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*Irrigation*

University of Reading

Department of Agricultural Economics

IRRIGATION IN BOTSWANA

M. Upton

Development Study No. 5

May 1969

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A report on the economic potential for

IRRIGATION IN BOTSWANA

by

M.Upton

May 1969

Development Study No.5.

## Preface

This report is the second arising from a continuing study by the Department of Agricultural Economics, Reading University, of Botswana's agricultural development problems. (The first report was on Agricultural Credit in Botswana by Alan Harrison). The research programme is being carried out in co-operation with the Ministry of Overseas Development who have provided research funds, and the Freedom From Hunger Campaign.

Thanks are due to many individuals in Botswana and the United Kingdom for assistance, information and constructive comment and in particular to R.G.Hampson Esq., D.F.C., M.B.E., Director of Agriculture, Botswana, and all his staff both at Headquarters in Gaborone and in the field.

Members of the Ministry of Commerce, Industry and Water Affairs, Botswana and other Government Departments in Gaborone, and A.J.B.Mitchell Esq., of the Directorate of Overseas Surveys, now working in Malawi.

## Irrigation in Botswana

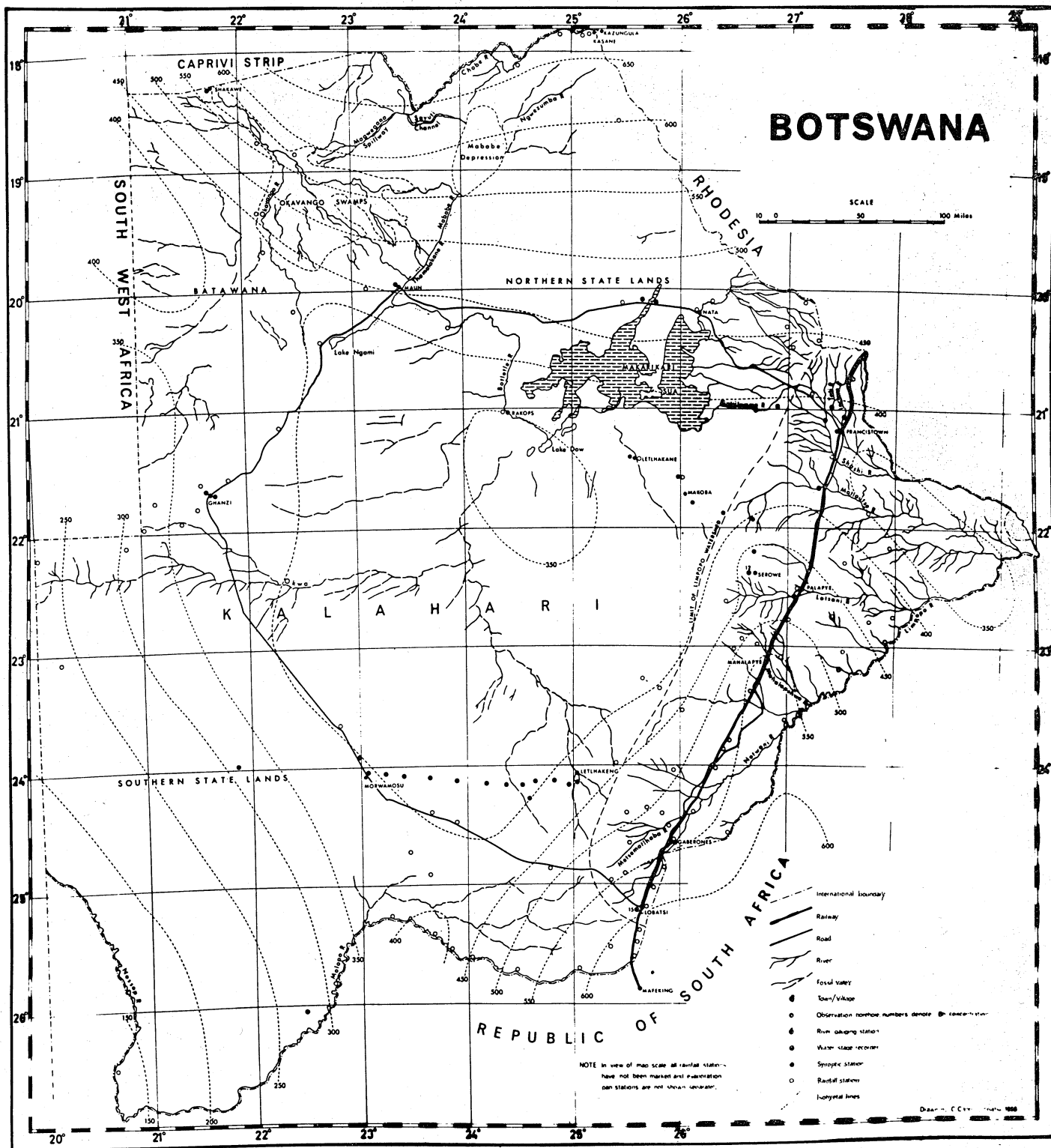
### Conversion Factors

1. One Rand = 100 cents = £0.581 sterling  
at exchange rates 1968
2. One acre = 0.473 morgen = .405 hectares
3. One thousand gallons = .0442 acre inches  
= 4.546 cubic metres
4. One thousand gallons per hour = .045 cusecs  
= .00126 cumecs

### Notes

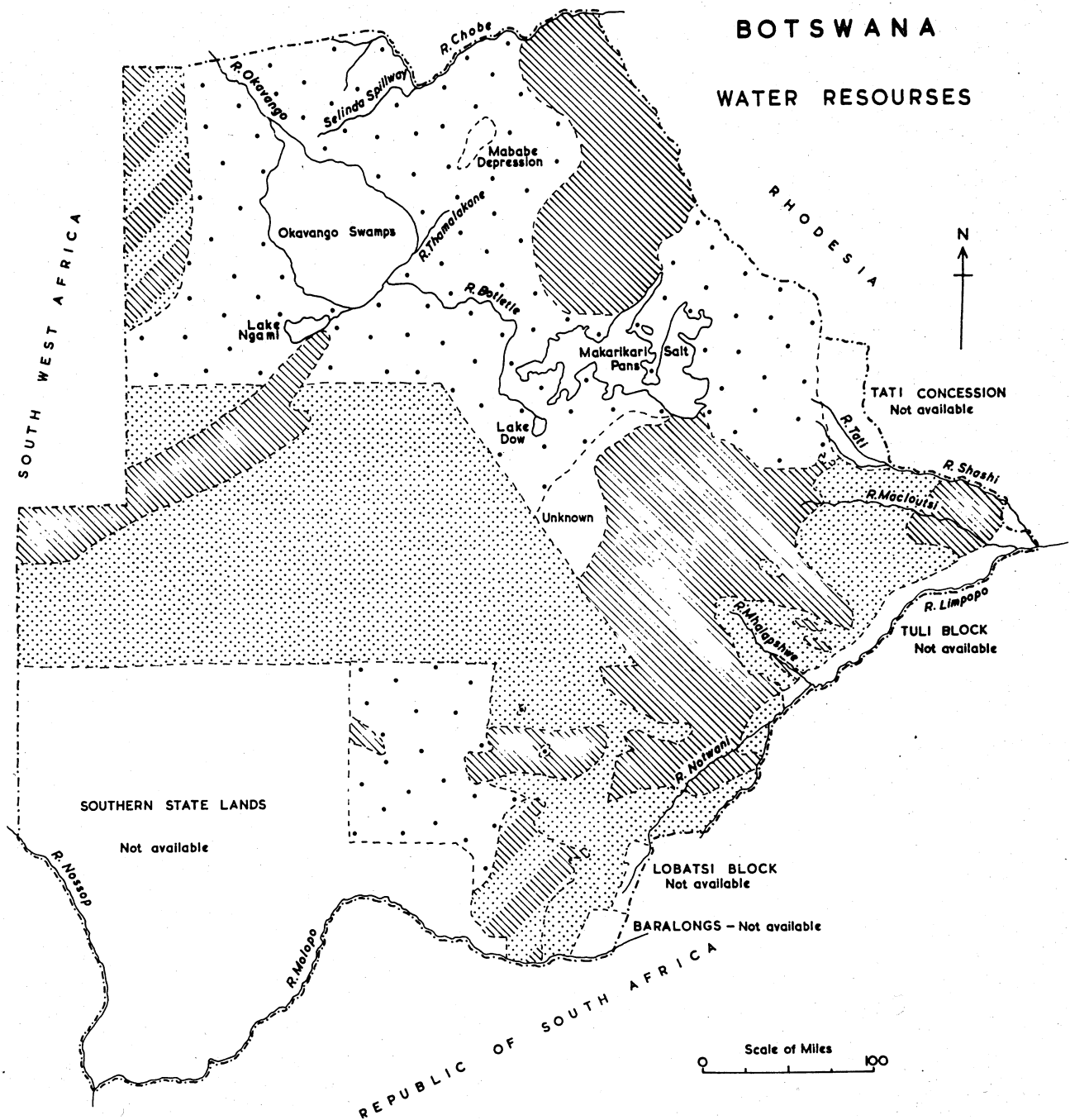
The Bechuanaland Protectorate became the Independent Nation of Botswana on 30th September, 1966.


# Map No. 1





# Map No. 2

## BOTSWANA WATER RESOURCES



 GOOD—over 50% success ratio

 POOR—less than 50% success ratio  
or only at depths below 500 feet

 SALINE

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# THE ECONOMIC PROSPECTS FOR IRRIGATION IN BOTSWANA

## I INTRODUCTION

### I.(i) CLIMATE OF BOTSWANA

1. There are two major deficiencies in the pattern of rainfall in Botswana, firstly that it is low on average and secondly that it is unreliable.

2. The climate is generally described as semi-arid with what rainfall there is generally falling in the summer months. (See Table 1.1).

The prevailing winds from the East and North East bring moisture from the Indian ocean, some of which falls over the Northern Transvaal and Southern Rhodesia, hence the moisture is depleted by the time the wind currents reach Botswana.

In the South East the average is 22" of rainfall and in the South West 8" per year. Two thirds of the territory receives over 16". (See Map 1).

3. The rain generally falls in thunderstorms of high intensity and short duration. There are therefore, high evaporation losses.

4. Evaporation and hence evapo-transpiration rates are high. The mean total annual evaporation for Gaborone is 84", for Shashi about 68" and Ghanzi in the West nearly 120". (Data obtained from A.Anderson, Chief Met. Officer, 1968).

It will be noted from Table 1.1 that at no time of the year is rainfall greater than evaporation. There will generally be a water deficit every month of the year. Obviously there is considerable variation within months and between years so mean monthly data only serve to give a general impression.

Table 1.1

Seasonal pattern of rainfall and evaporation for Gaborones

Mean of ten years 1958 to 1967 inclusive

	inches												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Total
Rainfall	3.3	3.1	2.0	2.2	0.5	0.2	0.1	0.1	0.2	1.6	2.0	2.3	17.6
Evap'n.	9.9	8.0	7.5	5.0	4.3	3.5	4.5	6.0	8.0	9.2	8.4	8.8	83.1
	Summer				Winter				Summer				

5. A more serious problem is the unreliability of rainfall; the variations in annual totals, the delays in the coming of the rains, the absence of rain at critical periods of crop growth and the extreme localisation of storms.

6. Botswana has recently experienced a serious drought. It lasted from 1961 to 1966. Reports state that famine was widespread and about one third of the national cattle herd was lost. In many areas the vegetation was entirely grazed away and permanent damage done to the veld. Again 1967-68 was a poor crop season.

7. Rose (1966) and Lund (1965) have investigated the variability of rainfall in Botswana, statistically. For instance, Rose gives a range of annual totals for Gaborones over 21 years of 16.12 inches to 23.38 inches but the total in 1962 for this centre was only 10.27 inches and in 1967, as high as 36.35 inches.

Lund gives a drought frequency map which shows that in Eastern Botswana, in seven years out of ten 85% of the mean annual rainfall can be expected. Thus in Mahalapye where the mean annual rainfall is 18 inches then 15 inches or more may be expected in seven years out of ten. Lund suggests that this level of reliability is in fact better than for 50 per cent of the African sub-continent south of latitude 18° south. Rainfall is less erratic than it may seem, at least in annual total.

Nevertheless the experience of the recent drought underlines the seriousness of the rainfall unreliability.

8. In addition to problems of water shortage and unreliability there are wide temperature variations. The winters in particular are

subject to wide diurnal temperature variations and occasional frosts.

In the South the danger of winter frosts precludes the growing of certain tropical crops such as rice and sugar cane.

I.(ii) THE PRESENT PATTERN OF AGRICULTURE

1. Nearly half the land surface of the country is included in the eight tribal territories (107,497 square miles) the remainder being made up of six freehold farming blocks mainly occupied by Europeans (8242 square miles) and State lands (104,497 square miles) which are largely uninhabited veld but include the Central Kalahari Bushman Reserve.

2. Within the tribal territories are found the cultivated "lands" usually surrounding the villages. Around and beyond the lands lie the cattle posts, which are either at boreholes or at wells dug in the sands of ephemeral rivers. This is only a very general description. Further details are given in the 1967/68 Agricultural Survey Report. (Department of Agriculture 1968).

3. By far the most important crop grown on the lands is sorghum but in some areas maize, millets, beans, cowpeas, melons and pumpkins are grown. These are basically subsistence crops although a few farmers grow cash crops specifically for sale and the ordinary family occasionally sends surplus crops to market.

4. The main source of cash income to most farmers is the sale of cattle. Even after the drought the national herd is estimated at over one million head. The typical farmer's herd is small, the modal size being from 11 to 50 head and the average off-take about 8 per cent.

5. An exception to the pattern of separate cultivated lands and cattle grazing areas is found in the Southernmost Baralong tribal area. Here farms are generally larger than elsewhere and crops and livestock are integrated into a system of mixed farming.

6. Irrigation is rare amongst the African farmers of Botswana. Water is generally scarce and humans have first priority to water supplies and livestock second.

The only large area of African farming with a regular water supply is in Ngamiland around the Okavango swamps. (See Map 2). Here crops are grown behind the receding flood waters of the swamps but the amount of crops produced in this way is relatively unimportant nationally. Today a few farmers around Maun have purchased pumps through the Agricultural and Livestock Officer and are growing small areas of vegetables.

7. Elsewhere few African farmers practice irrigation. By 1966 three farmers at Tonota were irrigating vegetable crops from the Shashi river. Another is successfully irrigating vegetables from the Macloutsi river. In Serowe there are over 30 irrigated vegetable gardens.

During this study a visit was made to a farmer irrigating vegetables with water pumped from a pool in a small mainly dry river in the Bamalete tribal territory.

Boreholes are also used, one by a farmer near Mahalapye, who sells vegetables in the town. A vegetable garden watered from a borehole has been established by a producers' co-operative at Mochudi near Gaberones.

However all these are small individual schemes amounting in total to perhaps less than 100 acres.

Certainly irrigation is not very common amongst African farmers at present.

8. Most of the freehold farming areas are devoted to cattle ranching except for the Tuli Block along the Limpopo river in the East of the country. Here nearly 4,000 acres are under irrigation for the production of cotton and other cash crops.

9. Irrigation is also found in Government supported schemes, the only two currently in operation being the Nxaragha valley settlement and the Mogobane Irrigation scheme. Others are under consideration at present and are discussed later in this report.

