PRESENT SITUATION

The North-West District Council contemplated enlarging their tribal game reserve during the 1960's. As a result of this proposed size increase, a survey to demarcate new boundaries to the west of the existing Moremi Wildlife Reserve boundaries was conducted with Tawana Land Board officials during 1971 (*Tudor, pers. comm.). This was basically done to establish that no existing villages would be included within the new extension. This satisfied, boundaries were demarcated by **Verner and Tudor (pers. comm.). Since then, however, it was established that one village consisting of about 20 residents, was or is now within the inclusion area at Moretu.

Seasonal migrations of hunting/gathering parties enter the M'borogha floodplains from various areas upstream and downstream of the new reserve's northern and southern boundaries respectively. This pattern has been followed by these inhabitants for many years now, and they will not easily abandon it, since wildlife, edible fruits and honey are more readily obtained here. To a lesser extent the same pattern occurs on the western floodplains of the conserved area where sausage tree *(Kigelia africana)*, Maroela *(Sclerocarya caffra)* and ebony *(Diospyros mespiliformis)* are occasionally found chopped down for mekoro manufacture, and *Terminalia sericea* is used exclusively for making ponting poles.

The M'borogha floodplains, following minor channels just off Chief's Island and then entering the Santantadibe River in the vicinity of N'tamine Island, is a main access route between Maun and the northern and north-western Delta areas. This access route will always have to remain open.

To the west of Chief's Island, the Boro floodplains also form a main access route between Maun and the north-western Delta. However, the main route is largely outside the reserve or along its actual boundary.

Tourists are and will always be able to enter the M'borogha River through two access routes without entering the Moremi Wildlife Reserve. The first is via the Moanashira River in the north, and the second up the Santantadibe River from the south east. However, the

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**P. Verner, Department of Surveys and Lands, Maun, Botswana.

lower Santantadibe River is blocked and navigation there is difficult. The most popular tourist access is up the Boro River from Matlapaneng.

During low flood years, viz. 1973, access to Chief's Island by vehicle is reasonably simple. Under similar conditions most of the new reserve's western floodplains can be traversed, and the most northerly islands above Chief's Island can be reached. The eastern floodplains are completely cut off from vehicle access during low or high flood years.

Two tourist camps and airstrips exist at present east of the Boro River within the new reserve boundaries. These are in the process of being relocated to the west of the Boro River and are bases for conducting organised tours of the new reserve.

The proclamation of the study area with slight amendments to the existing Moremi Wildlife Reserve appear in Supplement C of the Botswana Government Gazette dated 2nd July 1976 under Statutory Instrument No. 93 of 1976, "Moremi Wildlife Reserve" (Amendment) Declaration, 1976.

GEOLOGY

The whole of northern Botswana falls within the great Kalahari sand-covered plain, or Kalahari Beds of the Tertiary System, which were formed during the Eocene to Pliocene periods between 1×10^6 and 60×10^6 years ago (Du Toit, 1966). This system covers more than three-quarters of the land surface of Botswana concealing much of the older geological formations. Geological surface remnants of the Pre-Cainozoic Era remain as inliers, inselbergs or outliers providing the key to the solid geology of the Okavango Delta, and these clearly point to a vast inland drainage depression covering a large portion of northern Botswana.

Scattered outcrops of rock delimit indefinite margins of the Okavango and Makgadigadi basins. These are: to the north and north-east, the Goha, Gubatsaa and Shinamba Hills; to the northwest, the Tsodilo Hills and other outcrops towards the South West African border; to the west, the Aha and Koanaka Hills; to the south, the Mabeleapodi, Kgwebo and Haina Hills; and to the east of the Makgadikgadi Salt Pans the outcrops of Basaltic and Rhyolitic Lavas, and of the Stormberg Series forming the east-west rain divide and belonging to the Karroo System of the Mesozoic Era (Fig. 2).

The oldest rocks are granitoid gneisses of the Archaen Basement Complex, with outcrops occurring in the Xangwa Valley and again near the Chobe River. Geophysical evidence suggests that these rocks extend in a wide belt north-eastwards from near the Aha Hills through the northern or upper Delta areas, north of the Gomare fault (Hutchins, Hutton, Hutton, Jones and Loenhert, (1976).

The variably metamorphosed strata of the overlying Damara supergroup form the Tsodilo Aha and Koanaka Hills. They comprise quartz schists, quartzites and dolomitic marbles of late Pre-Cambrian Age. To the south a fairly expansive stretch of relatively unmetamorphosed Ghanzi Formation comprising quartzites, shales, and limestones and overlying the Kgwebe Formation is reasonably well exposed.

The Kgwebe Formation comprises two members, one a quartzfeldspar porphory which gives way laterally, northwards to the Toteng diabase. The Goha and Gubatsaa Hills are also composed of the quartz-feldspar porphory, which radiometric dating has given an average age of a little over 900 x 10^6 years (Boocock, 1968). The Ghanzi Formation bears statiographic similarities and possible structural relationships with the Katangan rocks of the Zambian copper belt and the copper-bearing Tsumis Formation of South West Africa, and also form the Haima and Shinamba Hills to the north-east (Hutchins *et al.*, 1976).

Faulted outliers of Karroo supergroup strata (Late Palaezoic to Mesozoic) occur in the region south of Lake Ngami and geophysical evidence suggests that they occur extensively below the Central and lower Delta areas. This formation consists of sandstones, shale and coal seams of Ecca Age underlying Stormberg Basalts.

Post-Karroo volcanic activity has given rise to the Kimberlite pipes of the recently discovered Orapa and related diamond fields south-west of the Makgadikgadi salt Pans. These penetrate the Karroo Basalt and provide direct geological evidence of Post-Karroo volcanism close to the axis of present day seismicity (Reeves, 1972). This contradicts the theory of diamonds being water transported to the east of the present Karroo outcrops divide, but the first diamonds were discovered from this locality (Civil Engineering Equipment Digest, 1972).

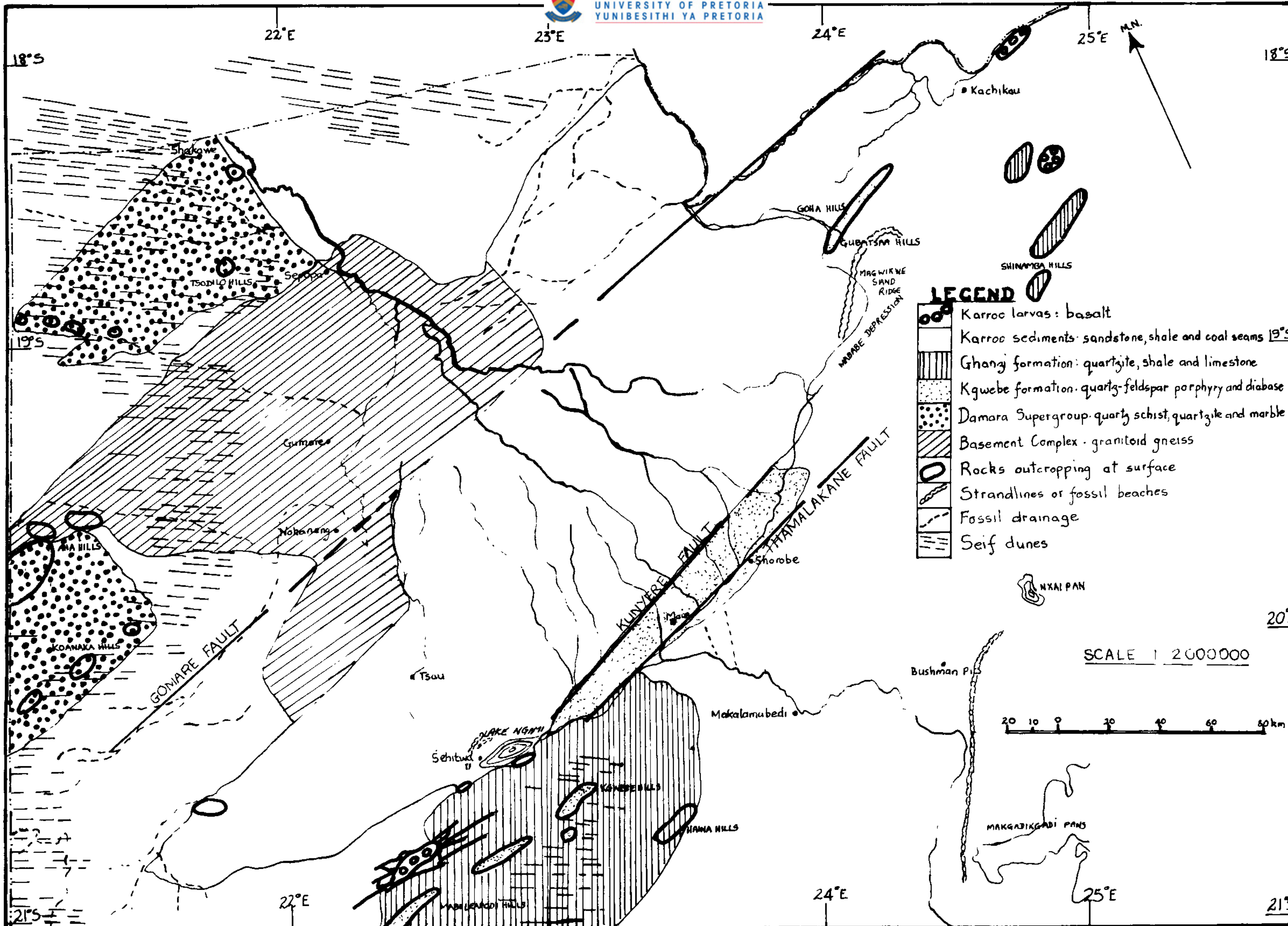

FIGURE 2 – Solid geology and geomorphology of Ngamiland and part of Northern Botswana showing surface features and interpreted bedrock geology after Hutchins, Hutton, Hutton, Jones and Loenhert (1976).

A great inland basin existed at this stage which was much larger than the present drainage system (Van Straaten, 1963; Grove, 1969). King (1963) has postulated that the Miocene epeirogenic uplift of this internal drainage basin by approximately 100 m may be responsible for shallowing and consequent lessening by evaporation of the free water surface area of the Okavango and Makgadikgadi basins.

Overlying the bedrock, except where exposed, are vast expanses of wind and water-borne sand in various thicknesses averaging about 50 m to 150 m, with a maximum of 300 m. These are medium to fine-grained sands and silts of Cenozoic Age, collectively known as the Kalahari Beds. Concretionary lenses of calcrete and silcrete are associated with these Kalahari Beds. (Hutchins *et. al.* 1976).No surface outcrops occur in the study area, the only surface structure being Kalahari Beds with associated concretionary lenses of calcrete mainly in the Xho Flats Area.

GEOMORPHOLOGY

The Kalahari Beds are the result of aeolian sands probably derived from broken down Stormberg Sandstones, and water-borne deposition (Wellington, 1955; Van Straaten, 1963; King, 1963). Poldervaart (1957) has produced petrographical evidence that the older Kalahari surface sands were derived from the northwest and blown in easterly to south-easterly directions. Numerous seif dunes exist to the northeast of the Delta's "sleeve" and to the west of the Delta (Grove 1969). These comprise rolling longitudinal sand ridges about 1,75 km wide trending approximately 102^{o}, except south of the Aha Hills where the trend veers to 80^{o}, but all formed during Tertiary times. Grove *(op. cit.)* states that the dunes were formed under prevailing easterly winds in a drier climate than the present. Satellite imagery provides evidence that tributaries of the larger fossil drainage to the west of the Delta have cut through these dunes. The dunes have also been eroded by former flood-waters on the western Delta margins providing evidence of increased flooding during former years in this area. The delimitation of seif dunes between the Delta's "sleeve" and the Kwando/ Linyanti system are in the extreme north only. Evidence of old drainage channels (Hutchins *et al., op. cit.*) and vegetation patterns show that this area between the Delta's "sleeve" and the Linyanti formed an extension of the Delta to the north in former days.

