	22.50	44100
	25.5	1200	0.0004	4	3.22	3.50	0.90	32.38	38850
C	-	-	0.0004						
D	24	2600	0.0004	4	3.13	3.50	0.88	32.38	84175
	5	500	0.0004	2	1.79	2.00	0.60	10.00	5000
E	22	1500	0.0004	4	3.00	3.25	0.86	28.84	43266
F	10	2300	0.0004	3	2.23	2.50	0.71	16.88	38813
F/G	39	900	0.0004	4	3.94	3.25	1.00	28.84	25959
G	16.5	1500	0.0004	3	2.83	3.25	0.80	25.59	38391
	2	400	0.0004	2	1.14	1.50	0.47	6.38	2550
H	54	2900	0.0004	5	4.34	4.50	1.08	52.88	153338
	2	700	0.0004	2	1.14	1.50	0.47	6.38	4463
I	54	1400	0.0004	5	4.34	4.50	1.08	52.88	74025
	30	700	0.0004	4	3.48	3.75	0.93	36.09	25266
	24	1260	0.0004	4	3.13	3.50	0.88	32.38	40793
	13	560	0.0004	3	2.53	2.75	0.76	19.59	10973
J	80	1360	0.0004	5	5.22	5.50	1.19		99110
									746068.8

Table 16: Lengths of Drains and Volume of Drain Excavation of sub Catchments

Sub-catchments	Length of drains (m)	Volume of drain excavation(m^3)
A	-	-
B	4860	99950
C	-	-
D	3100	89175
E	1500	43266
F	2300	88813
G	1900	40941
H	4500	183760

I	3360	140084
J	1360	99110
Total	22880	746068

Subcatchment A and C are ganged at points M9 and M8 respectively.

CONCLUSION

A project to design appropriate drainage system for tributary swamps, typified by Mbiabet tributary swamp in Akwa Ibom State, was undertaken to overcome the two main constraints confronting its development for agricultural production. Various data and a stereoscope used in the and their volumes to be excavated were made. It is believed that this project will benefit the swamps to improve their natural condition in a future agricultural development. Those for other tributary swamps, Itu south (**B**) and Itu North (C), were considered but were not reproduced here.

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NOTATIONS

A = wetted cross section, m^2
b = bottom width, m
h = water depth, m
k = Stickler roughness coefficient, $m^{1/3}s^{-1}$
I = energy gradient (or canal slope)
M = side slope (1 vertical: m horizontal)
P = wetted perimeter, m
Q = canal discharge, m^3s^{-1}
V = flow velocity, ms^{-1}

Sediment concentrations for tertiary swamp were 240-450 mgl^{-1} i.e. <1000ppm,
C = clay; CL = clay loam
SCL = sandy clay loam; S/M = silt underlain with medium textures soil CI = clay or stiff clay; = Silty Clay

Sediment or transport concentration for swamp (Enyong) was nil because electrical conductivity <1.0 ds/m^{-1}, Values ranged from 0.010- 0.15 ds/m^{-1}

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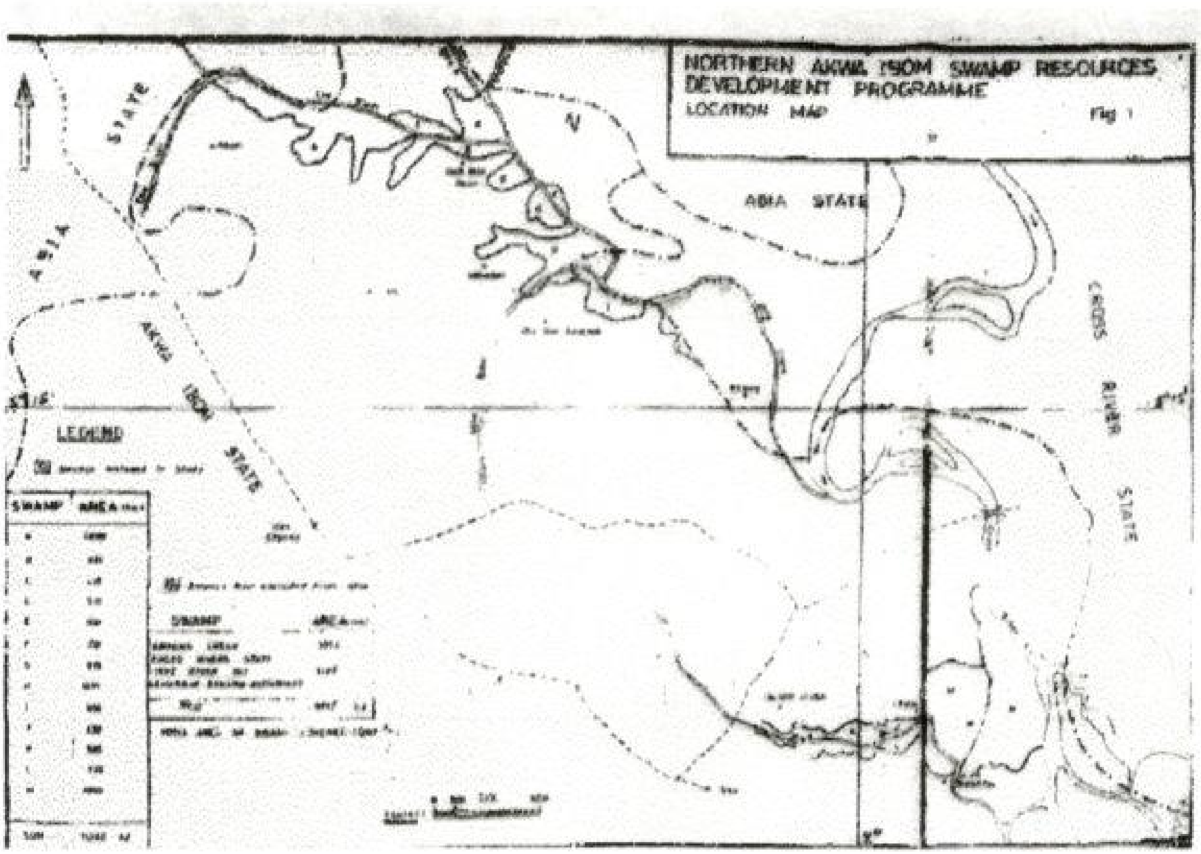