10. In the marketing of agricultural crops Botswana is in close liaison with the South African producer marketing boards for many of her exports.

Cotton, wheat, groundnuts and sunflower are all sold at prices fixed or guaranteed by the South African marketing boards and cereals and beans have a fixed floor price.

Of the possible cash crops only vegetables and citrus fruits seem to be subject to market risks. Vegetable prices fluctuate widely in South African markets and local urban markets have still to be established.

Citrus fruits produced in Botswana are not accepted by the South African Citrus Board and producers in Botswana are having difficulty in finding outlets.

11. For subsistence, or local food crops the stated Government policy objective is to make Botswana self sufficient, and at the same time to improve the dietary value by increasing the output of protein rich foods.

I.(iii) THE TECHNICAL CASE FOR IRRIGATION

1. With the existing pattern of climate and of agriculture in Botswana there is clearly a case to be made out for irrigation on technical grounds.

With a climate such that evapo-transpiration practically always exceeds precipitation water supply must act as a constraint on crop growth. If the water supply to crop plants can be increased by irrigation then almost inevitably crop yields must rise.

2. No precise experimental data is available from Botswana but the yield estimates presented in Table 1.2 for rainfed and irrigated crops give some idea of the possible benefits.

Table 1.2

Comparison of estimated yield for rainfed (dryland) and irrigated crops in Botswana

(Department of Agriculture personal communication)

	<u>Crop yield lbs.per acre</u>	
	<u>dryland</u>	<u>irrigated</u>
Cotton	500	2,400
Maize	500	4,000
Beans/cowpeas	350	1,400

3. These estimates are assumed to be the average results obtained over several years. In fact wide variations may be experienced, particularly for the dryland crops.

4. Apart from gains in the yields of crops already produced under dryland conditions, there is the possibility of introducing new crops and better varieties.

Vegetables are an example as most of these crops could not be grown in Botswana without irrigation. With irrigation they may prove to be highly successful crops.

5. Finally irrigation should avoid the risks of drought and rainfed crop failure. Irrigated agriculture can provide an assured return provided the water supply is not directly dependent on the rainfall and hence subject to failure. However, on the Gezira scheme in the Sudan there are wide fluctuations in both yield and price of cotton. (see Suliman (1965)).

#### I.(iv) AREAS OF IRRIGATION POTENTIAL

1. The country is divided into two dominant topographical regions and three drainage systems, (see Map 2) based on (a) the Limpopo (b) the Molopo and (c) the Okavango.

2. The East of the country is broken by a series of rocky hills, This area gives rise to ephemeral streams flowing generally eastwards into the Limpopo river. This river flows northwards, along Botswana's eastern boundary with the Republic of South Africa, and eventually into the Indian Ocean.

North West of Francistown there is a smaller area of similar geomorphology but here the streams flow west and south-west into the Internal Drainage System.

3. The remaining three quarters of the land area is covered by Kalahari sand which absorbs practically all the rainfall. Runoff is therefore negligible.

The south of the Kalahari region slopes gently to the Molopo and Nossob rivers on the borders of South Africa and South West Africa. Both these rivers which form part of the Atlantic Drainage System, flow occasionally from run-off in the adjoining territories.

The main part of the Kalahari, however slopes gently to the Makarikari salt pan in the North.

As there is no run-off, no rivers flow northwards in this area. It has been shown that most rainfall is held near the surface and lost by evaporation. There is little or no recharge of aquifers where there is more than 20 ft. depth of sand.

4. The central drainage system, centred on the Okavango swamps is of major importance as it receives some seven million acre feet of water annually from Angola. This amounts to about eight times the flow in all other rivers in Botswana, and three times the flow in the Vaal river which supports the Reef and Vaal Hartz Irrigation Scheme in the Republic of South Africa.

The water flows into Botswana along the Okavango River (across the Caprivi strip) and breaks up into an inland delta complex in the Okavango swamps. A small but important proportion of the flow passes down the Thamalakane River past Maun, then the Botletle River to Lake Dow and occasionally the Makarikari pan.

Occasionally the delta spills to the east onto the Mababe Depression or to the north east into the Chobe River and thence to the Zambezi.

5. The Okavango and Chobe are the only perennial rivers in Botswana. Most rivers flow for a short period, when flash floods recharge the sand of the bed and leave behind them a few scattered pools which gradually dry up over the winter.

Water continues to flow, though very slowly, through the sand and this water is tapped with wells sunk into the bed of the dry river. People and cattle are very dependent on these river wells and as a result the areas within reach of them have become heavily overgrazed.

6. In many parts of the country there are small pans in slight topographical depressions which hold water for some months of the year. These also form a source of water for human and livestock consumption.

It is possible to construct rainfall catchment tanks artificially to provide water. Experimental work on the construction and use of such tanks has been carried on at the Bamangwato Development Association Farm, Radisele and tanks have been made at several schools in the area.

7. In many parts of the country, small supplies of underground water can be found by drilling at geologically selected sites. Hundreds of boreholes have, in fact, been drilled opening up vast areas to grazing. Many of Botswana's towns rely on boreholes for domestic water supplies. The likely potential of underground water supplies is summarised on Map 2. In large areas of the country borehole water is too saline for irrigation.

8. Before water development can be planned hydrological surveys must be carried out. Many of these have been completed and are generally well summarised in a report on "The Surface Water Resources of Botswana" (1965) by B.G.A.Lund and Partners, hydrological consultants to the Botswana Government.

9. Lund draws heavily on the Bawden and Stobbs report of 1963 on "The Land Resources of Eastern Bechuanaland". These authors place 630,000 acres in the category "Land primarily suitable for cultivation with potentially irrigable soils", of which only 24,000 acres were

under cultivation at the time of their survey. This has led to the view that the potential for irrigated agriculture in Eastern Botswana is very large. However, Bawden and Stobbs were more cautious and said:

"Irrigation is not merely a matter of the suitability of the soil for water application. It involves many different factors including the economics of capital investment related to crop production and markets and the level of management which can be achieved, as this will limit the range of soils which are likely to be irrigated successfully. The possibilities for fairly intensive irrigation are confined to three areas which can be supplied with water from the Limpopo and lower Limpopo, and, in the Lobatsi land system where they could be supplied from the upper Notwani and its tributaries."

10. More detailed surveys of potential irrigable soils in Eastern Botswana (the Limpopo watershed) have been carried out by A. Mitchell, a soil surveyor seconded from the Land Resources Division of the Directorate of Overseas Surveys. At the time of writing, his final report is not available but before leaving Botswana he reported on 16 areas where he considered prospects for irrigation schemes were good. These areas amount in total to nearly 30,000 acres.

11. Certain of these areas have been revisited by D.K. Toumey, the Irrigation Engineer (1967) who has found that in some cases it would be difficult to command the area of suitable soils from a dam.

He considers the Kolobeng River Valley (Mitchell's area No.11) to be the most promising area.

12. A project, entitled "Surveys and Training for Development of Water Resources and Agricultural Production" was approved by the Governing Council of the United Nations Development Programme (Special Fund) in January 1967. The purpose of this project is to undertake hydrological surveys in selected areas and to strengthen agricultural extension services prior to the preparation of a land and water development plan.

The hydrological surveys will be concerned with the tributaries of the Limpopo and the Okavango area including the Botletle and Chobe rivers and the Makarikari depression.

In the proposals for this project (Ministry of Commerce, Industry and Water Affairs, Bechuanaland 1966) it is stated that apart from some 600,000 acres of potentially irrigable soils in eastern Botswana there are a further 50,000 acres in the Okavango area.

13. Reviewing these studies it is clear that a great deal of useful information is being collected on both the hydrology of Botswana's surface water resources and the suitability of associated soils for irrigation.

In particular it is to be hoped that the U.N.D.P. project will lead to proposals for harnessing the vast water resources of the Okavango. Although Lund and others have made suggestions no carefully costed proposals for the development of this area have been given serious consideration. In the words of the National Development Plan 1968-73 "However, in economic terms the run off from the ephemeral rivers of the Limpopo watershed is of greater immediate significance. The bulk of the population live in the eastern part of the country and most development will take place there". This statement is not necessarily true. Although it would require a huge capital investment to utilize the Okavango water efficiently the returns could possibly justify the investment.

14. To endorse the statement of Bawden and Stobbs quoted in paragraph 9 above, it is important to remember that hydrological and soil surveys are only preliminary approaches to irrigation development. Irrigation potential cannot possibly be assessed merely in terms of acreage commandable from dam sites or acreage of irrigable soils. In other words the naive "land use planning" approach is inadequate.

It is important that every proposed irrigation scheme should be treated as a project and subjected to economic appraisal. Only in this way, can the potential contribution of irrigation to economic development be determined. Furthermore, sociological aspects must be given due consideration.

15. This study attempts some very elementary economic appraisal of a few proposed irrigation schemes but it is highly desirable that in future appraisal should be carried out in more detail on all such proposed schemes.

## 2. RETURNS FROM IRRIGATED CROPS

In this section the method of estimating crop water requirements and the planning of systems of irrigated agriculture is first discussed. This is followed by a consideration of returns from individual arable crops, then the returns from a system of irrigated agriculture. Finally, returns from small scale vegetable growing are discussed.

### 2.(i) CROP WATER REQUIREMENTS AND THE PLANNING OF SYSTEMS OF IRRIGATED AGRICULTURE

1. A given supply of water can be used to irrigate varying areas of land. The maximum return per acre would be obtained by limiting the acreage so that it can be irrigated up to the technical optimum throughout the year.

However, the water could be spread over more acres by either

- (i) irrigating less frequently than the technical optimum
- (ii) applying less water than the technical optimum at each irrigation
- (iii) only irrigating one crop per year and storing water

during the fallow season. e.g. only growing summer crops and storing water during the winter to apply to the next summer's crops.

2. The first two methods represent a reduction in the amount of water applied to a specific crop. This would almost certainly lead to a reduction in crop yield but some loss of yield may be justified if this enables a greater acreage to be irrigated. Where reliable information is available on the relationship between water application and crop yield it is possible to work out the economic optimum rate of irrigation.

Research of this nature has been carried out in Israel, Kenya and America, but no information is available for Botswana. It is therefore, dangerous to recommend reduced watering rates as yield losses might be serious.

3. The third method is particularly attractive if one particular crop gives much better returns to irrigation than all other crops, or if summer crops give better returns than winter crops. This is apparently not the case in Botswana. Cotton, groundnuts, maize and some vegetables are summer crops producing returns which are no more attractive per acre or per 1,000 gallons of irrigation water, than the returns from winter crops such as potatoes, onions or possibly wheat. There is therefore, no justification for storing water to use only on one particular crop or during one season of the year in Botswana. Alternatively, if by watering in summer only, storage costs are markedly reduced i.e. barrages suffice, seasonal storage might be justified. This depends at least partly on the river regime.

In addition specialisation on one crop or on irrigation during one season can lead to serious work peaks. If there is sufficient labour to cope with the work peaks it will be under employed for much of the year. With a succession of different crops the work load is spread more evenly over the year.

5. It should be remembered that all methods of spreading a given supply of water over a larger acreage lead to increased costs of distribution. This is clearly the case where fixed canals and distributaries are used to carry water to the land. But it is equally true of portable pipelines such as are used with sprinkler irrigation systems. If the area to be irrigated is extended, longer pipelines are needed, and a more powerful pump to overcome the frictional pressure of the pipeline. With the method of irrigating at only one season of the year the cost per 1,000 gallons of water applied must increase because as with labour there will be a peak demand on the irrigation system, which will be underemployed for the remainder of the year. This problem would be particularly acute for a sprinkler system.

6. For these reasons year round irrigation, at or near the technical optimum rate, was assumed for the purposes of this report.

7. However, supplementary irrigation might well prove to be the most economical use of water, especially if used with other water conserving techniques such as mulching. (See report on Rainwater Catchment Tanks and Micro-Irrigation in Botswana I.T.D.G. 1969). Experiments to test the effects of sub-optimal irrigation should be instituted at the earliest opportunity.

## 2.(ii) RETURNS FOR INDIVIDUAL FIELD CROPS

1. In purely financial terms a scheme will be viable only if the returns per acre or per thousand gallons of water are greater than the costs.

2. Estimates of the gross margins for certain crops under irrigation are given in Table 2.1. These gross margins are calculated by deducting estimated costs of seeds, fertilisers and sprays from estimated value of the yield. Thus the margins must still cover, costs of labour and water and a return on capital. They were obtained from the Mogabane Scheme proposals prepared by G.Jackson, Agricultural Economist. He based his estimates on a consensus of opinion amongst agricultural officers with considerable local experience.

3. It should be noted that the estimated yields might be considered optimistic. Generally, average yields obtained for irrigated crops

on the Tuli Block, where the standard of management is high, are lower than the yield estimates given in Table 2.1. For example, the average yields of irrigated cotton and maize in the Tuli Block for the year 1966/67 were 2,188 lbs. and 1,600 lbs. per acre respectively, whereas the equivalent estimates for irrigated crops given above are 2,400 lbs. and 4,000 lbs. Average medium staple cotton yields on irrigated schemes in the Sudan for instance, are nearer 1,500 lbs. per acre.

4. In Table 2.1 gross margins under irrigation are compared with gross margins for the dryland crop. In the case of cotton and maize it is estimated that the margin is increased over sixfold with irrigation. For beans the margin with irrigation is nearly 5 times that for the dryland crop.

Table 2.1

Influence of irrigation on average crop returns per acre

Crop	<u>Dryland</u>		<u>Irrigated</u>		Net Return per acre
	Yield	Gross Margin	Yield	Gross Margin	
Cotton	500 lbs	16 R.	2400 lbs	103 R.	87 R.
Maize	500 lbs	5.5 R.	4000 lbs	49 R.	43.5 R.
Beans/cowpeas	350 lbs	4.7 R.	1400 lbs	45 R.	35.7 R.

Table 2.2

Margin per acre inch and per 1000 gallons water

Crop	Gross Margin per acre	Inches water	Return per acre inch
Cotton	103 R.	30	3.4 R.
Maize	49 R.	28	1.8 R.
Beans/cowpeas	45 R.	15	3.0 R.

5. Table 2.2 gives estimates of the return per acre inch of water. As data on water requirements of specific crops are lacking in Botswana, it is assumed that water requirements per month of the growing season are the same for all crops, (see Appendix I) a somewhat arbitrary assumption.

Generally the return appears to be around R3 per acre inch or 10c per 1,000 gallons.

7. The estimated water requirements given in Table 2.2. may require downward adjustment. On the Lobatsi unit farm a cotton crop was grown with only 25" of water applied during the season 1968/69. If the margin per acre is around R100 the margin per acre inch will be R4. Maize sold green for a gross return of R145 used only 12½" giving a gross return per acre inch of R11.6. Obviously the gross margin and the net return will be lower. At the same time Lobatsi has one of the highest annual rainfall totals in the country.

## 2.(iii) RETURNS FROM A SYSTEM OF IRRIGATED AGRICULTURE

1. In practice it will be impossible to grow a single crop, other than rice, of sugar cane continuously. Cotton has been rationed although in most countries this is forbidden by law. However, yields generally start to fall after 2 or 3 years. A rotation of crops is therefore likely to give a better overall return.

In addition labour requirements are spread more evenly over the year, income is spread more evenly over the year and risk is reduced if a combination of crops are grown.