The strandlines located mainly on the western shores of the now fossil lakes, viz. Makgadikgadi, Mababe and Lake Ngami, are clear evidence of previous extensive bodies of water where prevailing winds and consequent wave action have given rise to these landforms (Grove, 1969). The sands are dominantly white or grey to beige in the Delta, differing markedly from the red aeolian sands of parts of the central and southern Kalahari and show the relatively recent importance of water-borne deposition.

Study of satellite imagery of Ngamiland provides a basis for establishing a sequence of geomorphological events (Hutchins, *et. al.* 1976). The longitudinal seif dunes were formed during the Tertiary Period in a desert regime with winds from the east. The state of the Okavango River flow during this period is not known. Northeast trending faulting, with downthrow on the northwest side, interrupted dune formation and the ridges created by the faults held back and diverted waters to Lake Ngami, the Mababe Depression and possibly further afield to the Zambesi System. A wetter climate is indicated at this time cutting through parts of these dunes and giving rise to a more extensive Delta and lake system. A drier climate followed giving rise to fossil drainage to the west and south and the strandlines marking the former extent of shrunken lakes. Dessication of the Delta may have been additionally aggrevated by infiltration of waters within the Delta along the lines of neotectonic activity. The topography is extremely level with gradients in the order of between 1 in 4 000 and 1 in 5 000.

SEISMICITY AND FAULTING

The tectonically active nature of Ngamiland was only recently realised from the high incidence of earthquakes (Gane and Oliver, 1953; McConnell, 1959). Jones (1962) conducting photogeological investigations in the region, led to the recognition of tectonic control lines affecting the superficial formations and revealing the structural conditions responsible for the Delta. Green (1966) first plotted the northeasterly trending impounding faults at the distal end of the Delta on a geological map. These distal faults have given rise firstly to the Delta's existence and secondly probably to impeded flow, with the more proximal Gomare fault possibly initiating the impending of flow down the Theoghe River.

The Okavango Delta and Ngamiland lie within an area of continuing earthquake activity (Reeves, 1972). From 1950 to August 1965 a total of 44 seismic events occurred in Botswana, the highest on the Richter Scale being 6,7. The exact number occurring in the vicinity of the Delta are unknown but probably most did. From September 1965 to August 1974, 38 events were recorded with epicentres in the Delta or in the vicinity of Ngamiland. The epicentral plot is to within an accuracy of 50 km radius, and Table 1 gives the magnitude distribution.

Table 1. Magnitude distribution of 38 seismic events in the vicinity of the Okavango Delta, Ngamiland, Botswana during the period September 1965 to August 1974.

RANGE ON RICHTER SCALE	EVENTS	PERCENTAGE
5,0 – 5,9	1	2,6
4,0 – 4,9	4	10,6
3,0 – 3,9	26	68,4
Less than 3,0	7	18,4

A swarm of seismic events during 1952 (27 events ranging from 4,3 to 6,7 on the Richter Scale) has been postulated to have caused a major change in drainage pattern in the Delta (Pike, 1970) or more specifically in the northern central Delta and also increased the flow of the Boro River (Scholtz, Koczynski and Hutchins, 1975). Several of the later events are plotted as occurring on the northeastern and southwestern tip of Chief's Island and in the region of the Gomoti and Mokhokelo River headwaters. The majority of epicentral plots, however, occur in the vicinity of the Mababe Depression.

A micro-earthquake investigation during 1974 (Scholtz, *et al.*, *op. cit.*) revealed the most seismically active region to be the Maun-Toteng area, and this is associated with the Thamalakane and Kunyere faults. The Mababe Depression area yielded considerable activity whilst the central and upper Delta region was virtually inactive during this above study.

There is thus strong seismic evidence for rifting in the Okavango Delta and the focal mechanism is similar to that of the largest Kariba event (Grupta, Rastogi and Narain, 1972). This in conjunction with the persistent northeast trends of seismicity and faulting suggest that the Delta's activity is the southern extension of the Luangwa Valley – Kariba Gorge zone of seismicity and may mark an incipient arm of the East African Rift System (Scholtz *et al.*, 1975).

SOILS

Previous soil classification systems in Botswana were described by Van Straaten (1959); Van Straaten and De Beer (1959); Bawden and Stobbs (1963); d'Hoore (1964); Blair-Rains and McKay (1968); Mitchell (1968) and Siderius (1972). Tinley (1966) described soils of the Moremi Wildlife Reserve. The present description largely follows Siderius (*op. cit*) and partly Tinley (*op. cit.*).

The soils of Ngamiland and the Okavango Delta are predominantly sandy soils of the Kalahari basin. On the low ridges north of Maun and east of the Thamalakane fault pale brown sand capped with silcrete predominates. South of Maun the sand is fine to medium-grained and very white, whilst at Maun itself it is overlain by a metre of grey sand. The Delta islands, where not salt encrusted with evaporites, are formed of white sand. The Ngami lakebed deposits are dark grey, infertile silts with a low phosphorus content. (Hutchins *et. al.*,1976).

Siderius (*op. cit.*) recognises five soil complexes for northern and eastern Botswana, viz. the Limpopo Complex, the Makgadikgadi Complex, the Kalahari Complex, the Chobe Complex and the Okavango Complex, in total divided into 27 series. His Okavango Complex comprises five series which are present over the Delta and all are represented in the study area.

Molapo Series

Characterised by a Melanic A horizon overlying a gley horizon. These are deep poorly drained soils of a sandy clay loam to sandy clay texture. The gley horizon develops as a result of periodic saturation and varying groundwater levels. Seasonal flooding is necessary for the development of this profile. The parent material is classified as alluvium. The pH is neutral but increases slightly with depth to mild alkalinity. The colour varies from black at the surface through very dark grey, with brown encountered at about 1,5 m.

These soils support a mixed grass and sedge vegetation under normal seasonal inundation (Floodplain vegetation types). If inundation no longer occurs they evolve to carrying *Acacia nigrescens – Croton megalobotrys* marginal vegetation types, *Acacia tortilis* dryland vegetation type or *Colophospermum mopane* Woodland if clay predominates, or the other marginal or dryland vegetation types if sand predominates.

The local population utilises these soils for "melapo farming" but yields are generally low.

Boteti Series

Characterised by an Orthic A overlying a Regic sand (85 per cent or more sand). They are deep, very dark greyish brown fine sands excessively drained. Structural development is weak, horizonation is ill defined and natural fertility low. Carbonates are common in the deep subsoil Clay is extremely low (about 2 per cent) and silt about 11 per cent.

The parent material has been influenced by both aeolian and alluvial action. The presence of calcretes in the deep subsoil is associated with former lacustrine deposits, and the soil redeposited Kalahari sandstone over the calcrete formation. These soils support *Terminalia sericea – Combretum collinum* Communities or *Acacia erioloba* Communities. They are of no value for cultivation and when devegetated are subject to severe wind erosion.

Shorobe Series

Characterised by an Orthic A horizon overlying a dark brown calcareous B horizon. The texture is loamy fine sand with hard calcrete encountered at between 1,5 and 2,0 m depth. This soil is somewhat excessively drained, structural development is weak and horizonation is gradual.

The surface colour is dark greyish brown, and the clay percentage about 10. At the surface pH is neutral, but goes strongly alkaline with increasing depth. Depressions in this soil surface are common due to the solution of calcrete in the subsoil, and rain pans commonly form on this series. The soils support *Colophospermum mopane* Communities or *Acacia tortilis* Communities. The soil is low in fertility and arable cultivation unsuccessful.

Motopi Series

Characterised by an Orthic A horizon overlying a dark brown B horizon of a loamy fine sand texture. Structural development is weak and horizonation ill defined. These soils are somewhat excessively drained in the top 1,2 m, but their drainage may be restricted in the deep subsoil due to compaction and cementation of carbonates. The colour varies from very dark greyish brown up to about 1,2 m after which it lightens to a dark greyish brown. The clay percentage is very low (3 per cent) but may rise to 7 per cent in the deep subsoils. The silt fraction varies between 20 and 30 per cent with fine sand being dominant.

These soils occur commonly on old river terraces with a strong alluvial component and mainly support Closed Riverine Woodland and some of the marginal riverine woodland vegetation types. They are of low to medium fertility and have a limited capacity for arable farming.

Mababe Series

Characterised by being non to slightly cracking very dark grey clay soils, deep, poorly drained, highly alkaline and saline. The colour becomes paler with depth. The texture is clay to sandy clay; with the clay content ranging between 40 and 60 per cent. Silt fraction is about 8 per cent and the remainder mainly fine sand. Calcium carbonate, calcium and magnesium sulphate and sodium chloride are the common salts.

These soils support *Sporobolus spicatus* Island Grassland Communities where halomorphic and just above normal present floodlevels, but where removed from annual surface flooding support *Colophospermum mopane* Woodlands and Pyrophytic Scrub Savanna. Small or large pans are commonly associated with this series. These soils are of no value for arable cultivation.

CLIMATE

The Okavango Delta and northern Botswana is subject to the same general circulation and interaction of air masses from the north and southeast being responsible for the prevailing climate. During the winter months Superior air dominates the climate of this area. It is warm and exceedingly dry, and gives rise to warm, dry, sunny days with temperatures rising by about 20°C, followed by cold, clear nights during which terrestrial radiation occurs, and temperatures fall rapidly, occassionally to below freezing point. This weather is prevalent from April to September. During the summer months of October to March, Equatorial air from the north dominates the weather pattern. It is generally warm and moist, and gives rise to conditions conducive to the development of thunderstorms.

Due to the late establishment of a full meteorological station in the Central Delta only limited recordings of short duration were obtained. Climatic data for the study area is thus accepted as some intermediate between conditions prevailing at Shakawe (18°22'S and 21°51'E) and Maun (19°59'S and 23°25'E) where established weather recording stations exist. The study area and environs occur in the African Climatic Region of Köppen's classification referred to as Dry (B) Steppe (S) with an average annual temperature above 18°C (h), and with the dry season occurring during the low-sun period (w), abbreviated to BShw.

Rainfall

Table 2 presents the comparative precipitation data for the two stations during the period 1953/54 to 1973/74.

The highest total annual rainfall recorded for Maun (January to December) is 923,4 mm in 1974 and the lowest 221,5 mm in 1927 (over a record period of 51 years). However, a rainy season should be recorded on an annual basis from the beginning of October of one year to the end of September of the following year as this realistically effects the local flood regime. This is based on the fact that the rains from October of one year to April of the next year directly effect the magnitude pattern of the next flood; whereas heavy rains from October to December of any year have no effect on that year's previous flood pattern already experienced. On this basis the 1973/74 annual rainfall amounted to 1195 mm being the highest on record and the 1932/33 annual rainfall to 192,3 mm, being the lowest on record. The mean annual

Tabel 2 – Comparative precipitation data (in mm) for Maun and Shakawe on the peripheries of the Okavango Delta, Botswana for the Period October 1953 to September 1974 (from Gaborone Meteorological Office).

MONTH	MEAN		AVERAGE DAYS OF RAIN		MAXIMUM RECORDED		YEAR		MINIMUM RECORDED		YEAR		RANGE	
	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe
January	129,8	134,8	13	16	342,0	352,4	1974	1974	30,5	53,7	1960	1969	311,5	289,7
February	117,6	137,0	11	11	365,0	292,1	1974	1956	12,4	12,4	1971	1964	352,6	279,7
March	71,9	79,4	8	10	292,9	185,7	1961	1972	5,9	25,0	1965	1962	287,0	160,7
April	33,8	35,7	5	4	120,4	134,3	1967	1974	0,0	0,0	1964	–	120,4	134,3
May	4,0	2,6	1	1	33,8	17,8	1968	1960	0,0	0,0	–	–	33,8	17,8
June	1,1	0,7	0	0	17,1	11,3	1966	1955	0,0	0,0	–	–	17,1	11,3
July	0,3	0,1	0	0	5,8	2,0	1961	1961	0,0	0,0	–	–	5,8	2,0
August	0,6	0,2	0	0	9,6	2,3	1969	1962	0,0	0,0	–	–	9,6	2,3
September	4,0	5,7	1	1	29,2	35,9	1966	1960	0,0	0,0	–	–	29,2	35,9
October	15,5	13,5	3	3	99,7	66,5	1973	1954	0,0	0,0	–	–	99,7	66,5
November	51,6	65,8	9	9	111,9	291,5	1967	1954	2,0	0,0	1972	1972	109,9	291,5
December	89,4	98,8	9	11	264,0	229,0	1973	1954	13,0	28,2	1969	1961	251,0	200,8

rainfall for Maun from 1922/23 extended up until the 1973/74 season is 509,6 mm. The mean annual rainfall thus appears to be on the increase under present conditions since the figure for 1931 to 1950 is 457 mm (Tinley, 1966), for 1922/23 to 1968/69 is 491,1 mm (Pike, 1971) and for 1922/23 to 1973/74 is 509,6 mm.