Fig 1: Map of the Study Area

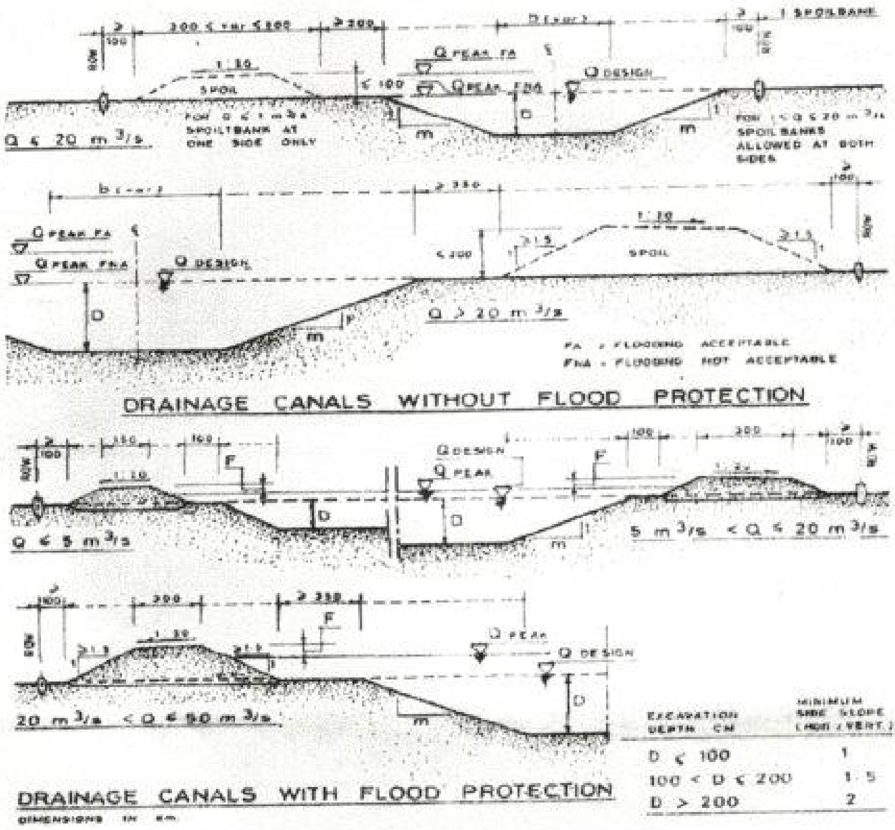

Fig 2 Typical Cross-section Drainage Canals

Fig . 2: Typical Cross-section for Drainage Canals

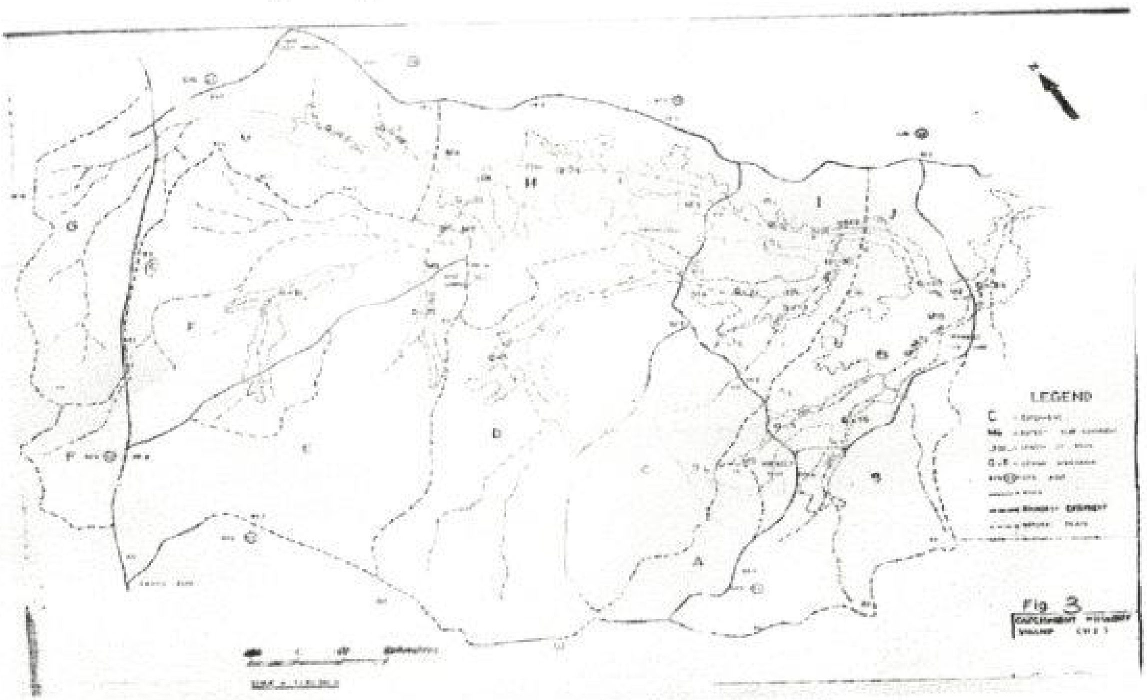

Fig. 3: Catchment Mbiabet Swamp (H2)