2. Returns from irrigation should, therefore, be measured in terms of the returns from a system of irrigated agriculture.

3. Since, at present, there are no records available of a financially viable irrigation scheme in Botswana budgets prepared by the Agricultural Economist G.S.Jackson are used as a guide as to potential returns.

4. These estimates, given in Table 2.3, are taken from the project proposals for the Mogobane Irrigation Scheme. The estimates were drawn up on the basis of all available information, and in consultation with various experienced officers of the Department of Agriculture. As already noted, these estimates are possibly somewhat optimistic.

5. Although the assumptions are identical with those made by Jackson the budget is presented slightly differently in that labour costs are not deducted in calculating gross margins. However, net returns are the same. These data represent the expected costs and returns once the scheme has reached maturity. The postulated gradual increase from lower returns in the early years has been ignored.

Table 2.3

BUDGET FOR THE MOGOBANE IRRIGATION SCHEME

From G.S.Jackson - Proposed plan for redevelopment  
to be submitted to the National Development Bank

<u>Cropping</u>			
<u>Crop</u>	<u>Acreage</u>	<u>Gross Margin</u>	<u>Total Gross</u>
		<u>per acre</u>	<u>margin</u>
		<u>R</u>	<u>R</u>
Cotton	82	103	8446
Green maize	30	84	2520
Maize (grain)	34	49	1666
Beans	68½	45	3082.5
Wheat	64	49	3136
Potatoes	9	127	1143
Sorghum	27½	36	990
Lucerne	8	65	520
<u>Total area - 250 acres</u>			<u>21503.5</u>
		<u>Total</u>	<u>per acre</u>
		<u>R</u>	<u>R</u>
Total Gross Margin		21504	86
Fixed costs		7900	31.5
Return to labour and irrigation		13604	54.5
<hr/>			
(a)	Labour priced at 65c per man day	7065	28
	Fixed costs with labour	14965	59.5
	Return to irrigation	6539	26.5
<hr/>			
(b)	Labour priced at 45c per man day	4892	19.5
	Fixed costs with labour	12792	51
	Return to irrigation	8712	35
<hr/>			
(c)	Labour priced at 35c per man day	3804	15.5
	Fixed costs with labour	11704	46.5
	Return to irrigation	9800	39

6. The estimated labour requirements are similar to estimates for the Sudan although considerably lower than the labour inputs on irrigated unit farms in Swaziland.

Three labour prices are used in this budget, 65 cents per man-day representing the Government wage rate, 35 cents as a more realistic commercial wage rate and 45 cents as a compromise rate which might be paid on a Government scheme.

7. The estimated gross margin per acre is R86; the return to labour and irrigation R54.5 per acre and at the intermediate wage rate the return to irrigation is R35 per acre.

8. The water use of this scheme is estimated at 767 acre feet = 207.8 million gallons. Hence the net return per acre inch is 95 cents or per 1000 gallons it is 4 cents.

9. Although these returns are adequate to pay an acceptable return on the relatively small amount of additional capital needed to refurbish the scheme, they are not very attractive in relation to expected costs of most sources of water (See Chapter 3). The plans prepared for the Mogobane scheme were subjected to the constraints imposed by considerations of marketing difficulties and maintenance of soil fertility. Linear programming was therefore used to determine the maximum profit which might be earned with the resource limitations and the alternative enterprises applying to the Mogobane scheme. It was also hoped that linear programming might throw light on some aspects of the planning and management of such schemes.

10. The only constraints applied to the linear programme were labour, limited to 13,500 man-days per year and 1,350 in any single month and irrigated land limited by water supply and distribution system to 250 acres. These assumptions and all input-output coefficients are similar to those used by Jackson. For convenience it is assumed that all crops are watered at the same rate (See Appendix I). The input-output coefficients are given in Table 2.4.a.

11. With these assumptions the optimum system includes:

84 acres	-	maize-green cobs
49 acres	-	potatoes
129 acres	-	lucerne
38 acres	-	onions
23 acres	-	late maize grain
9 acres	-	late field beans
<hr/>		
332 acres		crops grown on 250 acres cropped land by some double cropping.

This system which might need some adjustment in order to establish a rotation - gives a total gross margin of R31, 105 out of which labour and water costs have to be paid.

If labour is charged at 45 cents per man-day and fixed costs are as given in Table 2.3, the return to irrigation would be R18,313 or R73 per acre. The net return per acre inch of water would be R2 and 9 cents per thousand gallons.

12. It has been pointed out that the markets for green maize, potatoes, lucerne and onions are all somewhat speculative. Therefore cotton, early maize and wheat were included in the original plans as there are assured markets for these crops. However, the linear programme results suggest that the cost (reduction in total return) is nearly R7 for an acre of cotton introduced into the scheme, R8 for an acre of early maize and R2.5 for an acre of wheat.

13. There is surplus labour in total and in each month except September, November, March, April and June. In these months the marginal revenue product per man-day ranges from R1.35 in June up to R4 in September. Clearly if it is possible to hire casual labour at even 65 cents per man-day, increased labour use in these months would be justified. Even if labour can only be hired on a regular basis, the extra return in these months would justify using extra labour at an annual wage of up to R280.

14. Irrigated land only limits production in the months of September and October, in which months the marginal revenue product is R4 and R45 respectively. These marginal returns to irrigated land are not very attractive in relation to per acre costs of irrigation (see Chapter 3). There is therefore, the implication that the ratio of labour to land might profitably be increased.

15. For the reasons given above of market limitations, it is unlikely that the linear programmed margins could be achieved in practice. It is, therefore, suggested that the return to irrigation on a scheme might be between R30 and R40 per acre as shown in Table 2.3. The return per acre inch may approach R1 and the return per thousand gallons only 4 cents.

## 2.(iv) RETURNS FROM VEGETABLE PRODUCTION

1. With irrigation it is possible to introduce intensive vegetable production, which would not be possible under dryland conditions.

2. Yields and gross margins per acre obtainable from vegetable production are considerably higher than those from field crops already discussed (see Table 2.4).

Table 2.4.a.

INPUT - OUTPUT COEFFICIENTS FOR IRRIGATED CROPS

Gross margins and labour requirements per acre

	Gross Margin R.	Land + Water required		Total Labour Man days	Monthly labour - man days											
		from	to		Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.
Cotton	103	Sept	June.	50		1	6	5	3	5	4	4	10	10	2	-
Maize Grain	49	Sept	Dec.	21	-	-	3	5	10	3	-	-	-	-	-	-
		Jan.	Apr.		-	-	-	-	-	-	3	5	10	3	-	-
Maize Green Cobs	84	Aug.	Dec.	30	-	3	7	10	10	-	-	-	-	-	-	-
Field (Sugar)	35	Aug.	Jan.	37	1	6 $\frac{1}{2}$	2 $\frac{1}{2}$	2	2	23	-	-	-	-	-	-
Beans	45	Jan.	June		-	-	-	-	-	1	6 $\frac{1}{2}$	2 $\frac{1}{2}$	2	2	23	-
Wheat	49	Mar.	Sept.	20	3	5	-	-	-	-	-	5	2	2	2	1
Potatoes	127	Feb.	Jul.	61	9	10	-	-	-	-	-	20	7	5	5	5
Lucerne (4yr.crop say)	65	Whole year		19	-	-	-	4	3	2	-	-	-	5	5	-
Onions	210	Feb.	Oct.	80	10	16	8	-	-	-	-	6	20	7	7	6
Groundnuts	68	Sept.	May	30	-	-	2	1	4	1	1	1	5	15	-	-

Table 2.4

Gross margins from irrigated vegetables

Data obtained from a) Tuli Block Census b) Swaziland Report

Crop	Yield/acre tons	Gross Margin/ acre R	Gross Margin	
			per 1000 galls <u>cents</u>	per acre inch <u>R</u>
1. Onions	20	891	197	44.6
2. Tomatoes	10	519	115	25.9
3. Green beans	4	302	67	15.1
4. Cabbage	20	251	55	12.6
5. Potatoes	10	177	39	8.9
6. Green maize	5000 cobs	84	19	4.2
7. Green peas	1½	-5	-1	-.3

Grown on plot  
scale with  
mulching by  
Vernon Gibberd  
at Radisele -  
Micro-irrigation

Crop	Yield/acre	Gross Margin/acre	ins. of water applied		R.	R.
1. Tomatoes	25	2274	3	32.49	758.0	
2. Cabbage	10	670	19	1.57	35.3	
3. Green beans	2½	482	3	6.89	160.6	
4. Green maize	14000 cobs	435	2	9.67	217.5	
5. Green peas	1	307	5	2.72	61.4	

3. The expected gross margins per acre for many of these vegetable crops are well over R100. Although the negative margin for green peas serves as a reminder that losses are sometimes made on certain of these crops.

4. Generally there is considerable seasonal variation in the price of vegetables and hence risk is involved and good management and timing of production is essential.

5. Water requirements are estimated roughly at 20" or 453 thousand gallons per acre. On this basis, gross margins per thousand gallons are very much greater than the margins from field crops.

6. The latter half of Table 2.4 summarises the results of trials carried out at the Bamangwato Development Association, Radisele, by

Vernon Gibberd. Vegetables are grown there on a very small, experimental-plot scale and mulching techniques are used to conserve water.

The gross margin per acre for tomatoes (based on results from about 40 square yards) is well over R2,000. Returns to water are equally impressive. By using mulching techniques water consumption is restricted. As a result the irrigation requirements of tomatoes were reduced to 70,000 gallons per acre. The gross margin per thousand gallons is therefore R32.5.

7. Although no data on labour inputs are available it is apparent that far more labour is involved in growing an acre of vegetables than in growing an acre of field crops.

For instance the Chinese Agricultural Mission, Demonstration Farm at Gaberones is 14 acres in size (although only 7 acres were cultivated at the time of visiting). On this area 9 Chinese and 12 Batswana are employed full time besides a group of prisoners temporarily employed there. This represents a labour intensity of one man per  $\frac{14}{21} = \frac{2}{3}$  acre.

This scheme is basically a training and demonstration scheme, nevertheless it is probably reasonable to assume that each of the Chinese and the Batswana full-time trainees work 200 days per year, if the part-time labour of the prisoners is ignored. At this rate the labour input per acre of vegetables is 300 man-days per acre.

At this rate the gross margin per man day in vegetable production may be no higher than the gross margins or man-day obtained from field crops.

8. Markets for vegetables are not assured to the extent that markets for most field crops are. Vegetables may be exported to South Africa where there is generally a demand although prices fluctuate widely. For example in 1965 the Johannesburg price for tomatoes ranged from 2.7 cents per lb. in February up to 7.9 cents per lb. in September, onions ranged from 1.3 cents per lb. in December to 4.3 cents per lb. in May. Therefore timeliness of production is all important in order to obtain the best prices.

9. However, the present market for vegetables is severely limited. Since communications are generally poor and vegetables perishable, transport to distant markets raises serious problems. But local markets in small urban centres are limited.

For the Botswana grower there are large markets for vegetables in Johannesburg and other South African cities but communications are inadequate to justify sending produce there.

All the vegetables produced by African farmers in Botswana are sold in local markets and some producers are already finding difficulty in disposing of their produce.

10. It is to be expected, however, that with economic development increasing incomes and increasing influences of education the demand for vegetables in the towns will grow rapidly. At present it may be necessary for vegetable producers to give considerable time and energy to promoting sales. A case might be made for Government intervention to encourage vegetable consumption on dietary or purely social grounds.

### 3. COSTS OF IRRIGATION

1. In order to estimate the cost of irrigation per acre it is first necessary to determine water requirements per cropped acre. For reasons already given in Section 2.1, year round watering is assumed at or near the technical optimum. The estimates used are given in Appendix I.

2. Estimates are:-

I For surface water

- (a) furrow irrigation - average 0.2 inches or 4960  
galls/day/acre
- (b) sprinkler irrigation average 0.15 inches or 3534  
galls/day/acre

II For underground water

- (a) furrow irrigation - peak .06 inches or 1293  
galls/hr/acre
- (b) sprinkler irrigation - peak .03 inches or 647  
galls/hr/acre

3. Budgeted costs of various water sources are given in Appendix II. In these costings interest is charged at 8%. This is the standard rate of interest charged on all agricultural loans by the National Development Bank.

#### 3. (i) COSTS OF SURFACE WATER - GRAVITY FED - NO STORAGE

1. If the irrigated area adjoins the source of water as is the case with cultivated river banks or molapos subject to periodical flooding, no costs are incurred in providing the water. Land preparation might represent an annual expense of about R3 per acre (see Table AII.1). This is well below the returns which might be expected from irrigation.

2. However, without storage, control of water supply might prove difficult. This is a particular problem with schemes relying on flood waters. In some seasons there may be insufficient water, in others too much. As a result the returns estimated in the previous chapter for fully and regularly irrigated crops are unlikely to be achieved.

3. If the irrigated area is some distance from the source of water capital will be invested in providing a furrow, a canal or pipeline. Cost per acre will vary tremendously depending upon the distance covered and the acreage irrigated.

Capital investment might vary from R40 to R650 per acre and annual costs from R5.9 to R12.3 per acre (see Tables AII.2 and AII.6).

3.(ii) COSTS OF SURFACE WATER - PUMPED

1. Pumping costs are given in Table AII.4. Two examples are given, one from a relatively large scheme - 60 acres in the Tuli Block and the other for a small 3 acre unit.
2. The Tuli Block costs are based on actual capital investments recorded for a particular farm in a recent survey.
3. Afgate Sprinkaan pump costs are those recently incurred by an African farmer in the Maun area.
4. In both cases the additional capital cost per acre of pumping is around R70.

Estimated annual costs range from R35 to R45 per acre. The higher costs may exceed the expected return from irrigated crops.

5. To justify investment in pumping it is desirable to have an assured water supply. On the Tuli Block this is provided by storage weirs.
6. The pump may have sufficient head to operate sprinklers at little or no extra charge as with the Afgate Sprinkaan pump.

3.(iii) COSTS OF STORED WATER - SMALL DAMS

1. This refers to small earth dams such as those established by the F.F.H.C. dam building unit.
2. So far one has been completed which might be used for irrigation - Dam No. S.C.8.M. Estimated costs are given in Table AII.5.
3. This costing is based on information provided by the Land Use Planning Unit. Dam building machinery is depreciated at a standard hourly rate.
4. Alternative estimated depreciation of equipment is based on actual costs of equipment used by the Dam Construction and Land Use Planning Unit depreciated over 5 years.

The proportion of total depreciation attributable to Dam 8 was estimated on the basis of 7 dams being built in 11 months. This approach gives depreciation costs twice as great as those given in Table AII.5.

5. In addition a 3,000 ft. canal will be needed to carry water from the dam to the irrigated area. On the basis of this costing, capital and annual capital costs are higher at about R550 and R55 per acre respectively, than those given above for surface water.