The Shakawe station was established during late 1953 and since that period the highest mean annual rainfall recorded was 1134,9 mm during 1954/55 and the lowest 275,2 mm during 1969/70. Pike (*op. cit.*) records the mean annual rainfall as 520,3 mm (from 1953/54 to 1968/69), whilst from the period 1953/54 to 1973/74 it is 557,4 thus also showing an increasing tendency at present.

Temperature

Table 3 presents comparative temperature data for the two stations during the period 1964 to 1974.

The highest daily maximum recorded is 43,3°C (November 1930), and the lowest daily minimum recorded is – 4,4°C (August 1930) for Maun (Tinley, *op. cit.*).

During more recent times (1964 to 1974) the highest daily maximum recorded for Maun is 41,2°C (November 1966), and the lowest daily minimum is 0,1°C (June 1972). During the corresponding period Shakawe's highest daily maximum recorded is 39,6°C (November 1972) and the lowest daily minimum is 0,0°C (August 1972).

Relative humidity

Table 4 presents comparative relative humidity data for the two stations, Maun and Shakawe during the period 1965 to 1973. Relative humidity increases during the summer months when more moisture is available. However the annual surface flooding from Angolan rainfall usually arriving in early winter provides for higher winter relative humidity than would otherwise exist.

Evaporation

Table 4 also presents comparative evaporation data for the two stations, Maun and Shakawe during the period 1963 to 1968 taken from standard U.S. Weather Bureau Class A pans.

TABLE 3 – Comparative maximum and minimum temperature (°C) on a monthly basis for Maun and Shakawe on the peripheries of the Okavango Delta, Botswana for the Period 1964 to 1974. (from Gaborone Meteorological Office).

MONTH	MEAN MAXIMUM		MEAN MINIMUM		RANGE °C		HIGHEST MONTHLY MAXIMUM		YEAR		LOWEST MONTHLY MINIMUM		YEAR		LOWEST MONTHLY MAXIMUM		YEAR		HIGHEST MONTHLY MINIMUM		YEAR	
	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe
January	36,3	35,2	17,6	16,5	18,7	18,7	40,0	39,2	1973	1970	15,7	10,0	1972	1969	28,4	27,7	1974	1974	19,1	18,6	1966	1974
February	34,7	34,1	15,7	16,8	19,0	17,3	37,6	37,5	1965	1964	11,5	11,5	1972	1972	28,3	28,5	1974	1974	19,1	19,3	1974	1974
March	34,7	33,6	14,4	14,8	20,3	18,8	39,5	36,4	1970	1970	11,1	10,3	1970	1967	28,3	29,2	1974	1974	16,7	17,3	1974	1974
April	33,3	32,6	10,7	11,9	22,6	20,7	37,1	36,0	1964	1964	7,2	8,5	1972	1965	27,2	27,5	1974	1974	15,2	16,1	1974	1974
May	31,1	30,9	5,2	4,9	25,9	26,0	32,4	32,6	1970	1973	0,3	1,0	1972	1973	26,5	25,6	1974	1974	9,4	9,8	1968	1974
June	28,5	29,0	2,6	3,1	25,9	25,9	30,6	30,6	1972	1968	0,1	0,7	1972	1972	25,5	24,8	1974	1974	6,6	7,5	1974	1968
July	28.6	29,2	2,4	2,6	26,2	26,6	31,3	31,9	1968	1973	0,6	0,5	1967	1973	24,9	24,7	1974	1974	6,1	5,8	1974	1974
August	32,3	32,7	5,3	4,0	27,0	28,7	34,5	34,7	1968	1968	1,0	0,0	1970	1972	28,2	29,2	1972	1974	12,0	9,6	1968	1974
September	35.9	36,1	9,1	7,4	26,8	28,7	37,5	38,0	1972	1973	5,0	2,0	1969	1973	30,1	31,1	1974	1974	13,3	11,1	1974	1974
October	38,2	37,9	13,8	11,0	24,4	26,9	39,9	39,5	1966	1968	11,0	2,0	1965	1973	34,5	33,6	1974	1974	18,2	16,9	1974	1974
November	38,2	37,2	15,5	14,5	22,7	22,7	41,2	39,6	1966	1972	11,1	10,0	1972	1972	31,5	31,7	1974	1974	19,5	18,5	1968	1974
December	36,6	35,8	15,3	15,4	21,3	20,4	39,5	39,1	1969	1972	11,2	11,4	1971	1970	30,7	31,2	1974	1974	18,7	18,4	1974	1974

Table 4 – Comparative per cent relative humidity (1965 – 1973) and evaporation (mm) (1963 – 1968) data for Maun and Shakawe on the peripheries of the Okavango Delta, Botswana, (from Gaborone Meteorological Office).

MONTH	MEAN RELATIVE HUMIDITY				EVAPORATION						
	08h00		14h00		Evaporation pan Class A		Pan coefficients factor	Evaporation open water		Evaporation after correction factor 0,7 for advection effect	
	Maun	Shakawe	Maun	Shakawe	Maun	Shakawe		Maun	Shakawe	Maun	Shakawe
January	74	80	45	51	237	236	0,80	190	189	133	132
February	75	79	44	49	221	221	0,84	186	186	130	130
March	71	77	38	47	235	221	0,74	174	164	122	115
April	68	71	35	39	225	206	0,64	144	132	101	92
May	60	68	25	29	214	188	0,54	113	100	79	70
June	62	69	27	28	186	153	0,48	89	73	62	51
July	59	67	23	25	207	170	0,49	101	83	71	58
August	51	57	19	19	242	198	0,57	138	113	97	79
September	37	50	17	21	296	256	0,59	174	151	122	106
October	42	48	21	25	359	280	0,60	215	213	151	149
November	53	62	30	36	276	252	0,76	210	204	147	143
December	66	73	40	45	260	255	0,81	211	204	148	143

These figures are reduced by the given average class A evaporation pan coefficients for Maun to give mean evaporation from an open water surface. These latter figures are further reduced by a factor of 0,7 to compensate for possible advection effects of the "station climate" (UNDP/FAO, 1972). On this basis mean annual evaporation still exceeds mean annual rainfall sixfold. Evaporation is high throughout the year but shows peaks during September, October and November. Due to the vast expanses of open surface water in good flood years evaporation losses which maintain the diversity of vegetation types ecologically, remain a direct water loss to engineers and agronomists.

Mist

During approximately 30 per cent of the early mornings of winter months, a light low mist is seen to rise off the open water bodies in the Delta. This only lasts for one to two hours after sunrise and dissipates rapidly.

Dew

Light dew was recorded within the study area on a few occasions after still, cloudless nights mainly during the months of April, May and June.

Frost

On average frost is recorded for 5 days during the winter months from Maun's meteorological station. Within the study area it was recorded close to the proximity of water on the moist soils of the floodplain systems. As Tinley (1966) has noted, no ground (white) frost was found away from the surface water verges, but then temperatures were never below freezing point. (Table 3).

Wind

From the Maun meteorological station data and personal observation in the study area, it was clear that easterly, northeasterly and southeasterly winds predominate. The early mornings before sunrise are characterised by a light to medium easterly wind. Westerly winds are of low occurrence compared to easterly winds, but northwesterly winds occur during the summer months and bring some rain.

Small whirlwinds known as dust devils are common during midday periods, and cause some erosion especially over relatively freshly-burnt areas.

Cloud Cover

Personal observations for the study area and Delta in general show that during the winter months slight to total absence of cloud cover occurs. A small build-up in cloud cover usually commences during September or October with a peak in cloud cover percentage occurring during the afternoons of December, January, February and March.

Summary of Climate

Rainfall predominates during the summer months. Precipitation may commence during September but more usually during October or November. The bulk of rain falls during November, December, January and February with January and February showing the highest mean monthly recordings. The rainy season usually ends during April but rare light showers may occur during the period of May to September.

Daily temperatures are high throughout the year, reaching peak temperatures during October or November. If precipitation is late in commencing these peak temperatures extend into December or January. Lowest night temperatures are recorded during May, June, July or August when temperatures may drop to freezing point.

Relative humidity increases during the summer months as does cloud cover. Evaporation is high throughout the year but shows peaks during early summer months. Mist, dew and frost are rare, but occasionally are found in the proximity of open surface water mainly in the winter months.

Winds are predominantly easterly throughout the year and summer droughts are common.

VEGETATION

Early contributors to the vegetation types of Ngamiland include Passarge (1904), Lugard (1909), Seiner (1912)and Pole Evans (1948). Miller (1952) classifies the northern portion of Botswana, bounded in the south by the Mopane limit *(Colophospermum mopane)* as one vegetation region. This is divided into five sub-types. Four of these are present in the study area namely; Mopane country, Mogonono country *(Terminalia sericea),* Delta country and *Acacia* country; with Miller's Mokusi country *(Baikiaea plurijuga)* absent.

The latest vegetation map of Botswana (Weare and Yalala 1971) shows the Okavango Delta to contain three of their nine physiognomic types; Tree Savanna, Aquatic Grassland and Riparian Forest. Under these vegetation types the plant communities identified are Ngamiland Tree Savanna, Swamp Grassland and Okavango Fringe Forest. They have drawn heavily on work done by De Beer (1962) for producing their provisional vegetation map.

Tinley (1966) defined four main vegetation types for the Moremi Wildlife Reserve, with two of these subdivided into eight plant communities. All Tinley's vegetation types and plant communities occur in the study area. This classification is based on soil types.

In this study the vegetation of Chief's Island and the adjacent floodplain systems is divided into five main vegetation types based on water availability, and subdivided into 20 plant communities based on physiognomic species composition, physical water parameters and/or soil types. The dryland classification types follows closely that of Tinley (op. cit.).
Figure 3 presents a vegetation map of the study area showing major plant communities.

A. Aquatic vegetation types:

1. Filter Communities
2. Middle Channel Communities
3. Outlet Channel Communities
4. Madiba Communities
5. Flats Communities
6. Shallow Backwater Communities
7. Sump Communities

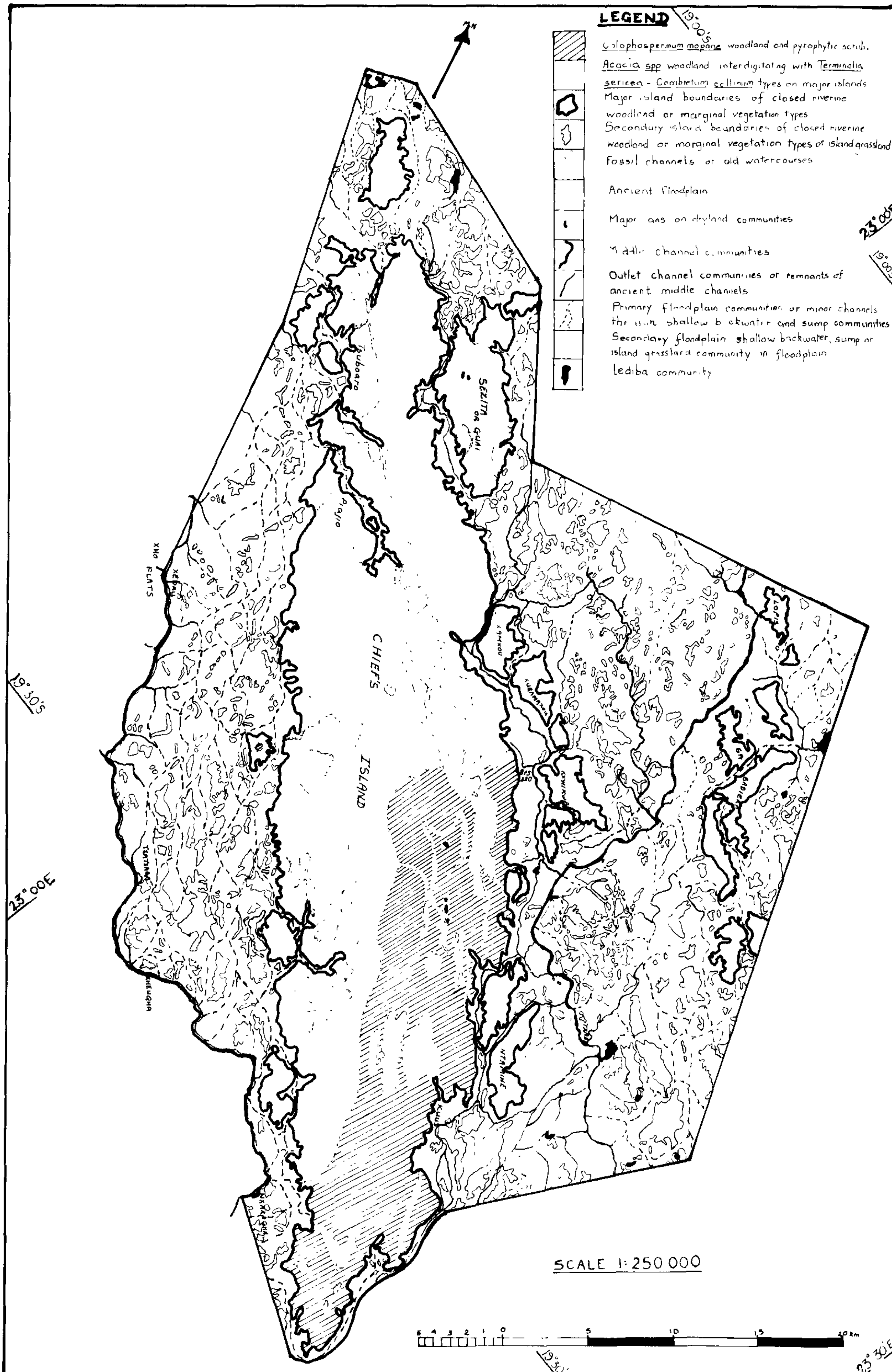

FIGURE 3 – Vegetation map of the study area showing major plant communities, Okavango Delta, Ngamiland, Botswana.

B. Floodplain vegetation types:

1. Primary Floodplain Communities
2. Secondary Floodplain Communities
3. *Sporobolus spicatus* Island Grassland Communities

C. Riverine vegetation types:

1. Closed Riverine Woodland
2. *Phoenix reclinata – Syzygium* spp Termitaria

D. Marginal vegetation types:

1. *Acacia nigrescens – Croton megalobotrys* Woodland and Savanna Woodland
2. *Hyphaene ventricosa – Croton megalobotrys* Palm Woodland and Palm Savanna Woodland
3. *Combretum imberbe – Croton megalobotrys* Woodland and Savanna Woodland

E. Dryland vegetation types:

1. *Acacia tortilis* Savanna Woodland
2. *Acacia erioloba* Woodland and Savanna Woodland
3. *Terminalia sericea – Combretum collinum* Savanna Woodland and Scrub Savanna
4. *Colophospermum mopane* Woodland and Pyrophytic Scrub Savanna
5. *Grewia* spp – *Croton megalobotrys* Scrub Savanna.

Okavango Delta Description

The Okavango River enters northwestern Botswana almost as a single channel but then immediately spreads out to form the "sleeve" of the Delta. This "sleeve" tends northwest to southeast for approximately 100 km and is 10 to 12 km wide, comprising upper channels, small islands and inundated floodplains. Below this "sleeve" lies the true Delta with its expanded distributaries, floodplain systems and varied-size islands.

The northern sectors of the Delta comprise upper channels with vast expanses of inundated swamp studded with small to medium-sized islands. The currents in thse channels are fast but slow in the madiba and heavily vegetated swamp areas.

Proceeding to the mid-Delta, channel size and flow is decreased, more backwaters, flats and areas of generally slower-flowing water are encountered. Distributaries and madiba are more numerous and islands increase in both size and number. Here floodplains subject to seasonal flooding are encountered.

In the lower-Delta dryland masses and islands increase whilst channels become narrower, blocked or dry. Seasonal water discharge and flooding pattern continuously change in this area.

Proceeding from the upper to the lower-Delta areas there is a marked increase in vegetation species. The collection of all the Delta's distributries discharge is at right angles to their main flow, along a northeast to southwest tending drainage line as a result of faulting in the area (Reeves 1972). About 45 km ENE of Maun in this latter drainage line a critical height exists which divides flow. The main discharge proceeds down the Boteti River towards "Lake Xau". "Lake Ngami" receives a lesser discharge via the Nghabe River.

Methods

Vegetation types are based on visual physiognomic classification of the more important characterising species, and for some communities on sampling methods as discussed in the following chapter on vegetation status and trends. Some physical water parameters i.e. depth and velocity were obtained by measurement. Light penetration, turbidity, depth, velocity and some chemical composition of waters was obtained from work by Reavell, Lee and White (1973), Thompson (1975), Smith (**pers. comm.**) and *Wilson (**pers. comm.**) Soil types are based on observation and tied in with comparitive types from work done by Tinley (1966) and Siderius (1972).

Quantitative vegetation analysis work was conducted in floodplain, riverine, marginal and dryland vegetation types (See Chapter on methods and tables for description of status and trends in the vegetation types). This also served to substantiate some physiognomic vegetation communities described. The description of vegetation types and their present status and possible future trends, are described and predicted seperately since this was required in the terms of reference by the Sponsors.

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Definition of terms

Terminology largely follows Tinley (1966) for vegetation and work done in the Delta by Wilson (1974) for hydrology.

Upper channels – Largest channels from 15 to 130 m wide and usually 5 to 7 m deep. Perennial flowing watercourses with average velocity of 0,6 m/s and discharge exceeding 25 m^3/s. Relatively stable to vegetation changes and usually not subject to blockages. Riverbed formed of Kalahari sand with no submerged aquatic vegetation. Marginal vegetation prodominantly *Cyperus papyrus* with much lesser quantities of *Phragmites mauritianus* and *Miscanthidium junceum* eg. Nqogha River.

Middle channels – separated from upper channels which feed them either via 'filters', blockages or 'restricted take offs'. They vary considerably in width and flow rates from almost zero upwards. Perennial watercourses generally free of floating or emergent aquatic vegetation except at blockages. Seasonal rise and fall usually small (0,2 m). Middle channels are less stable than upper channels in preventing vegetation changes due to their lower water velocities, depth, width and variable discharge eg. M'borogha River.

Outlet channels – carry water away from perennially flooded areas and are most variable in width, depth, overall vegetation composition and flow rates in both time and space. Perennial to annual watercourses which feed the seasonal swamps during flood times. These outlet channels are most subject to change in discharge and vegetation composition are often characterised by *Ficus verruculosa* eg. Santantadibe River.

'Restricted take-off' – a minor channel leaving an upper or main channel to feed a middle or lesser channel, the nature of take-off being at right angles or an obtuse angle to the main channel when measured between the downstream and take-off axes. Such a take-off allows very little or no sudd or floating debris to enter the lesser channel, when compared with the quantity of such floating down the major channel, eg. Boro River headwaters from Nqogha River.

Filters – level area of slightly impeded drainage, covered by tall grasses and sedges. Vegetation sufficiently dense to prevent sudd or floating debris from passing through it. Filters feed overflow water from upper channels to middle channels or madiba. eg. between upper Boro and Nqogha Rivers.

Madiba (si. lediba) – Setswana term frequently and incorrectly called 'lagoons'. Body of open water probably formed from old oxbow lakes and relicts of ancient river channels. Madiba vary in size, shape and depth but most surface water is open, eg. Xadikwe lediba.

Flats – level areas of impeded drainage showing no proper channel. About 1 m or less deep. Minor channels are kept open by hippopotamus, crocodile and/or outboard engine propellors. Flats appear to undergo little change and are covered by emergent sedges, grasses and floating aquatic vegetation, eg. Xho flats.

Sumps – small to medium-sized inundated areas, surface water partially open, rest covered with short emergent sedges and surface floating aquatic vegetation. Occur as slightly depressed areas within shallow backwater communities comprising tall aquatic grasses and sedges.

Blockage – (a): Consolidated or permanent blockage. Closure of a channel via loss of flow, consolidation of vegetation and deposition of silt. Sudd or floating debris may often appear to be the initiating factor, eg. Old Nqogha blockage.

(b): Surface blockage. Temporary blockage on the surface comprising mainly *Cyperus papyrus* sudd and debris or *Rotala myriophylloides* with other sedges or other aquatic vegetation establishing itself on this base. Temporary blockages are continually added onto by addition of sudd and floating debris and may become permanent. Water flow continues below a surface blockage, eg. Nqogha blockage.

Primary floodplain – depressed floodplain which is the first floodplain type to receive floodwaters overflowing from outlet channels in the seasonal swamp areas. Surface water generally covered with emergent or floating aquatic vegetation. Known in Setswana as melapo.

Secondary floodplain – higher-lying floodplain of grassland elevated above primary floodplains by 1 m or less. Annual duration of flooding dependent on present flood regime. Dry throughout the year in poor flood seasons.

Island grassland – A short grassland dominated by *Sporobolus spicatus* and characterised by the presence of evaporites. Occurs adjacent to small or medium-sized islands or almost enclosed by a circular periphery of Closed Riverine Woodland. Depending on the Island grassland's locality in the Delta and the magnitude of the reigning flood, surface inundation may be absent or up to 0,4 m. A high water table exists below this community but this has dropped in areas where this community is evolving to a dryland vegetation type.

Parkland – island-like patches or clumps of trees in floodplain grassland and/or sedge. Appearance due to available high ground above flood levels, i.e. formed as a result of termitaria.

Thicket – very dense almost impenetrable tree and/or shrub cluster, climbing plants common, grass discontinuous or absent.

Woodland – usually two-layered (tree and grass/forb community). Stands of savanna trees with crowns almost adjacent to overlapping, with a grass and/or forb ground layer. Shrubs may be present. Trees must not be greater than one half of a crown diameter apart.

Savanna woodland – stands of trees spaced from about twice their crown diameters apart to crowns overlapping where aggregations occur, with a grass and/or forb ground layer. Shrubs may be present.

Shrub savanna and scrub – Woody plant cover from approximately 0,30 m to 3 m in height. Individual plants may be single or multiple stemmed, scattered or aggregated with a grass and forb groundlayer. The term scrub will be used for secondary, short, woody growth which occurs in relatively small patches. The term shrub savanna is preferred where the shrub and/or scrub cover, whether of a primary or secondary nature, occurs over a large expanse of country.

Aquatic vegetation types

These include rooted submerged, free-floating (submerged and surface) and rooted emergent water-dependent plants. Short periods may be experienced when surface water is absent from the more marginal areas supporting some plant communities listed under this vegetation type. This may occur after a poor rainy season before the annual flood arrives, viz. May – June or after a poor flood before the commencement of the rainy season, viz. October – November. The quantity of water available is dependent on local rainfall and floodwater from the Cuito/Cubango catchment in Angola.

The aquatic vegetation components establish themselves probably as a function of various physical and chemical water conditions, viz. flow rate, water depth and thus light penetration, duration of flooding, water turbidity and nutrient availability. These conditions can be altered by plant succession, increased or decreased precipitation and thus flood extent or alteration in base levels resulting from seismicity. All are natural factors and except for increased or decreased precipitation (on a long-term basis), are very much in action in the unstable Delta conditions. Debenham (1954) and Thompson (1975) agree that aquatic vegetation is the dominant factor determining pattern of water flow in the Okavango Delta. Standish-White (1972) however is of the opinion that seismicity is the dominant factor.

Filter Communities

Filter communities occur in the upper portions of the Delta on the northern margin of the study area. The vegetation comprises mainly *Miscanthidium junceum* and *Cyperus papyrus. Phragmites* spp. patches or *Cyperus papyrus* are encountered on old channels within the filter communities.