6. Returns from irrigated agriculture are unlikely to be sufficient to cover such costs.

3.(iv) COSTS OF STORED WATER - BIG DAMS

1. Several dams have already been constructed in Botswana e.g. Gaberones, Mogobane, Nuane, and several others are proposed e.g. Shashi, Mahalapye, Palapye.
2. Two are costed in Table AII.6, the Gaberones Dam and the Shashi Siding Dam, with associated irrigation schemes which have been suggested.
3. The cost of water from the Gaberones Dam was estimated by W.B. Calder (hydrological Engineer with Water Branch) and his figure of 4.33 cents per 1,000 gallons is used here.
4. An irrigation scheme was proposed for Tlokweng village about four miles from the dam. Although this proposal is now in cold storage. It was proposed to irrigate 400 acres and for this purpose Toumey (Water Engineer) estimated that a pipeline costing in the region of R60,000 will be necessary. Ivey (Irrigation Agronomist) however estimated a cost of only R24,000.
5. At 4.33 cents per 1,000 gallons, the cost of water alone is likely to exceed the return from irrigated crops. When the cost of the pipeline is added the annual cost of over R80 certainly exceeds returns which might be achieved.
6. Costs of Shashi Siding Dam and irrigation scheme were estimated by B.G.A. Lund and Partners, Hydrological consultants to the Botswana Government.
7. Here an annual cost of about R40 per acre might be covered by the return from irrigated crops.
8. From these estimates it would appear that cost per 1,000 gallons of irrigation water is about 4 or 5 cents.

Costs vary with dam size and the geography of the dam site and with the water transport distance relative to the irrigated acreage.

9. Water supplies are more expensive to exploit than in wetter regions, not only because rainfall is sparse but also for several associated reasons. Dams have the great disadvantage, as compared with those of more humid lands, of being exposed to greater evaporation, greater sedimentation and greater uncertainty of supply. Evaporation is greater because of higher heat intensities and more hours of bright sunshine.

Sedimentation is greater because of sandy soils, and high rainfall intensities leading to high rates of run-off and erosion. There is an economical limit to dam size owing to a general increase of evaporation losses as the volume and particularly the surface area of stored water increases. The problems are aggravated in Botswana by the generally flat topography and hence the lack of good natural dam sites. Dam walls must be long in relation to the volume stored. Surface area and hence evaporation loss is high in relation to volume stored and because the catchment area is large and the dam shallow, capacity is rapidly reduced by silting.

### 3.(v) COSTS OF STORED WATER - CATCHMENT TANKS

1. Catchment tanks are generally pits dug in the ground and lined with an impervious material. Rainwater runs off a catchment area into the tank for storage.

2. Several such tanks have been established at the Bamangwato Development Association farm at Radisele by Vernon Gibberd on an experimental basis. Costs of materials given in Table AII.7 were obtained from him. These tanks follow designs proposed by M.G. Ionides of Doxiades Associates. Various different lining materials were compared. The cheapest by far was P.V.C. and the dearest Butyl. A detailed report on these tanks is being prepared on behalf of the Intermediate Technology Development Group and should be published shortly (1969).

3. It would appear that the cost of materials alone, ignoring the labour costs of making the tank, render the butyl-lined tank too expensive a source of irrigation water.

4. The polythene-lined tank has a high cost per 1,000 gallons or per acre irrigated and it is unlikely that farm scale irrigation could be justified from these tanks.

However, with very small scale intensive vegetable growing Gibberd is achieving gross margins well above the water costs. (See Table 4).

5. Little is known of the optimum pattern of usage of a catchment tank but it is quite possible that by use of a large catchment area and by frequent emptying, a tank could be made to fill several times in one rainy season. There would still be serious risks of it not filling at all during drought periods.

The cost of water might then be reduced below the estimates given here.

6. Catchment tanks may have a valuable contribution to make in providing small supplies at the point where they are required at specific critical times. For instance, catchment tanks on the lands could enable farmers to cultivate and plant before the major rains start and hence make far better use of the rains when they do come. The increased yield resulting from early planting might well outweigh the costs of the limited amount of water which would be required.

Then again catchment tanks if used to provide domestic water supplies in rural areas plus some water for an irrigated vegetable garden which is supplementary to the owner's main occupation, might give returns, in terms of improvements in welfare, greater than the purely financial gains from irrigated agriculture.

For further discussion see I.T.D.G. Report on Catchment Tanks and Micro-Irrigation in Botswana (1969).

### 3.(vi) COSTS OF UNDERGROUND WATER - BOREHOLES

1. Borehole water is used for irrigation purposes by a few African farmers in various parts of the country and by white settlers on the Tuli Block.
2. An irrigation demonstration unit based on a borehole has been established in Lobatsi intended to be representative of the type of irrigation scheme likely to be established by African farmers in other parts of Botswana. Table AII.8. Although it now seems unlikely that schemes based on boreholes will be encouraged (see para 10 below).
3. Costs of drilling and equipping the borehole are average costs given by the Geological Survey Department rather than the actual costs of the Lobatsi borehole.

Thus the mean depth of hole drilled during the last five years in Botswana is 240 feet. Apart from this a proportion of drillings are failures thus increasing the cost per successful hole.

The capital cost of a typical borehole is about R3500.

4. Average yields are generally lower than that of the Lobatsi borehole but very low yielding holes are unlikely to be used for irrigation. However it would be comparatively rare to be able to irrigate ten acres from one borehole.
5. It has been pointed out by Roblin (Agricultural Officer Ranches) that the Geological Survey results may give an overestimate of borehole costs for irrigation, as most boreholes are drilled for domestic or livestock uses. If a borehole is required for a village it must be drilled nearby even though the aquifer may be deep and low yielding. If a new enterprise, such as irrigation is proposed, it will only be

established where there is a good supply of water so drilling depth may be less and yield higher than average.

6. Even with a better than average performance the cost of borehole water at around R80 per acre is unlikely to be met by growing field crops under irrigation. Intensive vegetable growing might provide adequate returns.

7. The costs of a borehole in the Tuli Block are based on data collected from Van Roos the manager of Gesond Estate. Boreholes in this part of the Tuli Block are drilled through the alluvium on the banks of the Limpopo. Water is found at very shallow depths and the yields are very high by average standards.

8. Cost of water per acre under these conditions is only between R20 and R30 and together with sprinkler irrigation only between R50 and R60. See Tables AII.8 and AII.3.

9. Under these conditions irrigation from a borehole can be a sound commercial proposition but such conditions may only exist at the Northern end of the Tuli Block. However, the borehole used by the village co-operative at Mochudi, 10 miles North of Gaberones appears to give a much higher than average yield at less than average depth.

10. The most recent information available from the Department of Agriculture is that there is concern over the possible depletion of underground aquifers and in general the use of boreholes for irrigation will be discouraged.

### 3.(vii) COSTS OF UNDERGROUND WATER - SAND EXTRACTION

1. Many of Botswana's rivers are apparently dry sand rivers for most if not all of the year. However below the surface the sand is rarely dry and water can be extracted.

2. Basically a simple well of perhaps 3' diameter is constructed and water pumped out.

3. The costs of a typical sand extraction unit have been estimated by K. Butler, Senior Agricultural Officer (Animal Husbandry). These costs are given in Table AII.9.

4. The capital cost of a typical sand extraction unit is far below that of a borehole but sand extraction units may fill with sand, in fact one at Setsile has already done so a number of times. It is suggested that Monopumps - available in Bulawayo can operate even when buried in sand.

5. Another disadvantage is that sand extraction points may dry up. This may be avoided by pumping from several wellpoints during the year but the cost of establishing several points is of course greater.

6. Annual cost per acre and per thousand gallons are lower than the comparable costs for typical boreholes. However, farmers at the Northern end of the Tuli Block have all changed from sand extraction to boreholes as under their conditions boreholes are a cheaper source of water.

7. Nevertheless, it would appear that where sand extraction is possible (i.e. where there is an adequate water reservoir in a sand river) it can provide water at a cost low enough to justify its use for irrigation.

### 3.(viii) SUMMARY OF WATER COSTS

1. Comparison of the various sources of water (Table AII.10) suggests the following listing in order of increasing cost per acre.

- |       |  |
|-------|--|
| }     | 1. Surface water - no storage - gravity fed        |
|       | 2. Surface water - no storage - pumped - low cost  |
|       | 3. Borehole - low cost                             |
|       | 4. Sand extraction                                 |
|       | 5. Dam - low cost                                  |
| <hr/> |  |
| }     | 6. Surface water - no storage - pumped - high cost |
|       | 7. Small dams                                      |
|       | 8. Borehole - average cost                         |
|       | 9. Dams - high cost                                |
|       | 10. Catchment tanks                                |

2. Returns from irrigated field crops should be sufficient to cover the costs of water from sources 1 to 5 but not from source 6 onwards. Thus it is impossible to generalise about boreholes or dams, in certain circumstances costs may be low enough to make irrigation of field crops profitable.

3. Even the most expensive water from catchment tanks can be paid for from returns from intensive vegetable production.

4. For comparison some costs of surface water in Swaziland are given in Table AII.11. Although the capital costs per acre appear somewhat

higher than those for Botswana given in Table AII.10 for similar water sources, the annual running costs are quite close.

#### 4. SOCIAL COSTS AND BENEFITS

##### 4.(i) ECONOMIC AND SOCIAL PROJECT APPRAISAL

1. A simple comparison of direct costs and returns at current market prices such as has been implied so far ignores various other costs and benefits, which may be less tangible and hence less readily estimated.
2. The full costs and benefits of a project estimated at their real value to society as a whole are known as social costs and benefits. These social costs and benefits form the basis of full project appraisal using cost/benefit analysis.
3. Although full project appraisal is not attempted in this study it is important to discuss some of the other considerations which might be taken into account in making such an appraisal.

##### 4.(ii) RISK REDUCTION WITH IRRIGATED AGRICULTURE

1. Financial viability of schemes has been assessed in terms of whether average returns from irrigated crops are adequate to cover costs including a competitive return on capital investment.

This is a justifiable and widely accepted method of financial assessment.

2. However, irrigation has the major advantage over dryland arable farming of reducing the risk of complete crop failure besides increasing average returns.
3. Therefore, the full benefit of irrigation should be valued in terms of the increased return plus the value of risk reduction.
4. Insofar as complete crop failure is catastrophic the reduction of risk of this happening is a valuable benefit.
5. In the present study it has not been possible to place a value on this reduction of risk but it is important that this should be borne in mind in considering the financial assessments.
6. However, it is debatable whether dryland agriculture is necessarily more risky than irrigation. The existing pattern of both crop and livestock production in the agriculture of Botswana reduces risk through diversification. In drought periods when crop yields are reduced or negligible livestock sales are increased. There is a significant inverse correlation between livestock sales and rainfall. No

doubt the sale of stock is forced upon the farmers by the shortage of water but it must provide a source of income when crop returns are low.

7. Returns from irrigated crops are still frequently subject to wide variation. On the Gezira scheme in the Sudan there are wide fluctuations in both yield and price of cotton. (See Suliman 1965, Jackson 1969).

8. However, because of rainfall variation the surface water resources which might be used for irrigation are themselves subject to variation. Dams must be designed to store considerably more water than the amount actually required. For a given yield to be assured at all times there must be surplus capacity. Thus for much of the time, perhaps eight years out of ten there will be surplus water.

It has been suggested in Botswana that the entire assured yield of all large dams being constructed, will be required for domestic and industrial use but that the variable surplus should be used for irrigation.

9. Although there is a certain attractiveness in making use of this variable water surplus which would otherwise be wasted, risks would, if anything, be increased by introducing irrigation on this basis. The administrative problems of having no water in certain years, in which case presumably the scheme would have to close down, might be considerable.

One is therefore led to question whether crop storage might be a better way than irrigation of avoiding the risk of crop failure.

#### 4.(iii) IRRIGATION AS A SUPPLEMENTARY USE OF WATER

1. The argument so far has been concerned with irrigation as an alternative to other uses of water. However, in many cases it may be supplementary to other uses of water.

2. For example, a borehole might be drilled with the objective of providing water for domestic purposes or for livestock. However, the yield of the borehole may be more than adequate for these purposes so surplus water is available which might be used for irrigation.

This is quite likely to occur with stock watering boreholes. The number of cattle watering at one borehole is limited to about 400 by the carrying capacity of the veld. Water requirements per head are in the region of 8 gallons per day so a borehole yielding 2,000 gallons per hour need only be pumped for 1.6 hours per day. If it could be pumped for 10 hours per day a considerable surplus would be available

for irrigation. In fact more than 400 cattle are watered at some boreholes - but this will probably lead to deterioration of the veld. Thus use of the water for other purposes would have the additional benefit of restricting stocking density.

3. A similar situation may occur with a large dam constructed for the purpose of providing water for domestic and industrial use.

However, water supply for such uses must be assured in all years. Because of variation in annual rainfall, there will be a surplus in most years which might be used for irrigation.

The possibility of being without irrigation water in certain years is not very satisfactory. A major advantage of irrigation is the reduction of risk crop failure but if in drought years no water is available for irrigation then the risk is not really reduced.

4. This possibility of irrigation being a supplementary use of water has important implications for costing the irrigation project. In the extreme case, the borehole or the dam might be economically justified for the main use for domestic, livestock or industrial purposes. Returns from these sources are adequate to cover all water costs.

The surplus water is then available for irrigation at little extra cost other than pumping costs where pumped. Thus in costing a scheme based on surplus supplies water charges will be very small indeed. However, any extra investment on pipelines, canals, land clearing etc. should be charged for.

5. Even where returns from other uses are insufficient to cover the cost of providing water, irrigation would be economically justified if returns from the other uses and irrigation together are high enough to cover total water costs.

Supplementary use of water represents a reduction in real cost of irrigation water which has not been accounted for.

#### 4.(iv) SOCIAL COSTS AND BENEFITS

1. The costs and benefits of irrigation have been estimated at current market prices. However, it is argued that market prices don't necessarily reflect the costs and benefits to society as a whole. In this case to Botswana as a nation.

2. For instance, if wage rates are fixed well above the marginal product of labour in Botswana, then the wage bill will represent an inflated estimate of the cost to society of using that labour.

Conversely the social cost of capital (i.e. the competitive rate of return) might be considerably higher than the official rate of 8 per cent used in this analysis.

3. Again irrigation schemes might have beneficial effects or harmful effects on health and social life which are not measured simply in terms of market prices. For instance, an irrigation scheme might have the beneficial social effect of establishing a settled pattern of agriculture or the harmful effect of introducing Bilharzia.

4. Then again a large irrigation scheme might flood the market with irrigated crops and thus force the price down. Present market prices then represent an overestimate of the returns which might be expected.

5. The social benefits and costs which are not reflected in market prices are difficult to measure in financial terms. In this study no attempt has been made. However their omission might be justified on the following grounds:-

(a) They are relatively unimportant in that there is little Government interference with the pricing mechanism in Botswana so market prices tend to reflect social prices.

(b) Irrigation schemes in Botswana are unlikely to be big enough to influence prices by say flooding the market with produce, as the market for most Botswana cash crops is the large South African market.

(c) To some extent extra social costs and benefits will tend to cancel each other out; inflated labour costs, may be set against deflated capital costs; harmful and beneficial effects on health and social life may be set against each other.

(d) Other projects, with which investment in irrigation is to be compared, will equally have social costs and benefits.

#### 4.(v) GENERATED SECONDARY BENEFITS

1. A particular social benefit which is often emphasised in project appraisal is the generated secondary benefit. When a scheme is established in a new area it may set off a whole chain of developments. The employees of the scheme will wish to spend at least part of their incomes on consumer goods so traders will move into the area to supply their wants and this can gradually lead to the more general development of the area.

Some irrigation schemes in other parts of the world have been "justified" purely in terms of their secondary benefits.