Filter communities are medium to shallowly flooded areas of large cross-section and short axial length. Water is able to pass through this vegetation community in quantity with little loss of head (Wilson 1974), but sudd or floating debris is prevented from passing through and is thus passed on downstream in the upper channel. Besides receiving inflow from 'restricted take-offs', the headwaters of middle channels are supplemented from water passing through filter communities viz. the upper Boro River (or the Jao River as it should properly be called). In certain instances consolidated blockages have resulted in the main headwater supply being cut off. Such systems viz. the M'borogha River headwater are now supplied almost exclusively through filter communities.

The importance of this community is in keeping its water supply to middle channel headwaters free of sudd and floating debris.

Middle Channel Communities

The M'borogha and Nambope Rivers of the eastern floodplains are representative types being the only true middle channels in the study area in accordance with the definition. (Fig. 4). Within the study area in general (as within the Delta) the width and depth of any channel decreases as one proceeds downstream; however any channels may be interrupted by flats or madiba.

FIGURE 4 – Middle Channel Community, M'borogha River, Okavango Delta, Botswana.

Depth varies between 1 and 3 m with the average tending towards the higher limit, and width usually from 2 to 6 m, again with the average tending towards the higher limit. Where the channels are deep, viz. the M'borogha River for the major part of its passage through the study area, the central channel is free of all aquatic vegetation. Gibbs Russell and Biegel (1974) report similar conditions for the Moanashira River near Dassakao lediba, and state that the uncolonised conditions are the result of combined action of water velocity and hippopotamus movement. In areas of insufficient water velocity or depth (viz. parts of outlet channels) continual passage of hippopotamus alone will maintain an uncolonised central zone. Middle channel bottoms are comprised of Kalahari sand with some deposition of silt especially where flow is reduced and submerged aquatic vegetation well established.

From the submerged middle channel margins, and extending in towards the uncolonised zone, common submerged aquatics comprise *Ottelia muricata, O. ulvifolia, Ceratophyllum demersum, Lagarosiphon ilicifolius* and *Rotala myriophylloides.* On the channel verges the marginal vegetation consists mainly of *Cyperus papyrus* and *Miscanthidium junceum. Cyperus papyrus* may dominate the marginal vegetation over large areas. However, it only forms a narrow band marginally from 1 to 4 m which then gives way to *Miscanthidium junceum* in shallow backwater areas. In the marginal zone of *Cyperus papyrus* and *Miscanthidium junceum* ferns such as *Thelypterus dentata, T. totta* and *T. quadrangularis* are common. *Cladium mariscus* is also fairly common in patches of this marginal zone but appears absent on the Boro River channels to the west of Chief's Island. Forbs collected along these channel margins include *Commelina scandens, Hibiscus* spp. and the twiners *Mikania cordata* and *Vigna lateola.* Extending onto the channel surface from the margin *Vossia cuspidata* (Hippo grass) establishes itself in suitable protected conditions of slower velocity. In middle channels these form V. cuspidata mats (small) as opposed to the V. cuspidata beds (large expanse); more characteristic of the middle and lower-Boro River verges, i.e. outlet channels. Also in these protected situations, after the inner curve of a river bend *Nymphaea lotus* or *N. caerulea* may be present; the former being more tolerant of higher water velocity.

Woody vegetation species of the Middle Channel Communities margins include the figs *Ficus verruculosa* and *F. pygmaea.* Both fig species are more common on the outlet channels, and especially so on the Gomoti River. *Ficus verruculosa* probably prefers slightly acidic conditions and is therefore encouraged in areas of reduced water velocity (Thompson 1974).

Outlet Channel Communities

These communities are represented by the Boro River from where it commences to form the western boundary (in the Xho flats vicinity) until it leaves the study area just below Nxaragha Ledibo; and also by the small section of the Santantadibe River headwaters after the M.borogha River bifurcation below Xaba Island on the eastern floodplains (Fig. 5).

All outlet channels within the study area are perennial watercourses. Sand banks and sand bars are often exposed during low water conditions, and the channels are generally narrower, shallower and have a decreased water velocity. *Cyperus papyrus* is only present in the outlet channel's headwaters or as isolated patches proceeding a short distance downstream. The southern limit of *Cyperus papyrus* is approximately in the vicinity of the new reserve's southern boundary with only isolated patches occurring outside of it. Outlet channel beds are also formed of Kalahari sand with parts covered by substantial amounts of silt.

Aquatic vegetation in these channels includes *Rotala myriophylloides, Ottelia ulvifolia, Lagarosiphon ilicifolius, L. major, Potamogeton thunbergii, Elodea densa, Najas pectinata, Ludwigia stolonifera* and the water lillies *Nymphaea lotus, N. caerulea* and *Nymphoides indica. Vossia cuspidata* and/or *Echinohloa colona* in either bed or mat form are common.

Emergent aquatic vegetation species occur in parts of these outlet channels and the marginal species increase in number compared to middle channels. Grasses such as *Miscanthidium junceum, Oryza longisteminata, Leersia hexandra, Panicum repens* and *Sacciolepus typhura* are common on the channel verges. Sedge species such as *Cyperus articulatus, Scirpus corymbosus, S. cubensis, S. inclinatus* and *Pycreus lanceus* occur on the verges or extend into the channel. Pure stands of *Phragmites australis* or *Typha latifolia* occur in more open sluggish channel conditions.

The twiners *Mikania cordata* and *Vigna luteola;* ferns *Thelypterus* spp. and aquatic woody vegetation species of *Ficus* are common excepting for *F. verruculosa* in the Boro system below Xho flats. Plant specimens collected from exposed sands bars and sand banks included *Alternanthera sessilis, Crassocephalum picridifolium, Pentodon pentander, Plectranthus* sp. cf *P. cylindraceus, Ludwigia octovalis, Limnophila indica* and *Hemigraphis prunelloides.*

FIGURE 5 – Outlet Channel Community, Boro River, Okavango Delta, Botswana.

Rotala myriophylloides becomes dominant in patches and has emergent stems and leaves floating on the water surface. These serve to trap floating sudd or debris, as well as to serve as a base for the establishment of some sedges viz. *Pycreus lanceus*. *Rotala myriophylloides* where dominant is a major surface blockage commencing agent.

Phragmites australis tends to prefer shallower water than *Typha latifolia* and *Phragmites australis* spreads more rapidly in static water than in flowing water, whereas the converse is true for *Typha latifolia* (Haslem 1971). The absence of *Ficus verruculosa* in the middle and lower Boro system is possibly due to the presence of limestone ($CaCo_3$) outcrops in the Xho Flats area raising the alkalinity of the water below this region. Where *Ficus verruculosa* is present it is also capable of trapping sudd or floating debris and is also a surface blockage forming agent.

The isolated stands of *Cyperus papyrus* occurring in these lower velocity outlet channels appear unhealthy and reduced in size. Thompson (1974) terms them as relict patches and initially I was in agreement. However, during the field study period small patches of *Cyperus papyrus* were found to be establishing themselves in this area of the Boro River. Increasing flow down this channel may well be improving conditions for healthy *Cyperus papyrus* establishment.

Madiba Communities

Madiba occur in two major localities within the study area, viz the extreme northern tip of the new reserve above Chief's Island and the headwaters of the Gomoti River offtake from the M'borogha River. These two localities show the presence of several madiba whilst isolated single lediba occur within other parts of the study area. (Fig. 6).

These open water bodies of varying shape and size appear to have originated from oxbow lakes as relicts of old upper and middle channel flow. The largest existing madiba are either on or just off upper and middle channel flow. Numerous smaller madiba are well off present upper and middle channel flow, but island and vegetation patterns in the vicinity of these madiba show up former major watercourses.

Water velocity across madiba is slow to almost stagnant. Madiba on the main channels exhibit deltaic fans at the entrance point of the channel. These fans occur as a result of

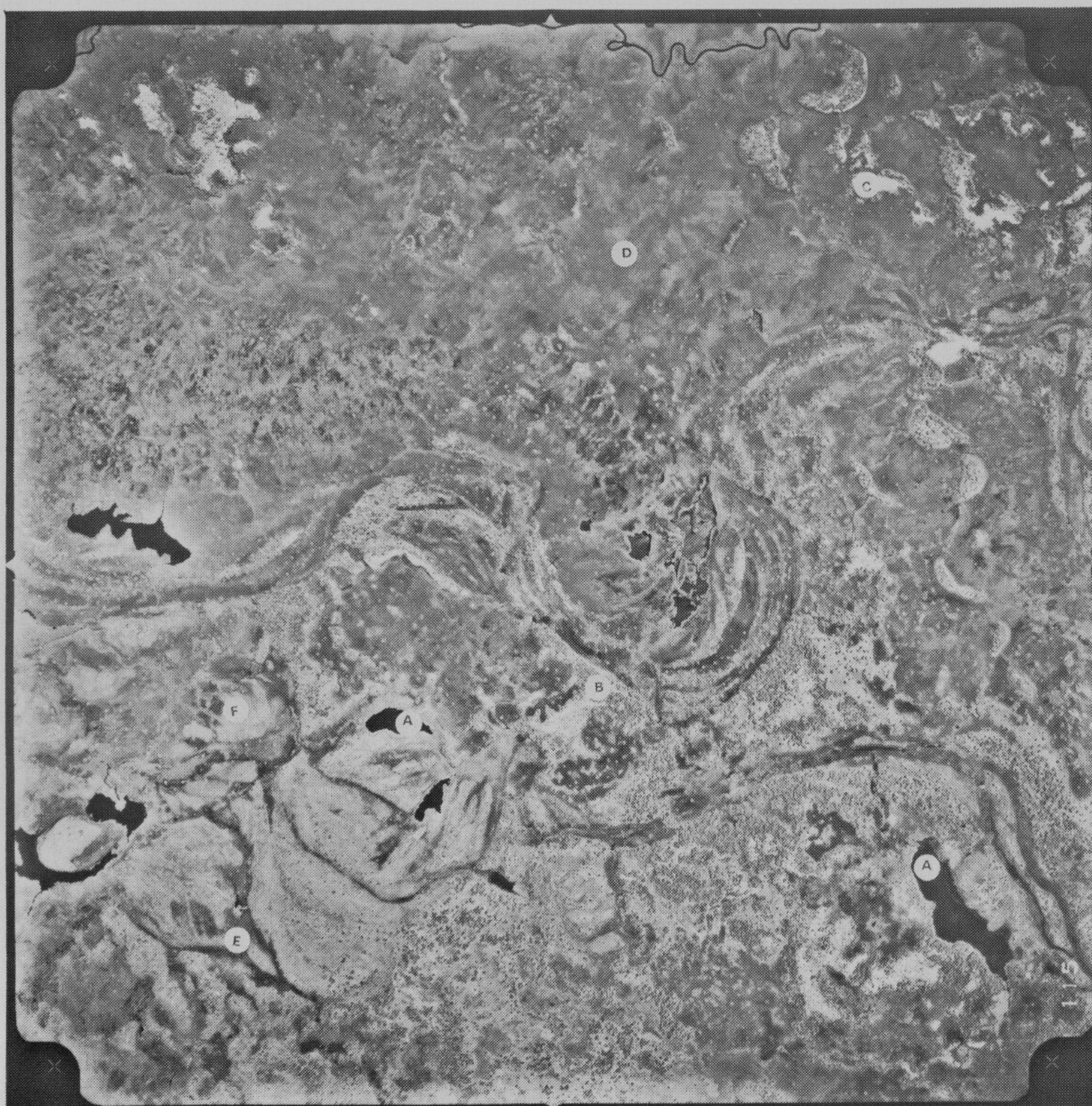

FIGURE 6 – Aerial photograph of section of the Okavango Delta to the north and northwest of Chief's Island, showing various plant communities and remnants of old Middle Channel Communities

A. Madiba Communities
B. Closed Riverine Woodland
C. *Sporobolus spicatus* Island Grassland Communities
D. Shallow Backwater Communities
E. Primary Floodplain Communities
F. Secondary Floodplain Communities

velocity decrease and subsequent deposition of the sand load. The deltaic fan so formed provides a suitable substrate for colonisation by some aquatic vegetation species, the natural evolution of which leads to a cut off of the major channel entering the lediba. Where velocity is very reduced through an on channel lediba, silt load may also be deposited.