2. Secondary benefits are not allowed for in this study and indeed it is not considered that they should be allowed for.

The reason has already been given in discussing social benefits, namely that when we are appraising irrigation schemes we are generally comparing them with other forms of investment. It is wrong to assume that if resources are not used for irrigation then they will not be used at all. But any other scheme or project for which resources might be used, whether it is a cattle ranch or a factory, will also bring with it, its own secondary benefits which might be just as great as the secondary benefits of irrigation schemes.

#### 4.(vi) FINANCIAL MATURITY AND TIME DISCOUNTING

1. In any project appraisal future net benefits must be discounted to their present value in order to determine whether new investment is justified.

2. This has been done by estimating the annual cost of a capital investment as a sinking fund annuity BUT this annual cost will be chargeable right from the date of establishment of the scheme whereas it may take several years before the scheme reaches financial maturity and the full return from irrigated crops can be expected.

3. The only case where this delay has been allowed for in assessing irrigation projects in Botswana is the redevelopment of the Mogobane scheme. In the proposals for this redevelopment it is assumed that full returns will not be obtained until the fourth year. Many authorities would consider this to be too short a period. In fact Gadgil (1948) suggests 30 to 50 years to be the period necessary for an irrigation scheme to reach maturity in Central India. Gadgil's is rather an extreme view but it does serve to emphasize the need for allowing for a period of growth to maturity.

4. However; even if maturity is only delayed a few years the discounting of the returns to be expected at maturity leads to a much reduced present value of net benefits, at the time of establishment of the scheme.

Hence the comparison of costs and returns at maturity represents an optimistic evaluation of the economics of an irrigation scheme at the time of establishment.

5. This discounting effect becomes greater if the rate of interest (i.e. discount rate) is increased. As has been remarked above 8% may be an unrealistically low measure of the real cost of capital.

5. A CONSIDERATION OF SPECIFIC SCHEMES

5.(i) NXARAGHA VALLEY SETTLEMENT

1. The Nxaragha valley is typical of many valleys which form the complex inland delta of the Okavango. The traditional practice is to cultivate the valley depressions (molapos) as the floods recede. The previous inhabitants were driven out by the advance of the tsetse fly in 1941, prior to which the valley had been regarded as one of the best maize producing areas in Okavango region.

2. Following a tsetse fly eradication campaign an Agricultural Officer was sent to the valley in 1957 to investigate its reclamation. Resettlement with irrigated agriculture was recommended. With the help of funds from OXFAM a crop experimental station was established at Moshu to provide information on the economy of major crops in this region.

The work at Moshu soon showed that high yields, particularly of cotton, could be produced in the area.

3. In 1965 a grant of R20,000 was obtained from OXFAM and fifteen settlers were selected and established in the valley. Each settler was provided with 25 acres of cleared and cultivated valley land and 1,300 acres of land for grazing communally.

It was estimated that the 25 acres of seasonally flooded valley land would provide a gross return of over R1000 or a net return to labour of R700.

4. In fact the budgets were rather optimistic, - the estimated yields have not been achieved and there may be problems in marketing the produce.

5. The tsetse fly has not been eradicated and cattle have to be strictly herded and kept to the south side of the valley. Cultivations are done by a tractor and machinery service unit provided free by the Government. These free services are justified on the grounds that it is a temporary measure until cattle draft can be used. However, despite this a charge is surely warranted.

6. During the first year (1965/66) the whole scheme was flooded out, the settlers moved back to Maun and the whole scheme was abandoned for that growing season. The Department of Agriculture insist that the flooding was due to "abnormal rains" but one questions how abnormality is defined. There is no justification for assuming that such floods will not occur in future.

7. During the season 1967/68 the valley is again being cultivated though the average cultivated area of molapo per farmer is  $15\frac{3}{4}$  acres not 25 as planned. A few settlers are cultivating the full acreage but the average is reduced by others who are cultivating very few acres and then using hired labour rather than their own family. Only  $\frac{1}{2}$  acre of cotton is grown on average per farmer as against 5 acres planned, whereas  $8\frac{1}{2}$  acres of sorghum are grown where only 5 acres were proposed.

8. The following conclusions may be drawn:-

- (a) some means of flood control is needed
- (b) the management of the settlement needs to be tightened up.
- (c) marketing problems may arise
- (d) the scheme should be economically viable and perhaps suitable for repeating elsewhere in the Okavango basin provided that the costs of (a) and (b) can be met.

9. Flood control

It will be difficult to justify capital investment in the land and to persuade settlers to remain if there is a danger of flooding. In other years there may be a danger of inadequate floods to water the area. Furthermore the present system of using the natural flood only gives the farmer one chance of getting benefit from the water. A system of bunds for flood control might well reduce the risk and improve the efficiency of water utilisation. The Government Land Use Planning Officer has prepared provisional proposals along these lines (Youthed S.H. memo of 4/7/67).

These techniques are being used to control swamp waters in Sierra Leone for irrigated rice production. Peace corps volunteers are working with local farmers in constructing bunds under the overall direction of an American farmer. This is a practical project rather than a research programme.

10. Management

Certain of the "settlers" are living outside the valley, using hired labour to do all the work and only cultivating a fraction of the available acreage. The fact that water and tractor and machinery services are provided free, encourage individuals with other occupations to apply for a holding in the valley.

Obviously where possible such individuals should be replaced by men who are prepared to live and work full-time in the valley.

Although, since, the land has customary owners, even though not occupied by them, it is difficult to get them to settle in the valley.

However, it would appear that a system of charges should be introduced, certainly for tractor and machinery services and perhaps for the use of cleared land. These charges would provide a return on capital invested in the scheme and perhaps help to pay the running costs. They might also serve as an inducement to settlers to improve their standards of farming.

11. Marketing problems

It perhaps needs emphasis that transport costs preclude the marketing of cheap, bulky staple foods or perishable goods like vegetables in Eastern Botswana. The market in the Okavango region is very restricted and marketing problems may arise.

12. Economic viability

Although as suggested above the estimates used were perhaps a little optimistic, a budgeted net return of R700 per family is better than that expected from most other agricultural schemes in Botswana. The return on the capital grant from OXFAM is well over 50%. On the basis of these estimates the scheme would appear a very attractive economic proposition.

However, in order to approach the returns budgeted, flood control and closer management would be essential.

5.(ii) THE PRESIDENT'S IRRIGATION SCHEME, CHADIBE

1. The source of water for this scheme is a spring on a hillside gravity fed onto the irrigable land. Water is virtually free. However it is estimated that a capital investment of R1936 is involved in providing a reservoir and main canal.

2. The water will be used to irrigate  $2\frac{1}{2}$  acres of vegetables so the capital cost per acre will be R774 representing an annual cost of R115 per acre.

3. This is a high level of investment per acre and intensive production with multiple cropping and high yields will be necessary to provide an adequate return.

5.(iii) THE TULI BLOCK - WHITE SETTLER PUMP SCHEMES FROM LIMPOPO  
RIVER AND FROM BOREHOLES

1. The Tuli Block an area of almost 2,000 square miles lying along the Western Bank of the Limpopo River was granted in perpetuity to the British South Africa Company with power to sell or lease the land. It has been divided into farms, most of which have been sold with freehold title to freehold farmers.
2. "The Limpopo is nearer to being a perennial river than any other river in Eastern Bechuanaland, but even so, its flow is usually interrupted towards the end of the dry season. Natural pools, however, often contain water throughout the year and there are a number of artificial barrages and tanks in the river bed which supply irrigation schemes. Wells are an essential additional source of water for both domestic and agricultural purposes." (Bawden and Stobbs 1963).
3. In fact the water flow in the river appears more reliable at the Southern (upstream) end of the Tuli Block (Parr's Halt to Martin's Drift) and in this area most of the farmers are pumping from the river, generally having installed a storage weir to improve the water supply. The flat gradient of the river in this area enables a 6 ft. or 8 ft. weir to hold water back for several miles.
4. In this area the West Bank is classified by Bawden and Stobbs as "land primarily suitable for cultivation with potentially irrigable soils".
5. Again at the extreme North Eastern end of the Tuli Block, further downstream, there is another area of irrigable soils. These are in fact deep alluvial soils. In 1963 these soils were watered from sand extraction units but today farmers in the area are using boreholes near the river. Boreholes require less maintenance and give higher yields than the sand extraction units.
6. The area of land under irrigation in the Tuli Block has rapidly increased in the last few years. In 1963 the estimated total irrigated area was 2,635 acres whereas in 1967 it was 3,818 acres, an annual growth rate of about 10%. Today Ian McFarlane, a farmer at the Northern end of the Block estimates an average expansion in irrigated area of 15% and on his own farm 25% per year. He estimates the rate of expansion would be greater if more credit were available.
7. In the parts of the Tuli Block mentioned above there exists the valuable combination of good irrigable soils and a good water supply near at hand. In these conditions irrigation is undoubtedly a profitable venture.

The net returns to irrigation estimated in Section 2 (i) of R67 per acre are considerably higher than the estimated annual costs of irrigation in the Tuli Block (See Tables AII.3, 4 and 8). Water pumped from the river and used for furrow irrigation costs R35 per acre per year (Table AII.4) and borehole water applied through sprinklers about R55 per year (Tables AII.3 and 8).

The return on capital invested is possibly of the order of 20%.

8. In addition to good soils and a water supply, African labour is available on the Tuli Block and markets, mainly in South Africa, are accessible. Also there seems to be considerable enterprise and willingness to innovate among the Tuli Block farmers. These near ideal conditions for the development of irrigation do not exist elsewhere in Botswana, as far as is currently known.

9. The potential of the Limpopo is being limited by the fact that South Africans are damming all the main tributaries. They have already erected 22 major dams in the catchment area.

#### 5.(iv) PRIVATE IRRIGATION SCHEMES INSTALLED BY AFRICAN FARMERS

1. In various parts of the country farmers are establishing small irrigation schemes, frequently with the encouragement of the agricultural extension service.

For example the Agricultural and Livestock Officer in Maun has established a demonstration plot on the Thamalakane River and is selling portable pumps to local farmers. Vegetables are recommended and grown.

In the Annual Report of the Department of Agriculture for 1965/66, over 30 irrigated vegetable gardens are reported to have been established in Serowe.

Private schemes watered from boreholes, sand extraction units and surface river water were seen during the author's visit.

Other private irrigation plots may be watered from small dams built by the F.F.H.C. Dam Building Unit.

2. In all cases vegetables are grown rather than field crops. This appears to be the best policy provided markets can be found for the vegetables. Most farmers are short of capital and cannot afford to embark on large scale production. They are therefore better advised to concentrate on high return, labour intensive crops such as vegetables.

3. Those schemes based on pumping from open water such as the Thamalakane River should be low in cost and therefore profitable. However some of the pumps are used for very few hours to water a very small area. Average costs are reduced by spreading the overhead costs of the pump over as many hours pumping and as many acres of irrigated land as possible.

4. The cost studies discussed in Section 3 of this report suggest that water from small dams, boreholes and sand extraction units may be rather costly for irrigation, (see Table AII.5, 8 and 9). Nonetheless, estimates given in Table 4 suggest that it is possible, with good management, to obtain returns from intensive vegetable production which would cover these high costs.

5. As already discussed, if the dam, borehole or sand extraction unit is established for some other purpose and irrigation is introduced as a supplementary enterprise to use surplus water, the economic cost of the irrigation water may be much reduced or even zero.

In such cases irrigation can provide a valuable addition to net family income.

#### 5.(v) THE MOGOBANE IRRIGATION SCHEME

1. This scheme consisting of around 200 acres irrigated from a dam was established on Bamalete Tribal Territory in 1940 with a Government loan of £2,000. It is difficult to believe that this sum represents the entire cost of the dam of 960 acre feet capacity, the main canals, furrows, fences and roadways and the land preparation. Judging from the costs of other dams (see Tables AII.5 and 6) the costs today might be nearer £100,000 or say R175,000.

2. Until this year (i.e. for over 25 years) the scheme has been operated by the Bamalete Tribe. The Agricultural and Livestock Officer responsible for extension work in the area was engaged in part-time management in an advisory capacity only.

3. "Owing to the policy of tribal labour and less than market prices for the product which led to low or negative profits, and the failure to depreciate the capital cost of the Scheme, there was no accumulation of capital to maintain the canal, the furrows, the fences and other capital works of the Scheme. These therefore steadily deteriorated, the dam is silting up rapidly, the concrete linings to the furrows are broken, the silt traps are completely undermined, the fences are down, a large acreage gets water-logged in a wet season and the Scheme is infested with couch grasses." (Annual Report of the Department of Agriculture 1965/66).

4. Proposals have therefore been submitted to the National Development Bank and later to OXFAM for redevelopment of the scheme. Under these proposals the Department of Agriculture would take over full control for five years, to transform the scheme into a "highly productive and economically viable concern." At the end of the period of Government management and improvement the scheme would be returned to the tribe.

5. Under these proposals a loan of R37,000 has been requested to "refurbish" the existing distribution system, to increase the capacity of the dam by raising the spillway and the sagging centre of the dam wall, to install a sprinkler irrigation system on an 80 acre block, to purchase new machinery and equipment and to provide working capital for the first year's operations.

6. It is questionable whether the estimated capital requirement is adequate as only R3,200 have been requested for the entire improvement of the dam and distribution system.

D.Toumey. SCAAP water engineer estimates that the present dam, capacity 960 acre feet, does not provide sufficient water to irrigate 200 acres. He suggests that a minimum capacity of 2,000 acre feet is needed to ensure full use of the scheme and allow for evaporation. The total cost of increasing the dam capacity to 1,690 acre feet he estimates to be R7,000. This with some possible recharge might be adequate.

7. G.S.Jackson, Agricultural Economist has prepared budgets for the Mogobane Scheme based on crop margin and input estimates which have been quoted in Table 2.3. He has estimated margins net of labour and other unallocated costs of R2,990 in years 1 and 2, R9,030 in year 3 and R11,930 in years 4 and 5 and presumably thence onward. This represents an internal rate of return on the R37,000 loan of 1% in the first 5 years. However, if the annual return of R11,930 can be maintained over 20 years or longer the return on the capital loan would be about 20%.

The net margins represent the gain from the new investment as currently the scheme is operating at a loss.

Thus the estimated returns on new capital are satisfactory and the new investment justified.

8. However, apart from questioning the adequacy of the loan requested, Toumey has suggested that the waterlogging will not be permanently cured. This is because the tribe will not accept the lowering of the ponded water along the river course. Mitchell's view is that the river level need not and should not be lowered, but that the reeds choking the channel should be cleared and a weir put in to prevent the rise of several feet that often takesplace as the result of quite

a small addition of flood water.

If the waterlogging is not cured one might question whether the performance envisaged by Jackson will be achieved. In fact the only major change suggested in the new proposals is that the Agricultural Officer responsible will be engaged full-time on the scheme rather than part-time. Hence the budgets might be rather optimistic as suggested earlier.

9. Although the existing proposals suggest a good return on capital, advantage is to be taken of the fact that the dam, distribution system and other assets are already in existence at Mogobane.

Clearly, to establish a similar scheme from scratch today would cost perhaps five times the new investment at Mogobane. The long-run return on capital on a new scheme might be only 4%. Not a very attractive rate.

10. Similar arguments might apply to the Bathoen dam, a smaller scheme which it is also hoped to redevelop.

5.(vi) TLOKWENG IRRIGATION SCHEME FROM GABERONES DAM

1. Proposals for this scheme are now in abeyance (1969) but consideration is still justified

- (a) because the proposals may be resurrected at some stage
- (b) because the discussion may influence thinking on other proposals for irrigation from big dams.