Zonation of vegetation on madiba is present as a function of water depth and flow (Gibbs Russell and Biegel 1974). Submerged aquatic plants include *Lagarosiphon ilicifolius, Najas pectinata, Ottelia ulvifolia, O. muricata* and *Websteria confervoides.* Rooted floating-leaved plants include *Trapa natans, Brasenia schreberi, Nymphaea caerulea, N. lotus* and *Potamogeton thunbergii.* Rooted emergent plants include *Cyperus articulatus, Eleocharis acutangula, E. dulcis, Scirpus inclinatus* and *Typha latifolia.* Margins of *Cyperus papyrus* are common. Large thicket clusters of *Ficus verruculosa* occur centrally in some madiba or as smaller thicket clumps on the verges. *Azolla pinnata* and *Eichornia natuns,* free-floating aquatic plants were also collected.

These *Ficus verruculosa* thickets form nesting colonies for openbill stork *(Anastomus lamelligerus),* Marabou stork *(Leptoptilos crumeniferus),* wood stork *(Ibis ibis),* sacred ibis *(Threskiornis aethiopicus)* and darter *(Anhinga rufa).* Where plant succession leads to cut-off of a channel feeding a lediba from formation of a deltaic fan, alternative channels may be commenced by hippopotamus. The information of an alternative water route leads to the lediba now becoming off-channel and fed only by minor channels and/or overflow water. Islands in the vicinity of madiba often support a very luxuriant Closed Riverine Woodland on higher ground or *Sporobolus spicatus* Island Grassland Communities on lower ground due to high water conditions.

Flats Communities

None of the large expanses of flats occur wholly within the study area but Xho Flats adjoins the boundary and extends partly into the reserve. The Jao Flats and the Xho flats are the largest while the Xaralous Flats are fairly extensive.

Flats comprise extremely level areas usually flooded to 1 m and less in depth, dotted with occasional termitaria and small to medium-sized islands supporting woody vegetation growth. The passage of water flow through flats is greatly impeded and very little open water exists. Flats communities with their associated islands thus form a parkland type of vegetation.

Common rooted emergent aquatic vegetation comprises *Eleocharis dulcis, E. acutangula, Cyperus articulatus, C. Longus, Scirpus inclinatus, S. cubensis, Echinochloa colona, E. stagnina, Miscanthidium junceum, Polygonum limbatum, P. pulchrum* and *Phragmites australis.* Rooted submerged or with floating leaves and free-floating plants include *Ottelia ulvifolia, Nymphaea caerulea, Nymphoides indica, Ludwigia stolonifera, Potamogeton thunbergii, P. octandrus, Najas pectinata* and *Ultricularia* spp. In the upper and mid-Delta areas the termitaria and small islands support the woody species *Phoenix reclinata, Syzygium* spp., *Diospyros mesiliformis, Ficus* spp., *Capparis tomentosa, Euclea divinorum* and *Acacia nigrescens* spp. predominantly.

Minor water channels are kept open by hippopotamus, crocodile and outboard engine propellor via boat travel. These channels and flats areas are important since due to impeded water flow through them any man-made channel improvements are likely to take place here.

Shallow Backwater Communities

Shallow Backwater Communities occur in the study area on the M'borogha and Nambope floodplains, and along the reserve's western boundary above the Xho flats on the Boro River floodplain system. (Fig. 7). These communities occur either adjacent to the middle channels or displaced well off them but usually in close proximity to the perennial swamp area.

The Shallow Backwater Communities are dominated by tall grasses and sedges occurring on slightly elevated ground, but flooded for about six to nine months of the season. These communities are linked to Sump Communities covering the more depressed areas. Water flow is very slight to stagnant and the surface is covered by large amounts of deposited silt.

Miscanthidium junceum forms the major vegetation component. Other grasses such as *Oryza longisteminata, Leersia hexandra* and *Panicum repens* and the sedges *Cyperus articulatus C. longus, Scirpus inclinatus, S. corymbosus* and *S. uninodis* make up the bulk of this community. *Utricularia* spp are usually present. Numerous small termitarium islands occur usually with a single tree and shrub-thicket growing on it.

FIGURE 7 – Shallow Backwater Communities adjacent to a Middle Channel Community (M'borogha River), Okavango Delta, Botswana.

Sump Communities

Sump communities occur in the same localities given for the Shallow Backwater Communities. The former form a mosaic with the latter community, with the Sump Communities covering the more depressed areas. Sump Communities may also occur adjacent to Middle Channel Communities.

In appearance, Sump Communities are similar to madiba but are much smaller in expanse, much shallower and have far less open surface water. Vegetation comprises submerged, surface-floating, emergent and free-floating aquatic plants. Sump Communities are characterised by the absence of water velocity and no definite drainage, with soils comprising large quantities of silt. In exceptionally dry seasons Sump Communities may show no surface water but these sump communities dry out after the Shallow Backwater Communities.

Sump Communities adjacent to middle channels are characterised by sedges namely *Cyperus* spp., and *Scirpus* spp., whilst those occurring within Shallow Backwater Communities are characterised by other sedges, viz. *Eleocharis* spp. Rooted aquatic plants with floating leaves are common to both. The Sump Communities adjacent to middle channels are dominated by *Nymphaea caerulea* and *Nymphoides indica* closer to the open channel with some *Brasenia schreiberi* closer to the dryland verge. *Potamogeton thunbergii, P. pectinatus, Ottelia ulvifolia* and *Najas pectinata* are commonly submerged throughout this community. Emergent aquatic plants includes *Cyperus articulatus, C. tenuifloris, Scirpus inclinatus, S. corymbosus, Fimbrystylis hispidula* and *Fuirena* sp. *Utricularia* spp. and *Lemna purpusilla* were encountered in the almost stagnant waters and *Aeschynomene fluitens* was also collected from this area.

Sump Communities within Shallow Backwater Communities support *Brasenia schreiberi, Nymphoides indica, Najas pectinata, Potamogeton octandrus* and *Utricularia* spp. Common emergent aquatic plants from this locality are *Eleocharis dulcis, E. acutangula, E. atropurpureus, Cyperus denudatus* and *C. fastigratus.*

Floodplain vegetation types

Floodplain vegetation types are intermediary between wetland and dryland types, but is more closely associated to the wetland type, and can be divided into Primary and Secondary

Floodplains Communities and *Sporobolus spicatus* Island Grassland Communities. The Primary Floodplain communities (Setswana = melapo) are inundated virtually throughout the year, but do dry out in poor flood years for periods of up to seven months. This, however, only happens in an exceptionally dry season, viz. 1972/73. Primary Floodplain Communities in the lower-Delta dry out for longer periods (one to two months) than Primary Floodplain Communities in the mid-Delta. Secondary Floodplain Communities are characteristically open grasslands (classified as secondary from order in receiving surface inundation) which should be inundated for at least two or more months per annum to prevent species alteration and encroachment of woody plant species. The *Sporobolus spicatus* Island Grassland Communities should receive annual inundation for at least two months or more per annum but due to the locality and insufficient annual inundation of some of these areas they are evolving towards marginal or dryland types.

Primary Floodplain Communities

Primary Floodplain Communities are located west of Chief's Island on the Boro floodplain system mainly within the seasonal swamps in the study area. They also occur east of Chief's Island within the M'borogha and Nambope River systems where decreased quantities of floodwaters are progressively leading to drier prevailing conditions in central parts of this perennially classified swamp (Fig. 8).

Primary Floodplain Communities are inundated between 0,5 m and 2 m during the flooding periods. Water depths are up to 2 m in exceptional seasons at the deepest central part, but usually 1 m or less on average in the same locality. The topography here is that of a shallow trough with no marked banks and soils are of a sandy clay loam nature (Siderius 1972). The Primary Floodplain Community distribution follows the course of lowest levels in the seasonal floodplain, flooding subsequently onto Secondary Floodplain Communities and *Sporobolus spicatus* Island Grassland Communities and around the margins of islands. The vegetation is primarily aquatic grasses and sedges with very little open surface water.

The vegetation centrally comprises mainly the aquatic species *Cyperus articulatus, Scirpus inclinatus* and *Miscanthidium junceum*. *Cyperus longus, C. denudatus* and *Rhynchospora cyperoides* are fairly common. Within the lower lying central area the grasses *Sacciolepus typhura, Leersia hexandra, Panicum repens* and *Sorgastrum friesii* are common; whilst towards the shallower margins *Setaria sphacelata, Cymbopogon*

FIGURE 8 – Primary Floodplain Community to the west of Chief's Island, Okavango Delta, Botswana, with an adult male reedbuck centrally.

excavatus, Ischaemum afrum, Eulalia junciformis, Eragrostis patentissima and *Digitaria eriantha* are found. Common aquatic forbs include *Ottelia kunenensis, O. ulvifolia, Nymphoides indica, Alternanthera sessilis, Polygonum salici folium, Ludwigia octovalvis, Neptunia oleracea* and *Potamogeton thunbergii.*

Primary Floodplain Communities show a good silt deposition and are used lower down in the Delta as moisture cultivation fields when dry (see section on utilisation). In the mid-Delta areas and parts of the lower Delta they form very important habitat types for red lechwe *(Kobus leche leche)* when inundated and for many mammalian species when almost dry or completely dry. These shallow drainage floodplains are linked to middle and outlet channels and after drying up in poor flood seasons, are reflooded from both upstream and downstream junctions during the following season's flood arrival. When these two advancing flood water heads join up, a general slow flow then takes place towards the lower junction. This gives a strong indication of the small gradient and the slowness in flooding pattern. Primary Floodplain Communities are of great importance to this ecosystem and are unquestionably a source to engineers to prevent water loss from the outlet channels. The method of bunding (blocking off the entrance of floodwaters from outlet channels to primary floodplain systems by means of an earth wall) was used by Naus in the 1920's on the Santantadibe and Gomoti River headwaters. Bunding was also suggested by early authors for drying up parts of the western half of the Delta (Jeffares 1938, Brind 1954). During 1972/3 the Anglo American Corporation adopted bunding in conjunction with channel improvement for manipulations on the lower Boro River.

Natural factors such as seismicity and blockages cause water diversion, with more water becoming available to Primary Floodplain Communities, which in conjunction with large scale hippopotamus movement may result in the evolution of such a Primary Floodplain Community to a channel. Stigand (1923) quotes the haMbukushu natives telling him that during the reign of Letsholathebe I (c. 1840–1874) " . . . the Ng-gokha River (Nqogha) was formed. Prior to this it was just a 'molapo' or shallow swamp channel or channels and that the Thaoge River was the Okavango River's continuation. Hippopotamus in great numbers breaking through and trampling a big 'hippo path' created the initial Ng-gokha River and the inflowing water did the rest . . ."

Termitaria are of great importance in all floodplain and aquatic vegetation communities which dry up for part of any year. In Primary Floodplain Communities termitaria are established during dry times. These have become eroded by weather and animal usage often to the point where they form slightly elevated circular areas in these floodplains. They are usually free of woody vegetation, are covered with lawn-like *Cynodon dactylon* and *Sporobolus spicatus* and form vantage points or resting up areas for red lechwe.

Secondary Floodplain Communities

Secondary Floodplain Communities occur on the lower Boro River floodplains and in some suitable areas between the M'borogha and Nambope River floodplains within the study area (Fig. 9). Secondary Floodplain Communities are more common in the seasonal swamp areas and are more extensive lower down in the Delta out of the study area.

They comprise either uniform, short (0,2 m) or medium-height (1,0 m) open, grassland areas probably depending on flooding frequency and utilisation and occur on level sandy soils with small amounts of clay or silt present. Forbs and sedges are present in varying densities again possibly as a function of animal utilisation and flooding frequency and duration.

In poor flood seasons they receive no surface inundation whatsoever, whereas in extreme rain and flood seasons they may be inundated for periods of up to seven months. Under average conditions these areas are inundated for two to three months of the year (during the winter) from floodwaters. On average inundation depth varies from 0,01 m to 1 m. However, in poor flood seasons no surface inundation occurs. Termitaria with woody vegetation are present on some Secondary Floodplain Communities giving a parkland appearance.