2. Proposals have been made for an irrigation scheme in Tlokweng village to be fed from the Gaberones Dam. It has been suggested that the scheme should be started on 100 acres but it would ultimately be expanded to over 400 acres.

3. A branch from the main pipeline would carry water to the Central prison to irrigate 20 acres of vegetables.

4. A. Mitchell, the soil surveyor found 1,000 acres of irrigable soil in the Tlokweng area which could be commanded from the dam, but Toumey, the water engineer considers that there will be sufficient water for only 450 acres. Furthermore, irrigation will only be possible when the needs of domestic and industrial users have been met. The surplus over these needs is variable and likely to increase, and, on the basis of estimates for the Shashi Dam it would appear that irrigation will be limited for four years out of ten and will not be possible for two years out of ten.

This situation will not arise for several years as current daily consumption is one and a quarter million gallons per day, but it is predicted that this will rise to six million gallons.

5. Toumey estimates that the cheapest method of conducting water from the dam to the irrigation site would be by pipeline at a total cost of R56,350. The distribution system would cost a further R40 per acre for furrow irrigation. Ivemy estimates only 24,000 however.

6. The capital investment per acre of pipeline and distribution system is therefore R100. (See Table AII.6). As already stated (Section 3) if a charge is added for the water stored in the dam it would be difficult for the scheme to provide an adequate return to cover these costs. However, the dam has already been justified and is in existence. The irrigation scheme would therefore be a supplementary project and no extra costs are involved in making water available.

7. If a net return of R40 per acre could be obtained (see Section 2, Returns from irrigated crops) the return on capital would be about 24%. However, if no water is available in two years out of ten and is restricted for a further four years the average return might be under 14%.

8. The administrative problems of having no water in certain years, in which case presumably the scheme would have to close down, might be considerable. If a cost could be applied to the periodical closure of the scheme the net return on capital might be further reduced.

9. The prison scheme and the Chinese Agricultural Mission Demonstration Farm, which are, or will be supplied with water from Gaberones dam are relatively small in scale. Non-financial considerations will weigh heavily in the justification of these projects. (See additional notes under para ix).

#### 5.(vii) IRRIGATION FROM THE SHASHI RIVER

1. The soil surveyor found about 1,500 acres of irrigable land commandable from the Shashi Siding dam, within 16 miles downstream on the South bank. According to Lund the canal to command this would be 31 miles long.

2. Two schemes have been proposed for this area:

(a) a 3,000 or perhaps 4,000 acre scheme to be fed by canal from the new Shashi Siding dam. (Costed in Table AII.6). These proposals have now been dropped but discussion is still justified for reasons given under discussion of the Tlokweg scheme.

(b) a pilot irrigation project of 115 acres to be fed from sand extraction units in the Shashi River.

3. Both proposals are currently in abeyance and may be discarded because it has been suggested that there may be insufficient water. Dr. Stivens of Sir Alexander Gibb & Co., Consultants to the World Bank, has stated that all the water stored in the dam will be required for domestic and industrial use and the construction of the dam may cut off the supply of water in the sand below the dam site.

4. In the original proposals for the dam and irrigation scheme (a) above, by B.G.A. Lund & Partners it was assumed that the irrigation scheme would be watered with the variable surplus over and above the assured supply, all of which would go to domestic and industrial users. Lund used the technique of simulation on a computer to estimate the variation in availability of irrigation water, and suggested water would be available in eight years out of ten for the irrigation scheme.

5. It is difficult to see why the situation should be any different. Domestic and industrial supplies must be assured and this means that, since there is variation in annual rainfall, there will be surplus water in most years.

6. Detailed budgets have been prepared for this scheme by Lund, Taylor, the then Agricultural Economist, and Weare, Chief Agricultural Officer (research), and others. It was suggested that the scheme should be made up of four acre holdings each producing cotton, maize, legumes and winter wheat. The portion of the capital cost of the dam chargeable to the scheme was reduced to allow for the unreliability of water supply (Table AII.6.).

7. The total capital cost per acre of this scheme is estimated at over R700, R500 for water supply (Table AII.6) and over R200 for buildings, services and equipment.

8. At an estimated crop return net of all cultivation costs of over R100 per acre the return per farmer would be about R430 out of which capital interest and repayments would have to be met. After these repayments the net family income would be R120.

Alternatively, if R120 is charged for the farmer's labour out of the R430 income then the return on capital is about 11%.

9. Subsequent estimates suggested higher returns but these were surely over-optimistic. The estimated net return per acre of over R100 is unlikely to be achieved (See Section 2).

10. An income per family of R120 is unlikely to be attractive (for example, a miner can earn a minimum of R165 net, plus board and

lodging and free medical attention) and 11% is not a particularly attractive rate of return.

11. A further consideration is that water may not be available in two years out of ten so the average annual return on capital would only be 8%.

Against this it may be argued that the charges for part of the cost of the dam and for services such as roads and agricultural advice should not be included. The former because the water would otherwise be wasted so no extra cost is involved in supplying the water to the scheme and the latter because these are social overheads available free of charge to other producers.

Nonetheless, although water would be available for this scheme it is questionable whether it can be justified economically.

12. Toumey, the water engineer, has suggested that a small scheme (b above) watered from sand extraction units might well be feasible after the dam is built.

The local catchment below the dam is at least two miles wide so he suggests that for every mile of river length sufficient water should be collected to irrigate 35 acres. At a point 15 miles below the dam there would be sufficient water stored to irrigate a scheme of 200 acres.

13. Furthermore if the dam fed scheme is not established the periodical surpluses could be released from the dam into the sand river below the dam.

14. The estimates for the pilot irrigation project of 100 acre settlement and 15 acres of irrigation, allowed for a capital investment of about R300 per acre. On this basis it should be possible to obtain a return of around 20%.

15. It is apparent that the costs of sand extraction in this case are expected to be considerably lower than those given in Table AII.9., the estimated capital cost per acre being only R57.50.

If these estimates are realistic and if the water supply in the sand is assured this scheme could prove financially viable. (See additional notes under para (ix)).

5.(viii) IRRIGATION FROM THE MADABE DAM

1. "A dam has been constructed by the Rhodesian Government at Madabe on the Ramaquabane River which forms a boundary between Rhodesia and Botswana. At the request of the Botswana Government, the dam was built sufficiently large to supply water to both countries. In return for an agreed capital contribution of R18,000 towards the cost of the dam, the Botswana Government is entitled to use 186,000 gallons per day". (National Development Plan 1968/73).

2. Proposals were made for selling the water to the Rhodesian Railways but this arrangement apparently was not acceptable. It is now proposed that the water should be used for an irrigation scheme in the area. Using the estimates given in Appendix I there should be sufficient water to irrigate about 53 acres with sprinklers or 37 acres with furrow irrigation.

3. The soils surveyor, Mitchell, did not find soils suitable for irrigation in the region of the dam. However, the least unsuitable soil is found on the ridge tops which are already usually cultivated. This is a deep pale acid sand, well drained, found about  $\frac{1}{2}$  mile from the dam but it would require pumping about 60' above dam level. Mitchell suggests that sprinkler irrigation would be essential.

Other more suitable soils are found on the floodplains, consisting of dark grey neutral soils and slightly acid sandy soils. These are some distance from the dam and a three mile long canal would be required.

4. The hydrological engineer, Calder, has estimated a cost of dammed water of about 3.5 cents per 1,000 gallons. In this case this full sum should be charged against the irrigation scheme which is in no sense a supplementary use of water. It is desirable that the scheme should pay the costs of the dam incurred by the Botswana Government.

This represents a capital cost per acre of R347 on 53 acres or R497 on 37 acres.

5. Adding distribution costs, the total capital investment per acre for sprinkler irrigation might be R500 (i.e. about R350 for water, R50 for pumping and R150 for sprinkler equipment).

For furrow irrigation on the floodplains the capital cost would be much higher. The 3 mile canal might well cost in the region of R40,000 judging from estimates made for the Tlokweg and Shashi schemes. This alone represents a capital investment of R1,080 per acre. So the total would come to about R,1500 per acre.

6. With net margins per acre of irrigated field crops of about R40 a return of about 10% might be obtained from sprinkler irrigation on the ridge tops. However, the operating costs of pumping and operating sprinkler equipment might amount to R20 or R30. The final return on capital might then be less than 8%.

For this reason Mitchell is justified in recommending that highly intensive production would be desirable. Vegetable production would give higher per acre returns than field crops and hence a higher return on capital. In addition he points out that as the soils are only marginally irrigable, inputs of organic manure and fertilisers will also be high and irrigation will need to be in frequent small doses owing to the low water holding capacity of the soil.

7. With net margins of R40 per acre from furrow irrigation of the floodplains the return on capital of about R1,500 is only 3%. Spread as an annuity at 8% over 20 years the annual cost of the capital investment would be over R150 per acre.

The second proposal therefore, cannot be justified as an economic venture.

8. Problems would arise in implementing any irrigation scheme from the Madabe Dam. In particular there is the problem that the land lies within the Tati Concession and is now owned by the Tati Company Limited of South Africa. Proposed new legislation might have to be introduced before any irrigation scheme could be started in this area.

5. (ix) EXPERIMENTAL AND DEMONSTRATION SCHEMES

1. Moshu experimental station
2. Chobe experimental station, Kasane
3. Chinese Agricultural Mission Demonstration Farm,  
Gaberones
4. Vernon Gibberd's work on catchment tanks at Radisele
5. Irrigation demonstration unit, Lobatsi.

1. Each of the experimental projects is aimed at obtaining information on one or more of the following kinds:-

- (a) technical - crop water requirements, yields under irrigation etc. (e.g. 1, 2, all the others in part)
- (b) economic - the costs and returns from irrigated agriculture (e.g. 4 and 5)
- (c) social and organisational - the problems of introducing and organising irrigation schemes.

2. For experiments to provide useful information it is important that
  - (a) results are carefully and accurately recorded and published
  - (b) that comparative data are obtained. e.g. that an untreated control is included for comparison or various levels of application are used
  - (c) that replications are made.

### 3. Technical data

There is an urgent need for technical data on irrigation in Botswana. It is to be hoped that the findings of all research in this field will be published.

In particular it is important that information should be obtained on the effect of varying the level or frequency of watering on crop yields.

A multi-level irrigation experiment would enable the production function to be established and the economic optimum level of water application to be determined.

Furthermore, it would be valuable to determine inter-relations between water and fertiliser use in experiments incorporating both factors.

### 4. Economic data

It is questionable whether the unit-farm, experimental approach is the best method of obtaining economic data on irrigated agriculture.

For the results to be valid it would be necessary to have controls for comparison - perhaps dryland farms. Yet for the comparison to be meaningful it would be necessary that conditions on the irrigated and non-irrigated farms should be identical apart from the irrigation. Investment per acre is likely to be higher on irrigated farms because it is an intensive system of agriculture.

Secondly, both irrigated and non-irrigated farms should be replicated, otherwise performance on the individual farm may be highly biased by the efficiency of the manager. It would also have to be replicated over a series of years to allow for inter-year variation.

For these reasons economic surveys of existing farms may be preferable to the unit-farm approach. However, in Botswana there are

insufficient numbers of African farmers practicing irrigation to make up a survey sample.

The remaining alternative is to base budgets for irrigated farming on physical relationships established in technical experiments and other sources and market price data.

This is the approach used in this report. It is limited in this case by the lack of technical data. Whilst unit farms may not provide such useful or reliable technical data as experiments would, they do often give useful experience on what can or cannot be expected from the irrigator - something which is all too often missed in the more abstract type of assessment.

#### 5. Social and organisational data

Similarly it is questionable whether an experiment can be established with adequate controls and replications to prove one form of organisation better than another.

In this respect it is surely better to base planning on experience gained from irrigation schemes in other parts of Africa viewed in the light of existing knowledge and information on the social structure and attitudes of the 'Tswana farmer.

#### 6. Demonstrations

Demonstrations may be valuable as a means of extending the use of irrigation but local farmers must understand what is being done and feel technically and economically capable of doing the same themselves.

Unit farms may, of course, serve as demonstrations but they frequently fail in this respect since local farmers do not feel capable of obtaining similar results or of acquiring the necessary capital.

6. IRRIGATION COMPARED WITH OTHER FORMS OF INVESTMENT

6.(i) RETURNS FROM DRYLAND ARABLE CROPS

Returns from irrigated crops are considerably higher per acre than returns from dryland crops. (See Table 2.1). However, in most of Botswana there is no apparent shortage of land and returns to labour and capital are far more important criteria for selecting development projects and policies.

2. Very useful information on the potential of dryland farming has been collected on the unit farms at Sedibeng and reported by the Agricultural Economist, H.S.Squire (1967 and 1968). This does not conflict with the argument presented earlier that economic surveys of existing farms may be preferable to the unit farm approach.

3. These unit farms are mixed dryland arable and livestock farms but Squire has estimated the inputs and returns for crop and livestock separately. The dryland arable crop returns for 1965/66 and 1966/67 were as follows. (Table 6.1).

Table 6.1

Returns from arable cropping on unit farms

	Labour, Manage't and investment income	Return on capital assuming lab.cost of $\frac{1}{3}$ total income	Return to family lab. after ded'g. 8% return on capital
	<u>R</u>		<u>R per family</u>
Tractor unit 1965/66	463 (2 families)	6%	22
Tractor unit 1966/67	1090 (1 family)	13%	650
Ox unit 1965/66	341 (1 family)	15 $\frac{1}{2}$ %	224
Ox unit 1966/67	665 (1 family)	30%	545

Capital investment per family (arable cropping)

Tractor unit R 2750 on 78 $\frac{1}{2}$  acres  
Ox unit R 1450 on 63 $\frac{1}{2}$  acres

4. It should be noted that 1965/66 was quite a poor year with only 14" of rainfall, badly distributed. In 1966/67 on the other hand a total of 35" fell and this is the main factor accounting for the more favourable results. Despite this wide variation in conditions Weare (Senior Agricultural Officer (Research)) who has considerable experience in the country, considers that better results could be obtained on average in this area. Four private farms in the Baralong/Bangwaketse pupil farmer scheme were recorded and these compared favourable with the unit farms, in terms of crop yields, returns per acre of land and per hour of labour.

5. Squire showed that certain of the crops grown did not contribute to the overall net return. In 1965/66, the dry year, maize returns were inadequate to cover costs of production and in 1966/67 cotton and legumes made a net loss over costs of production. If these crops had been omitted it is possible that considerably better returns to labour and capital would have been made. Sorghum and sunflowers appear consistently to give a reasonable return over costs.

Thus some replanning of the systems of farming is suggested for these units.

6. However, although the results given in Table 6.1 could almost certainly be improved upon, they compare favourably with most of the irrigation schemes under consideration. Certainly the proposed Shashi Scheme would not provide such attractive returns.

7. The standard of management on these unit farms is much better than that on the average farm in Botswana and the amount of advice and supervision much higher. With the existing pattern of extension it is unlikely that these standards of production will become widespread in the near future (Lever 1968). However the successful introduction of irrigation must depend upon the provision of considerable advice and supervision, probably of similar intensity to that given on the unit farms. Hence we are justified in comparing these results with those of irrigation schemes.

8. The potential expansion of dryland arable production is very great as shown in Table 6.2.

Table 6.2

Potential expansion of dryland arable production  
 (data from National Development Plan 1968-73)

	Total land area (acres)	Est'd.cultivable area (acres)	Under cult'n.and recent fallow (acres)	C as % of B
	<u>A.</u>	<u>B.</u>	<u>C.</u>	
Eastern Watershed	23,970,000	8,170,000	1,227,000	15%
Okavango Region	28,017,000	2,700,000	90,000	3%
Chobe	5,120,000	256,000	11,000	4%
Total	57,107,000	11,126,000	1,328,000	12%

possible overestimate

9. The potential returns might not be as great in most parts of the country as in the Baralongs, where the Sedibeng unit farms are located. However, the rainfall in much of Northern Botswana, the Okavango and the Chobe is similar to that in the Baralongs. The generally better results obtained from dryland farming in this particular area are more probably due to the social structure. However, this implies that with social change in other areas similar results might be obtained.

Table 6.3

Returns from livestock on unit farms

	Manage't.and inv't.income	Return on capital assuming family lab. cost negligible	Returns to family lab. after deductin 8% return on capital
	<u>R</u>		<u>R per family</u>
Tractor unit 1965/66	425	12%	145
Tractor unit 1966/67	785	17%	425
Ox unit 1965/66	245	7½%	negative
Ox unit 1966/67	480	13½%	200

Capital investment per family (livestock)

Tractor unit	R 3,500	Breeding herd	50	livestock equivalents on 850 acres
Ox unit	R 3,400	"	" 50	" equivalents on 800 acres

6.(ii) RETURNS FROM CATTLE PRODUCTION

1. The cattle industry is the most important industry in Botswana. Livestock and livestock products account for approximately 90% of national exports.

2. Much of the country, unsuited to dryland arable production, is only usable as grazing. As compared with an estimated potential arable area of about 1 million acres there are about 12 million acres of grazing. (Annual Report of the Department of Agriculture 1965/66). However, for the country as a whole with a semi-arid climate and a sparse population, cattle ranching is the logical method of land use.

3. Some information on the potential returns from cattle production is available from the Unit Farms at Sedibeng, a pilot holding/finishing ranch which was established alongside the unit farms, and a ranching unit established at Nata in the Northern Crown lands.

4. Cattle returns obtained on the unit farms in 1965/66 and 1966/67 are given in Table 6.3. Although the cattle enterprise on the ox unit did not provide an 8% return on capital in 1965/66 it should be noted that no allowance has been made for the fact that this enterprise is providing the motive power for crop production on this unit. The returns to capital are therefore, quite satisfactory in general, labour inputs being very low.

Table 6.4  
Budgeted returns from cattle production  
Schemes planned to be operated by two families

	Livestock equiv'ts.	Labour, mgm't. & inv't.income		Return on capital per cent		Family income after paying int't.at 8%
		<u>R</u> Capital inv't.	<u>R</u> & inv't.	(a) <u>gross</u> of family labour	(b) <u>net</u>	
A.Southern State Lands Breeding and Fattening	210	16,780	3,090	18½%	15½%	874
B.Southern State Lands Finishing Enterprise only	200	17,800	3,490	19½%	16½%	1,033
C.Northern State Lands Breeding & Fattening	400	23,000	2,150	9½%	7%	155
D.Northern State Lands Breeding only	400	23,000	3,100	13½%	11½%	630

5. Water consumption by cattle is also very low in comparison with irrigated crops. An allowance of 8 gallons per day per livestock equivalent is somewhat generous. Therefore the annual requirement of 50 livestock equivalents would be at most 150 thousand gallons or less than 200 gallons per year per acre of grazing.

The positive returns per thousand gallons of water are very high. In Table 6.3 water costs are already subtracted in estimating net returns but the residual net return per thousand gallons of water

ranges from R1 up to nearly R3. Certainly the grazier can afford to pay more per unit of water than can the irrigator.

6. The Sedibeng pilot holding ranch ran at a loss for two years although growth performance of cattle was very good. The reason is clearly that grazing fees were too low at 40 c. per month as the benefits to cattle owners were probably worth at least three times as much. In addition the stocking rate could have been higher, though this might have required some publicity of the facilities offered, amongst cattle owners. Thefts also became a problem.

7. Financial results were not available for the Nata Ranch but budgets have been worked out, on the basis of some of the results, for cattle ranching on Northern and Southern State Lands. Budgets were calculated by the Government Agricultural Economist, Squire and by officials of the Commonwealth Development Corporation (Squire; 1968 private communication) based on the results obtained on their ranch on the Molopo in Southern Botswana. (See Table 6.4).

8. Reasonable assumptions based on actual results achieved in practice appear to have been used. These budgets suggest acceptable returns to labour and capital except in the case of breeding and fattening on the Northern State Lands. It is perhaps implied that cattle should be bred on the Northern State Lands and finished in the South.

9. The major problem is that for a Batswana farmer to obtain the incomes quoted from cattle production alone, he would need to control a large amount of capital and land. In the Northern Statelands this might amount to R12,500 and 10 to 12,000 acres.

In the Southern Statelands however, if a family income of say R150 is acceptable,\* this might be earned (on the basis of Table 6.4) with less than R3,000 capital and 700 acres of grazing. The family would, of course, be under-employed.

10. Thus cattle production can provide satisfactory returns to capital and labour but considerable capital resources are required to start ranching. Of course similar capital investment is required for some irrigation schemes.

\*Note: this may be compared with an estimated family income for the Shashi scheme of R120 or from mining of R165.

6.(iii) RETURNS FROM DRYLAND MIXED FARMING

1. In the areas of cultivable soils, mixed farming is probably the best system of dryland agriculture.

As already mentioned the Sedibeng unit farms are both operated as mixed farms. The overall results for 1965/66 and 1966/67 are given in Table 6.5.

Table 6.5

Returns from mixed farming - Sedibeng unit

	Labour,mgm't.& inv't. income	Return on capital- allowing R150 for family labour	Return to family farm lab.allowing 8% return on capital
	<u>R</u>	<u>per cent</u>	<u>R</u>
Tractor unit 1965/66	440	6½	80
Tractor unit 1966/67	1,875	17	1,075
Ox unit 1965/66	585	9	185
Ox unit 1966/67	1,145	20	745

2. In the wetter year of 1966/67 the returns to labour and capital compare favourably with those expected for most irrigation schemes. In the dryer year of 1965/66 returns were not so attractive but as already suggested certain crops may not contribute to the overall net return and some replanning of the holdings is desirable.

Table 6.6

Programming data for dryland mixed farming

Constraints

Alternative activities	Gross Margin	Capl. R	Total lab. <u>man-days</u>	labour in man days											
				Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Cotton	16.0	18	34	1.0	2.0	5.0	8.0	10.0	7.0	2.0	.5			.5	
Maize	7.5	18	7	.5			1.5	2.8					.3		
Cowpeas	9.3	18	17	.3		11.5	4.0	1.0						.3	
Sorghum	6.3	18	5		1.0	1.0				2.0	.8			.3	
Sunflower	6.0	18	9	3.0			2.3	3.5						.3	
Breeding cattle	15.5	67	4	.3	.3	.3	.3	.5	.5	.5	.5	.3	.3	.3	
Fattening cattle	11.0	35	2				.3	.3	.3	.3					

3. A linear programme was therefore prepared based on the results obtained at Sedibeng although with certain adjustments on the basis of field experience suggested by Weare. The data used are given in Table 6.6. The only constraints considered were capital limited to R4,000 and family labour restricted in total to 600 man-days. Ox power was ignored as a constraint but one team could obviously plough and cultivate the 20 acres of arable appearing in the optimal solution.

4. The optimal solution for a single family dryland holding includes

- 6.5 acres cowpeas
- 5 " sorghum
- 9.5 " sunflower

100 head of fattening cattle

requiring perhaps 20 acres of arable land and 2,000 acres of grazing.

The total gross margin is R1248. Deducting a third for fixed costs (as with irrigation programmes) gives a return on capital of 21%.

5. This programme made no allowance for variations in riskiness between enterprises and different assumptions would, of course, give rise to a different optimum solution. It is interesting to note, however, that this system accords fairly closely to what Squire considered might be a good system.

It is also interesting to note that cotton does not appear in the optimal solution.

6. Of the constraints, August labour was found to be the most critical. An extra man-day in August would increase the total gross margin by R34. In all months except January, March, July and August there is surplus labour, there is also surplus capital.

Increasing the farm capital would therefore, have no effect on the total revenue or on the pattern of farming selected. In fact the capital could be reduced by R224 without altering the optimal plan.

7. As an alternative to direct investment in large scale irrigation schemes the Botswana Government might consider the establishment of dryland farming settlements. Indeed the first aim in setting up the unit farms was "to investigate the economics of suitable farming systems for African family settlement under non-tribal conditions in South-Eastern Botswana".

A possible system for a dryland settlement was therefore, planned by linear programming. The expected inputs and returns given in Table 6.6 were used but it was assumed that it might be of similar scale to the Mogobane Irrigation Scheme. The constraints of R100,000 capital and 13,500 man-days of labour were therefore used.

8. With these assumptions the optimal solution includes:

212	acres	maize
92	"	cowpeas
297	"	sorghum
53	"	sunflowers
2521	head	of fattening cattle

This gives a total gross margin of R32,363 which is higher than that programmed for irrigated agriculture.

Thus dryland mixed farming might well give higher returns to the limited resources of labour and capital, than irrigated agriculture. It is emphasised elsewhere that there are possible advantages in terms of greater yield reliability from irrigated agriculture. This is questionable however, on the basis of Sudanese experience. (See Suliman (1965) ).

9. This system would require a vast area of land; perhaps 600 acres under cultivation and 40,000 acres of grazing, at 20 acres per head of cattle. If land is also introduced as a constraint the returns from the optimal solution would be reduced.

10. These results support the general hypothesis that irrigation is most effective as a means of raising agricultural productivity where land is a major limitation i.e. where there is a dense population. This is because irrigation improves productivity of land at the expense of greater inputs of capital and labour.

The introduction of irrigation represents an intensification of land use.

11. In Botswana, therefore, where labour and capital are limited rather than land, the case for irrigation may be somewhat weaker than in other countries with denser populations.

#### 6.(iv) RETURNS IN COMMERCE AND INDUSTRY

1. Information on returns in commerce and industry is limited but it is clearly stated in the National Development Plan 1968-73 that "it is highly desirable to seek ways of reducing the economy's dependence on the agricultural sector".

2. This implies that, in the view of the national planners, greater net social benefits can be obtained by investment outside agriculture. Indeed it is likely that industrial and mining projects can provide higher returns to water, capital and labour than can most agricultural projects.

3. For these reasons, an ordering of priorities for water use in Botswana, which appears to be generally accepted in the Ministry of Commerce, Industry and Water Affairs is as follows:

- A. Domestic
- B. Industrial/commercial including mining
- C. Livestock
- D. Irrigation

As already remarked, big dam building is aimed at providing water for domestic and industrial uses. Irrigation may only be introduced as a supplementary enterprise to make use of the unreliable water surpluses available in most years.

4. However, at the time of the last census it was estimated that 90% of the population was engaged in agriculture, forestry, hunting and fishing, leaving less than ten per cent in all other occupations. It is therefore likely that agriculture will make up the largest sector of the economy for many years to come. In the short and perhaps medium term it seems likely that improvements in the Motswana's standard of living must come about through increases in agricultural productivity.

7. GOVERNMENT POLICY CONSIDERATIONS

7.(i) ENCOURAGEMENT AND CONTROL OF PRIVATE WATER USERS

1. In view of the scarcity of water it is essential that this resource be treated as an economic asset. Government action is required to ensure that water is not wasted and to avoid monopolisation of water supplies by one or a few individuals.
2. As a first move in this direction legislation was enacted in the Water Act of 1967 which came into force on 9th February 1968.\* The Act provides for the establishment of a Water Apportionment Board which is responsible for allocating water rights to different water users.
3. Existing water rights must be registered within one year from February 1968 for a registration fee of R1. New water rights, if granted will be subject to a fee of R50 which can be reduced by the Minister (presumably of Commerce, Industry and Water Affairs).
4. After February 1969 it will be illegal to divert, dam, store, abstract or use public water or discharge any effluent into public water except in accordance with a water right granted under the act. This law will not apply to existing rights to take and use less than 5,000 gallons per day or to water used for the immediate purpose of watering stock or drinking, washing and cooking or use in a vehicle.
5. Thus individual rights to water are to be legally established and protected and a charge for these rights will be made in the registration fee.
6. There are certain social benefits to be derived by making a charge, even for water which is "freely available" on the surface or underground. The charge may have an effect, similar to that of economic rent charged for land, as an incentive to efficient use of the scarce resource. However, from this point of view it would be desirable to apply an annual charge which is related to the quantity of water taken.
7. Clearly if the Government incurs costs in making the water available, for example by surveying and drilling boreholes or by constructing dams, charges should be made, adequate to cover costs including return on capital. This argument should be applied to the activities of the small dam building unit.

\*Note: Much of the information which follows was obtained from W. Calder, Hydrological Engineer.

8. Various controls to be exercised by the Board are specified in the act, such as the prevention of pollution of public water, the laying down of conditions on which water rights are granted, and the possible cancellation or reduction of water rights in certain circumstances such as periods of drought.

A minimum spacing of 250 yards between boreholes is also laid down in this act.

9. It may well become apparent that this Board must establish either a system of regular charges for public water or much stricter controls on the uses to which water is put, if serious wastage is to be avoided. In parts of the Sudan, for instance, the Ministry of Agriculture actually stipulates the rotation to be followed when licencing a water right.

10. Arrangements must also be made for the cleaning and maintenance of water courses and structures provided by Government, such as the small dams. If possible the responsibilities for such maintenance should be made proportional to the benefits.

It has been suggested by Youthed, the Land Use Planning Officer (1967) that these responsibilities should be enforced by Local Government (District Council) Bye-Laws, but in view of the national strategic importance of water supplies it is desirable that provision be made for their maintenance, in national legislation.

11. The control of monopolisation of water resources has been mentioned as a necessary part of Government policy. Under the existing Act it might be possible for one individual to acquire rights to a whole water-course and to use his monopoly position to charge excessively high rates for the use of this water. This possibility must be guarded against.

12. Controls and water charges although necessary may act as a disincentive to the natural expansion of irrigated agriculture. However, encouragement could be provided by publicity campaigns by the Agricultural Extension Service and perhaps more particularly by the provision of loans specifically for investment in irrigation.

For example, such a campaign mounted by McPherson, the Agricultural and Livestock Officer in Maun has had considerable success.

#### 7.(ii) DIRECT PARTICIPATION IN IRRIGATED AGRICULTURE

1. In view of the lack of knowledge and experience of irrigation amongst the Batswana and hence the slow rate of expansion of private irrigation schemes, there is a natural tendency to consider direct

participation of Government in developing irrigation schemes.

The commonest form of this participation in Africa has been the settlement scheme, in which the initiative is taken by government.

2. A further incentive for this type of development lies in the large capital cost of providing irrigation water in many cases, especially in large dam construction. In order to recoup this expenditure the Government may well consider that it must participate directly in controlling the productive use of the water.