Grasses dominate the plant species composition of Secondary Floodplain Communities and include *Eragrostis lappula* var. *divaricata, E. lappula* var. *lappula, E. lehmanniana, Brachiaria humidicola, Cynodon dactylon, Panicum repens, P. aphanoneurum, Setaria woodii, S. sphacolata, Imperata cylindrica* and *Trachypogon spicatus.* Sedges include *Cyperus longus, C. denudatus* var. *sphaerospermus* and *Bulbostylis burchelli.* Forbs include *Nicolasia costata, Sphaeranthus humilus, Indigofera charleriana, I. flavicans* and *Lightfootia denticulata.*

Towards the ecotone with islands or on and around raised ground, viz. termitaria, *Setaria sphacelata, Cymbopogon excavants, Cynodon dactylon* and *Imperata cylindrica* replace the above grass species. Forbs encountered in these ecotonal areas include *Nidorella*

FIGURE 9 – Secondary Floodplain Community to the west of Chief's Island, Okavango Delta, Botswana, with an isolated *Combretum imberbe* on an eroded termitarium and the western margin of Chief's Island in the background.

Blumeacaffra, Ipomoea hackeliana and *Lessertia bengurellensis.* After inundation, *Crinum* sp. cf *C. caroloschmidtii* and *Waltheria indica* were collected from Secondary Floodplain Communities.

Frequency and duration of flooding in conjunction with the dry time period which Secondary Floodplain Communities are available for animal utilisation play an important role in their vegetation composition and trend.

Sporobolus spicatus Island Grassland Communities

The *Sporobolus spicatus* Island Grassland Communities occur on both the eastern and western floodplain systems, adjacent to most islands and madiba at the extremity of the flood limits where suitable conditions exist (Fig. 10). Two types of this short island grassland exists. In general these may be separated into (i) Island Grassland Communities of the permanent swamp areas, characterised by predominantly *Sporobolus spicatus* and short sedges, the surface largely covered with evaporites, having a very high water table and inundated to a depth of 0,1 to 0,4 m in almost any flood season, and (ii) Island Grassland Communities of the seasonal swamp areas again characterised by *Sporobolus spicatus* but with other grasses dominating the species composition. The water table is lower, evaporites less common or nearly absent and these Island Grassland Communities are only flooded during high flood years to a depth of up to 0,3 m.

The most common grass species are *Sporobolus spicatus* and *Cynodon dactylon.* Where evaporites are common and flooding more regular the sedges *Juncellus laevigatus* and *Eleocharis fistulosa* occur, and the forb *Asclepias fruticosa* is often present. Under drier Island Grassland Community conditions the sedges, *Kyllinga alba, Cyperus fulgens, C. sphacelatus* and *Mariscus squarrosus* are present, as well as the grasses *Eragrostis cilianensis, E. viscosa* and on the more elevated sectors *Aristida argentea, A. meriodionalis* and *Chloris virgata.* Forb species also occur under the drier conditions namely *Cleome rubella, Hermannia modesta* and *Hirpicium gorterioides* on lower areas whilst *Pluchea leubnitziae* invades from higher ground.

The various plant associations of these Island Grassland Communities depend probably on local base levels, water table and flooding regime. The formation of termitaria on island verges is causing evolution towards island closure and the cut off of floodwaters from entering into these Island Grassland Communities. This in turn causes the plant composition to evolve towards a marginal or dryland community.

FIGURE 10 – *Sporobolus spicatus* Island Grassland Community centrally in figure with the process of "island closure" almost completed, leading to non-flooding of the community and its evolution towards a marginal or dryland vegetation type. Note Closed Riverine Woodland bottom left and arc of flooded Primary Floodplain Community above island.

Riverine vegetation types

According to Tinley's (1966) definition, no true forests exist in the Okavango Delta. Riverine vegetation types are luxuriant large tree species with overlapping crowns forming a deep shade layer in which herbaceous sciophytes predominate. These latter comprise mainly annual grass and forb species. The water table is close to the surface, and in high floods the marginal woody stem bases may become inundated for short periods.

Closed Riverine Woodland

On the slightly elevated margins of most islands, except where local lower levels exist which permit floodwaters to enter and inundate adjacent island grassland, a dense, narrow band of partially evergreen woody vegetation exists. These Closed Riverine Woodlands occur on the elevated margins of most islands throughout the study area, but their development is dependent on the proximity of surface water and thus of a high water table. The more permanent the water level in proximity to this slightly elevated dryland verge the more luxuriant is the development of this Closed Riverine Woodland. Under converse conditions the Closed Riverine Woodland is poorly developed or completely lacking. The soils consist of a sandy loam in which mature trees average 20 m in height and have a diameter at knee height (d.k.h.) of up to 1 m.

The most prominent woody species are *Diospyros mespiliformis, Garcinia livingstonei, Ficus sycamorus, F. burkei* and *Lonchocarpus capassa.* In conditions of very high water table *Syzygium* spp. and *Phoenix reclinata* are usually present with *Myrica serrata* in some localities. The low *Phoenix reclinata* population on the M'borogha floodplain islands is however not clearly understood.

Common, but less prominent woody species include *Croton megalobotrys, Hyphaene ventricasa, Rhus pyroides, R. tenuinervis, Kigelia africana, Berchemia discolor, Euclea divinorum, E. crispa, Gardenia spathulifolia, Ximenia americana, Grewia bicolor. G. schinzii, G. villosa, Vernonia amygdalina, V. colorata, Acacia nigrescens, A. sieberana* and *Ziziphus mucronata.*

Herbaceous sciophytes form a dense understorey. The most common forbs are *Achyranthus sicula, Commicarpus africanus, Celosia trigyna, Abutilon ramosum, Pupalia atropurpurea, Wissadula restrata* and *Dicliptera micranthes.* Grasses in this shade layer are mainly annuals and include *Setaria verticillata, Leptocarydion vulpiastrum, Cymbosetaria sagittifolia, Eragrostis biflora, Sporobolus fimbriatus, Panicum maximum* and *Digitaria zeyheri.* Other forbs collected include *Abutilon angulatum, A. austro-africanum, Polygonum limbatum, Chenopodium album, Solanum nodiflorum, Monechma debile* and *Dilcis petiolaris.*

Unhealthy appearing Closed Riverine Woodland indicates dessication of what was previously established. Fire devastation may also be responsible, but close examination of the stratum readily reveals this factor.

Phoenix reclinata – Syzygíum spp. Termitaria

In the more permanently flooded northern zone of the Delta and of the study area, and also in the eatern portions of Xho Flats within the study area, termitaria provide the only high ground areas for the establishment of woody species. These termitaria must have been established during drier periods or during an altered flooding pattern, and the termites were subsequently killed by rising water levels. The termitaria then became colonised by vegetation after erosion of the termitarium had commenced. Tinley (1977) stresses the importance and evolution of termitaria in floodplain systems.

These termitaria occur in almost permanently inundated Flats or Shallow Backwater Communities and combined with those communities form a parkland vegetation type. They are, however, treated solely as termitaria due to the criterion chosen in separating vegetation types. The soils are a sandy loam and during high floodwater conditions the bases of the tree stems are inundated up to 0,3 m.

In the almost permanently flooded areas and due to the high water table these termitaria are mainly colonised by *Phoenix reclinata* and *Syzygium* spp. The termitaria verges are colonised by marginal grass species i.e. *Setaria sphacelata, Cymbopogon excavatus* or *C. plurinodis, Imperata cylindrica* and *Digitaria eriantha,* whilst *Cynodon dactylon* covers part of the actual termitarium. Forb species collected from termitaria include *Rhynchosia caribaea, R. minima, Asparagus nelsii, Portulaca oleracea, Amaranthus thunbergii, Heliotropium ovalifolium, Kedrostris hirtella, Acalypha indica* and *Zehneria marlothii.*

Woody species common on termitaria in the mid and lower-Delta are *Diospyros mespeliformis, D. lycioides, Ficus sycamorus, F. burkei, Vernonia colorata, V. amygdalina,* *Phyllanthus reticulatus, Jasminum fluminense, Capparis tomentosa, Maytenus senegalensis, Grewia schinzii, G. villosa, Gomphocarpus fruticosus* and *Garcinia livingstonei.*

Under drier floodplain conditions where termitaria exists, almost any woody species occurring in the Delta is found established on these termitaria viz. *Acacia sieberana, A. nigrescens, A. galpinii, Albizzia harveyi, Combretum* spp. and *Colophospermum mopane.*

Erosion of termitaria proceeds both by rain and animal utilisation of the area, breaking down and spreading out the termitarium into a slightly elevated circular island. The degree of erosion is dependent on the death of the termites and the duration that the termitarium is subject to weathering agencies before vegetation colonisation takes place. The linking-up of adjacent eroded termitaria provides for increase in island size. Termites are one of the greatest factors in establishing raised levels and thus form suitable bases for island formation and enlargement.

Marginal vegetation types

These marginal vegetation types occur on soils slightly more elevated and slightly sandier than those supporting Closed Riverine Woodlands and thus also where a slightly lower water table exists. In certain instances only marginal woody species occur on an island; with the Closed Riverine Woodland being absent. The marginal vegetation types of the mid-Delta do not occur over extensive areas.

Acacia nigrescens – Croton megalobotrys
Woodland and Savanna Woodland

Acacia nigrescens – Croton megalobotrys Woodland or Savanna Woodland occurs in small stands on some of the small to medium-sized islands on the Boro River floodplain as well as on the M'borogha and Nambope Rivers' floodplains in the study area. On some of the larger islands of these floodplains larger stands develop but from personal observation not to the extensive size or density that this community occupies lower down in parts of the Delta (Tinley, 1966). The soils are a sandy loam and the communities are not subject to surface inundation.

Acacia nigrescens and *Croton megalobotrys* are the most common trees. Since this community usually abuts onto Closed Riverine Woodland, some of the common but less prominent woody vegetation species of the Closed Riverine Woodland extend over into the *Acacia nigrescens – Croton megalobotrys* Woodland and Savanna Woodland Community. *Kigelia africana* is often present in this community. Grasses and forbs also extend over from the Closed Riverine Woodland, but due to greater light penetration in parts more grasses (individuals and species) are present in this marginal vegetation type. *Plicosepalis* spp. of hemiparasites are common on the *Acacia nigrescens* trees. More often *Acacia nigrescens* occurs as a minor species in *Hyphaene ventricosa – Croton megalobotrys* Palm Woodland. An *Acacia nigrescens* specimen located in Closed Riverine Woodland adjacent to a lediba was of exceptional size having a d.k.h. of nearly 2 m.

Hyphaene ventricosa – Croton megalobotrys
Palm Woodland and Palm Savanna Woodland

The *Hyphaene ventricosa – Croton megalobotrys* Palm Woodland or Palm Savanna Woodland are very common on most small and medium-sized islands of the central and lower floodplains in the study area. Soils are classified as sandy loam and the water table is reasonably high, but surface inundation of stem bases does not occur.

Hyphaene ventricosa may occur in almost pure stands or with some *Croton megalobotrys*. *Hyhaene ventricosa* occurs either as a single-boled 20 m high palm or less commonly in a scrub form. *Kigelia africana, Garcinia livingstonei* and *Ziziphus mucronata* occur occasionally in this type of woodland. This community also abuts onto Closed Riverine Woodland and some overlap of woody and herbaceous species from the closed Riverine Woodland occurs into this marginal vegetation type. The more open canopy in this community allows greater light penetration and grasses become more prominent and forbs less prominent when compared to the Closed Riverine Woodland. *Setaria verticillata, Sporobolus fimbriatus* and *Cynodon dactylon* are common grasses in this community.

Where fire has passed through the *Hyphaene ventricosa – Croton megalobotrys* Palm Woodland or Palm Savanna Woodland there is evidence of numerous palm seeds germinating and it is possible that fire may act as a stimulant to *Hyphaene ventricosa* germination. *Hyphaene ventricosa* sap is tapped by the Delta inhabitants for producing an alcoholic beverage, but no large scale alteration of *H. ventricosa* Woodland to Palm Scrub was detected as is reported for *H. natalensis (H = crinita)* over its range on the east coast of Zululand (Tinley 1966).

Combretum imberbe – Croton megalobotrys
Woodland and Savanna Woodland

Combretum imberbe – Croton megalobotrys Woodland or Savanna Woodland occur on some medium and large islands on the floodplains of the Boro, M'borogha and Nambope River systems in the study area (Fig. 11). The soils supporting this type of marginal woodland, probably have a slightly higher sand content than other marginal woodlands characterised by *Acacia nigrescens* or *Hyphaene ventricosa*, and surface inundation may only occur in seasons with abnormally high water levels.

The most conspicuous woody vegetation species are *Combretum imberbe, Croton megalobotrys* and *Lonchocarpus capassa* with *Diospyros mespiliformis, Grewia schinzii, Acacia nigrescens, A. tortilis, Dichrostachys cinerea, Ziziphus murconata, Kigelia africana, Maytenus senegalensis* and *Garcinia livingstonei* also present. The herbaceous layer is made up of the grasses *Cenchrus ciliaris, Sporobolus fimbriatus, Cynodon dactylon, Digitaria pole-evansi, Panicum maximum* and *Enteropogon macrostachys;* and the forbs *Blepharis diversispina, Tephrosia lupinifolia, Celosia scabra, Hibiscus engleri, Monechma debile* and *Oxygonum delagoense.*

Dryland vegetation types

Dryland vegetation types are not normally subject to surface inundation from floodwaters. Surface inundation can, however, occur under certain circumstances and this may result in the death of those species present which cannot tolerate flooding, viz. *Acacia erioloba* and *Pluchea leubnitziae.* This may occur as a result of:-

1) Some ancient drainage courses or old floodplains which have not been subjected to surface inundation for many years, and have evolved to a dryland type supporting woody vegetation, are suddenly subjected to surface inundation from extremely high flood levels or from an altered flooding pattern.

2) Some ancient floodplains which have not been subject to surface inundation for many years and due to some marginal raised levels via termitaria are now 'cut off' from surface flooding, are subjected to heavy local rainfall, the drainage off of which is now impeded, viz. some northern parts of Chief's Island during the heavy 1973/74 rainy season.

FIGURE 11 – *Combretum imberbe – Croton megalobotrys* Woodland on an island in the Boro River floodplains, Okavango Delta, Botswana, with Secondary Floodplain Community in the foreground.

Acacia tortilis Savanna Woodland

Acacia tortilis Savanna Woodland occurs mainly on the upper eastern and western margins of Chief's Island and centrally on some of the larger islands especially of the eastern floodplain system in the study area. These communities occur adjacent to the present floodplain extremity and on ancient floodplain where the soils comprise a compact silty alluvium. Surface inundation occurs in some parts of this community (see 1 & 2 above) in years of exceptionally high water levels.

Well developed stands of *Acacia tortilis* trees occur with lesser numbers of *A. hebeclada, A. sieberana, Albizzia harveyi, Colophospermum mopane, Ziziphus macronata, Rhus quartiniana, R. tenuinervis, Hyphaene ventricosa, Ximenia americana, Garcinia livingstonei* and *Grewia* spp. Grasses occurring in this community are *Cynodon dactylon, Sporobolus salsus, Panicum coloratum, Chloris gayana, C. virgata* and *Urochloa brachyura.*

Acacia tortilis Savanna Woodland Communities interdigitate and lie adjacent to *Acacia nigrescens – Croton megalobotrys* Woodland and Savanna Woodland Communities on higher ground, *Acacia erioloba* Woodland and Savanna Woodland where the substrate is sandy, or present-day floodplain verges.

The herbaceous layer in *Acacia tortilis* Savanna Woodland was the most heavily utilised of all the areas examined. Grasses were cropped off at ground level and maintained in this state. Some of these areas examined in 1973 showed that floodwaters did not cover the intermediate adjacent floodplains. This was also probably the case in the previous dry years and has led to a state of no rest during the flood and heavy overutilisation by game. This explains why large parts of the herbaceous layer in this community was held in the state of a barren lawn. Damage to mature *Acacia tortilis* trees caused by elephant *(Loxodonta africana africana)* was evident. *Acacia tortilis* shrubs and seedlings were hardly evident in this community, substantiating Tinley's (1966) records for the Khwai *Acacia tortilis* community. *Acacia hebeclada* occurs as localised thickets usually on the margins of rain pans in this community.

Acacia erioloba Woodland and Savanna Woodland

Acacia erioloba Woodland and Savanna Woodland occurs from the southern parts of Chief's Island northwards mainly up the western side of the island with an increasingly wider distribution as one proceeds northwards (Fig. 12). Apart from its distribution on Chief's Island some of the islands having a suitable sandy substrate support stands of *Acacia erioloba* Woodland or Savanna Woodland in the study area.

Acacia erioloba in general and throughout the study area occurs on sandy alluvium or on firmer Kalahari sands (Tinley 1966). *Acacia erioloba* is widely distributed, but dispersed, following old sandy drainage courses and some old sandy floodplains. The areas over which *Acacia erioloba* Woodlands or Savanna Woodlands occur is not subject to surface inundation except under the exceptional flood conditions mentioned also for *Acacia tortilis* Savanna Woodland.

Acacia erioloba is conspicuous in this community with other woody species such as *A. fleckii, Terminalia sericea, Grewia subspathulata, G. schinzii, G. flavescens* and *Ziziphus mucronata* present. The herbaceous layer is made up of the grasses *Brachiaria brizantha, Tricholaena monachne, Eragrostis pallens, Digitaria eriantha, Cynodon dactylon, Pogonathria fleckii, Aristida stipitata* and *Stipagrostis uniplumis;* and the forbs *Borreria paludosa, Commelina benghalensis, Pluchea leubnitziae, Cleome rubella, Blepharis diversispina, Bergia pentherana* and *Asclepias burchelli.* A common sedge in this community is *Bulbostylis burchelli.*

Acacia erioloba Woodland and Savanna Woodland occurs in patches or courses forming a mosaic and alternating with *A. tortilis* Savanna Woodland, *A. nigrescens – Croton megalobotrys* Woodland and Savanna Woodland, and *Terminalia sericea – Combretum collinum* Savanna Woodland and Scrub, depending on the pattern of substrate distribution from old flooding conditions. Numerous *Acacia erioloba* seedlings and small trees were evident and the savanna woodland type is more commonly encountered than the woodland form of this community.

Terminalia sericea – Combretum collinum Savanna Woodland and Scrub

On Chief's Island and on medium to large-sized islands *Terminalia sericea – Combretum collinum* Savanna Woodland or Scrub is established on loose pallid Kalahari sand. This community is not subject to surface inundation and appears to have established itself on the original wind-deposited sands.

The main woody vegetation species present are *Terminalia sericea, Combretum collinum, Bauhinia macrantha, Lonchocarpus nelsii, Maytenus senegalensis, Rhus tenuinervis, Acacia leuderitzii, Commiphora africana* and *Boscia mossambicensis.* Grasses recorded are

FIGURE 12 – *Acacia erioloba* Savanna Woodland northern Chief's Island, Okavango Delta, Botswana. Note heavy mammalian utilisation of herb layer.

typically tall large tufted species such as *Aristida stipitata, A. meridionalis, Stipagrostis hirtigluma, Schmidtia pappophoroides, Eragrostis curvula* and *Urochloa brachyura.* Forbs include *Barleria lancifolia, Pollichia campestris, Monechma divaricatum, Acatho-sicyos naudiniana, Blepharis diversispina, Tephrosia lupinifolia, Corallocarpus bainesii* and *Acrotome inflata.*

On southern Chief's Island this community occurs in a mozaic form alternating with *Colophospermum mopane* Woodland or Pyrophytic Scrub Savanna. In the central and northern Chief's Island areas, *Terminalia sericea – Combretum collinum* Savanna Wood-land or Scrub Savanna alternates in patches with *Acacia erioloba* Woodland or Savanna Woodland and *Acacia tortilis* Savanna Woodland; each community occurring on suitable substrate. The scrub form of *Terminalia sericea – Combretum collinum* are most com-monly encountered on medium to large-sized islands on the M'borogha/Nambope flood-plains.

Colophospermum mopane Woodland and Pyrophytic Scrub Savanna

The largest *Colophospermum mopane* Woodland and Pyrophytic Scrub Communities occur from the southern tip of Chief's Island extending up the eastern half of the large island to an approximate northern limit in the vicinity of the primary survey beacons BPS 280 (Fig. 13). These communities also occur on some of the larger islands of both the eastern and western floodplains, but are more prevalent on the eastern floodplains and always covering the central core of all islands it occurs on. Isolated *Colophospermum mopane* trees may be found on termitaria of the central Delta areas; on island or flood-plain termitaria but usually in fairly close proximity to the large *Colophospermum mopane* Woodland or Pyrophytic Scrub areas from whence the seeding probably must have come. *Colophospermum mopane* Woodlands occur on grey clay pan soils and are not subject to surface inundation.

Colophospermum mopane is dominant and occurs in almost pure stands either in the single-boled tree form or as a dense shrub form, probably as the result of fire damage to young plants (Van der Schijff, 1957) which then forms multiple coppice growth. Some interdigitation or overlap of the single-boled tree form and shrub form occur but this appears to follow and old burn pattern. Other woody species occurring in the *Colophospermum mopane* Woodlands or Pyrophytic Scrub Savanna include *Croton megalobotrys, Grewia*

FIGURE 13 – *Colophospermum mopane* Woodland southern Chief's Island, Okavango Delta, Botswana.

bicolor, G. flava, G. villosa, Commiphora africana, Acacia tortilis and *Boscia mossambicensis.* Rain pans are common in the *Colophospermum mopane* Woodlands due to the relatively impervious clay soils and localised small *Acacia hebeclada* thickets are invariably found associated with these pans. Isolated species of *Acacia tortilis, Albizia harveyi, Combretum imberbe* and *C. hereroense* may also be found locally around these rain pans, or small thickets of *Capparis tomentosa, Ximenia americana* or *Maytenus senegalensis* on old termitaria in the same locality. The herbaceous layer is generally poorly developed and includes the following species *Eragrostis curvula, Setaria verticillata, Aristida stipitata, Chloris virgata, Achyranthus sicula, Tribulus terrestris, Sesuvium nyasicum, Ruellia patula, Acanthosicyos naudinianus, Harpagophytum* sp. and *Bidens schimperi.*

Parts of the *Colophospermum mopane* Woodlands are damaged by elephant via bark stripping or "green splint" type of break. Damage is, however, no where near as serious as in the *Colophospermum mopane* Woodland southwest of the Dombo Lediba in Moremi Wildlife Reserve (pers. observ.). The thick layer of dried *Colophospermum mopane* leaves covering the soil are an ideal fuel for fire due to their high resin content.

Grewia spp. – *Croton megalobotrys* Scrub Savanna

On medium and large-sized islands with a sandy substrate, the central core of the island is often sparsely covered with tall woody vegetation. The bulk of the woody vegetation is formed by a *Grewia* spp. Scrub Savanna with *Croton megalobotrys* present. These *Grewia* spp. – *Croton megalobotrys* Scrub Savanna are present centrally on medium and large-sized sandy islands of both the eastern and western floodplain systems in the study area. This community occurs on a sandy substrate not subject to surface inundation. *Croton megalobotrys* occurs mainly as a small tree or shrub but is absent from parts of this community.

The main woody shrub species present are *Grewia flavescens, G. schinzii, G. retinervis* and *Croton megalobotrys.* Other woody species present as trees or schrubs include *Acacia erioloba, A. tortilis, Ziziphus mucronata, Lonchocarpus capassa, Hyphaene ventricosa, Commiphora african, Ximenia americana, Diospyros lycioides* and *Gomphocarpus* sp. The herbaceous layer comprises *Urochloa brachyura, Eragrostis rotifer, E. tricophora, E. biflora, Setaria verticillata, Schmidtia pappophoroides, Chloris virgata, Pseudobrachiaria deflexa* and *Cynodon dactylon* as grasses; and *Clerodendron uncinatum, Pluchea leubnitziae, Blepharis diversispina, Ipomoea mignusiana, Hermannia glanduligera* and *Gisekia africana* as forbs.