It should be remembered, however, that it might be possible at the expense of a somewhat longer distribution canal to sell water, even from a large dam, to small independent producers. Thus areas of irrigation would be scattered along the length of the main canal. This type of development is called "string of pearls" development by Ionides (private communication 1968).

3. The extent of Government participation may vary considerably from perhaps a partnership scheme such as the Gezira, through more closely controlled settlements to plantations under Government employed managers.

4. The introduction of irrigation may well cause radical social changes. There is need for discipline and effort in irrigation not required for traditional arable cropping and livestock grazing. It requires permanent residence on or near the irrigated land throughout the year and prevents movement to the cattle posts during the winter. It may require a switch from subsistence production to production solely for cash.

Therefore in the early stages of the introduction of irrigation, a high degree of management and control may be necessary.

This is apparent from the Mogobane and Nxaragha valley schemes both of which appear to have failed due, at least in part, to loose overall management.

5. This implies that in the first instance schemes should be operated as plantations or as settlements with a high degree of Government control.

However, since managerial staff represent an additional major cost to Government it is desirable that decision making responsibility should eventually devolve upon the settlers, either individually or through a co-operative management committee.

6. If the Government is to control an irrigation scheme, rights to land and water must first be established.

On tribal land the only way in which Government or more specifically, the Ministry of Agriculture can establish legal rights to administer an area of land is through the Concessions Law. It is therefore, recommended that before embarking on direct participation in an irrigation scheme the Ministry should obtain a concession on the land involved.

Water rights can be registered by the Ministry of Agriculture under the 1967 Water Act.

7. On a settlement, settler training must form an important element in management in the early stages. How far this should be instilled by disciplining is a question frequently discussed. Certainly on many successful irrigated settlements an ejection clause for bad husbandry is incorporated in the lease.

At any rate, the administration must have teaching and disciplining roles in some combination, though ideally the individuals carrying out these roles should be clearly distinguished.

8. Another consideration in planning a settlement is the size of each holding. Generally the two criteria used in reaching a decision are firstly level of family income which can be produced and secondly the area which can be managed with family labour.

The two criteria may not give the same solution. On the Vuvulane Irrigated Farms Settlement in Swaziland 8 acre holdings appear to provide an acceptable family income but leave most families under-employed.

Although the allocation of holdings all of a standard size may be considered equitable and likely to avoid discontent and friction it may limit productivity of the whole scheme, productivity might be increased if the more progressive, harder working or more efficient settlers could acquire extra land possibly at the expense of other settlers.

9. In order to recoup costs, Government must institute a system of levies to be paid by the settlers. Indeed in some schemes (e.g. the Gezira scheme in the Sudan) the charges paid by the settlers are more than adequate to repay the costs of development and form a major source of Government Revenue.

10. The questions of the form and scale of payment for irrigation water and land have many solutions which depend on the degree of freedom of choice of water and land use left to the cultivator, the feasibility of measuring the water used, the methods available for collecting payments and the attitude of the Government to the purpose of the scheme. (Thornton 1966).

11. One system of levies frequently used is that of crop sharing. If decision making is equally shared between the settler and the manager this system of dividing rewards is a logical one. It also has the following advantages:

(a) In communities where cultivators' cash reserves are always small, the collection of charges is easier by deduction of part of the proceeds of sales than in the form of cash.

(b) Risks and uncertainties and resulting income fluctuations can be shared; this being particularly important in the early stages when irrigation is a new venture to most farmers.

(c) Tax collection can be associated directly and simply with other charges in the Government's share.

12. However, crop-sharing can also be criticised on the following grounds:

(a) where systems are complex, many different crops are grown and there is no simple sharing of responsibility for decision making, the logic and practicability of crop-sharing breaks down.

(b) crop-sharing reduces the incentive for the settler to increase production, the benefits of any improvements he makes, having to be shared with the management.

(c) crop-sharing tends to lead to inflexibility, as it is difficult to allow for even minor changes in the pattern of cropping, if this is going to influence the levies paid to Government.

13. It is therefore generally agreed that, in the long-run at least, water charges are preferable to crop shares as a method of recoupment.

14. The supplier of water incurs two kinds of expense, firstly the initial investment and secondly the annual operating expenses.

There are at least two good reasons for making separate charges for these two different kinds of expense: first, the cost of providing the facility for irrigation should be distinguished from the

these topics in promoting the development of irrigation. Research is possibly required in some cases.

None of these problems is sufficient cause for abandoning the development of irrigated agriculture, but none should be ignored.

2. Salinity could well become a major problem as a result of the development of irrigation in Botswana, as in other semi-arid countries where evaporation rates are high. This problem has already reached serious proportions in West Pakistan where vast areas have become unproductive desert due to the build up of salinity following from irrigation.

In Botswana, the Makarikari salt pan is evidence of the potential for build up of surface salinity, and over large areas of the country underground supplies are saline (i.e. over 5,000 ppm salt - see Map 2).

The Geological Survey Department recommends that at salinity of over 5,000 ppm water is not potable and over 1,000 ppm not suitable for irrigation. But even at levels below 1,000 ppm which might also be found in surface water, surface salinity could eventually build up to a serious level.

3. Silting up of dams could also become a serious problem. Lund (1965) suggests that in the Limpopo River for example, the silt load is about 5% by volume. This silt load is, naturally deposited if the water flow is stopped by means of a dam or weir. He therefore suggests that all the major storage dams in Botswana will gradually silt up, thus reducing their storage capacities. He considers they will need dredging within 25 years.

To ease the problems silt traps may be constructed around dam sites. Certainly the problem cannot be ignored.

4. Bilharzia (schistosomiasis) is another problem likely to increase with the development of irrigation. This disease is spread through a snail intermediate host which lives in water; thus it is through contact with open water that humans become infected. Furthermore, the rate of transmission of the disease is correlated with human population density. (Pitchford 1966).

"Many irrigation and resettlement schemes throughout Africa have had or inadequate water supplies; this situation is coupled with a local increase in the human population density resulting from the disruption of the traditional living conditions of indigenous

peoples. These alone are sufficient reasons for the apparent increase of schistosomiasis without postulating an increase in the snail population". (ibid).

In the same paper Pitchford suggests that "environmental and water conservation measures are sufficient in themselves and may be more effective than molluscicides in reducing schistosomce transmission". He also gives details of what these environmental and water conservation measures might be.

Although these control measures would increase the costs of an irrigation scheme, Pitchford arrived at a non-recurrent cost of less than R2 per head for controls of a permanent nature on a South African scheme. It is highly desirable that the development of irrigation should not become the means of spreading this harmful disease.

5. Crop pests such as Quelea birds and baboons may cause more serious damage on irrigation schemes where sole crops may be grown on large areas. Special control measures may be necessary.

8. SUMMARY: THE PLACE OF IRRIGATION IN THE DEVELOPMENT OF BOTSWANA

8.(i) THE TECHNICAL CASE

1. In view of the low and unreliable rainfall of Botswana, irrigation is an obvious possibility for improving agricultural productivity.
2. However, the present pattern of agriculture is largely based on cattle production with some dryland arable cropping. The only major area of irrigated agriculture is the Tuli Block where nearly 4,000 acres are irrigated by white settlers. A few African farmers grow small areas of irrigated vegetables in various parts of Eastern Botswana and the Okavango region and there are two Government sponsored schemes, one in the Nxaragha valley on the Okavango and the other at Mogobane in South East Botswana.
3. Various hydrological, hydrogeological and soil surveys have been and are being done. These will provide invaluable information on the resources available for irrigated agriculture but the ultimate test of the potential for any irrigation scheme must come from full cost-benefit appraisal.
4. It is to be noted that apart from the Okavango and Chobe there are no areas of open water, on which to draw as a cheap source for irrigation. The land being generally flat, dam sites are difficult to find.

The Okavango has a vast potential but at present is remote from the main centres of population and poorly served by communications. The waters of the Okavango are not controlled or used for irrigation to any significant extent.

8.(ii) RETURNS FROM IRRIGATED CROPS

1. As there are no relevant statistics available on costs and returns of irrigated crops, estimates of physical inputs and yields, made by officers of the Department of Agriculture, Botswana with considerable local experience are used.
2. Gross margins per acre for irrigated crops are estimated to be several times greater than the margins for the same crops relying only on rainfall. The highest estimated margin under irrigation is for cotton at about R100 per acre although it is suggested that the estimated yield and hence this margin is rather high. Gross margins per 1,000 gallons of water are estimated at from 8 to 15 cents. At Lobatsi a gross return of R145 per acre has been obtained but the margin is presumably considerably lower than this figure.

Certain other mixed costs must be met from gross margins besides the cost of water.

3. Linear programming was used to estimate returns from a system of irrigated agriculture. For a 250 acre scheme the major crops suggested are maize, potatoes, lucerne and onions, giving a total gross margin per acre of R124, or per thousand gallons of water, of 15 cents.

4. Although cotton and wheat were incorporated in the linear programme as possible alternative crops they did not appear in the final solution.

5. Linear programming suggests a net return of R73 per acre or 9 cents per thousand gallons of water. However, because of market limitations it may be safer to use the budgeted return for the Mogobane scheme.

This suggests a net return to irrigation of about R40 per acre or 4 cents per thousand gallons of water.

6. Higher returns can be obtained from intensively managed irrigated vegetables, although at the cost of greater labour inputs.

7. Gross margins per acre of vegetables are generally well over R100 in fact on small, mulched plots at Radisele a margin of R2274 per acre was obtained from tomatoes. Gross margins per thousand gallons or per acre inch of water are much higher than those for field crops.

8. Labour inputs could be as high as 300 man-days per acre on vegetables, so return per man-day may be no higher than the comparable figure for field crops.

9. There are no assured markets for vegetables, prices fluctuate widely and hence there are risks attached to vegetable production.

#### 8.(iii) COSTS OF IRRIGATION

1. Preliminary cost studies of various water sources in Botswana suggest the following, ranking in order of increasing cost per acre.

1. Surface water - no storage - gravity fed
2. Surface water - no storage - pumped (low cost as in Tuli Block)
3. Low cost of boreholes (as in Tuli Block)
4. Sand extraction
5. Low cost dam - (as Shashi siding dam)
6. Surface water - no storage - pumped (high cost as at Maun)
7. Small dams

8. Average cost borehole (as at Lobatsi)
9. High cost dams (as small dams, Gaberones dam)
10. Catchment tanks

2. For the first 5 of these, cost per acre is less than R40, the estimated net return from field crops.

However, for the average borehole, many dams and catchment tanks the cost of irrigation is likely to exceed the return from irrigated field crops. Only vegetable production could provide an adequate return.

#### 8.(iv) SOCIAL COSTS AND BENEFITS

1. Simple comparison of direct cash costs and returns, does not allow for the full social costs and benefits of irrigation.

2. Besides increasing yields irrigation reduces the risk of complete crop failure. This is an important benefit which should be taken into account in assessing irrigation development.

3. The use of water for irrigation may be supplementary to other uses of a dam or borehole. In such cases the real cost of water for irrigation is reduced perhaps to zero if the introduction of irrigation incurs no extra costs.

4. Market prices may not reflect the true social costs and benefits of irrigation. Certain beneficial or harmful side effects cannot be evaluated in money terms. A case can be made, however, for ignoring these effects in evaluating a project.

5. Secondary benefits of general development of an area may be generated by the introduction of an irrigation scheme. However, the same secondary benefits might be derived from any development scheme such as a new factory or a dryland arable settlement.

6. In the above costings a rather optimistic estimate of the returns from irrigation has been made in that there is no allowance for the gradual maturing of a scheme. If there is a delay of several years before irrigation schemes mature, returns should be discounted and hence reduced below the figures given under heading (ii) above.

8.(v) SPECIFIC SCHEMES CONSIDERED

1. Nxaragha Valley Settlement

- (a) Some means of flood control is needed
- (b) the management of the settlement needs to be tightened up
- (c) subject to the above provisos the scheme should be economically viable. It could give a return per settler of R700 or over 50% return on capital.

2. The President's Irrigation Scheme, Chadibe

High level of capital investment per acre - therefore intensive production necessary to provide adequate return.

3. Tuli Block Pump-Schemes

Good conditions for irrigation; good soils, cheap water, labour supplies and markets generally in S.Africa. Hence good returns on capital investment of the order of 20%.

4. Private irrigation schemes by African farmers

Already some small scale units in existence, for vegetable production. Generally economically viable where the standard of management is adequate. Particularly suited in areas of open surface water (e.g. Okavango) or as supplementary use of small dam, borehole or sand extraction unit.

5. Mogobane Irrigation Scheme

Proposals for redevelopment of scheme should provide an acceptable return on capital of 20% over 20 years. But it is questionable whether waterlogging will be cured and the budgetted returns obtained. Capital costs may be higher than estimated hence return on capital lower.

The capital necessary to establish a similar scheme from scratch would be considerably higher and hence returns significantly lower.

6. Tlokweg Irrigation Scheme from Gaborones Dam

Arguable that irrigation represents supplementary use of water so no charge should be made. However extra costs arise in providing canal and distribution systems. It is further argued that water might not be available in two years out of ten. Hence average return on capital invested in the pipeline might be about 14%.

In view of the uncertainties regarding water supply and the possible need to charge for water from the dam, the scheme is a doubtful proposition.

7. Irrigation from the Shashi River

Irrigation from Shashi Siding Dam according to Lund's proposals would only give a return on capital of 8% or R120 per family. As with Tlokweng scheme this appears a doubtful economic proposition.

Irrigation by sand extraction below the dam should be possible and more attractive economically than irrigation from the dam.

8. Irrigation from the Madabe Dam

Possible to justify pumping water 60' on to ridge tops only for intensive vegetable production.

Impossible to justify a three mile canal to water floodplains.

In either case land tenure problems might arise.

9. Experimental and Demonstration Schemes

Urgent need for technical data on inputs and returns for irrigated crops. In particular, response curves to water and fertiliser in combination.

It is questionable whether sufficient useful information on the economics and social problems of irrigated agriculture can be derived to justify running schemes specifically to obtain such information.

Economic budgets can be based on technical and market data. Social problems can be studied from surveys of schemes in other parts of Africa and amongst the Batswana.

8.(vi) IRRIGATION COMPARED WITH OTHER TYPES OF INVESTMENT

1. Returns from dryland arable crops are much lower per acre than returns from irrigated crops. However, returns to labour and capital in dryland crop production on the Sedibeng unit farms, compare favourably with those for most of the irrigation schemes under consideration.

2. Returns from cattle production obtained on the unit farms and budgetted for ranch conditions, also compare favourable with returns from irrigation schemes. However, cattle production requires more capital and land per producer than does arable crop production.

3. Returns from dryland mixed farming again, are possibly better than the returns from many irrigation schemes. To some extent risk is reduced by mixed farming, cattle sales are increased during drought periods when crop yields and hence sales are reduced.

4. In the absence of significant exogenous water supplies, large scale irrigation is unlikely to provide an attractive return on capital. This is due in part to the scarcity and hence high cost of exploitation of local water supplies. But it is also due to the limited benefit obtained when an intensive system is introduced in an area where population density is such as to favour extensive methods of agriculture.

The limited benefit of irrigation arises because in sparsely populated semi-arid zones, land is not a constraint on production, only labour and capital. The aim of development policy must be to increase the productivity of labour, possibly by bringing more land into productive use.

Irrigation, however, increases the marginal productivity of land at the expense of greater inputs of labour. Indeed the intensification of agriculture by the introduction of irrigation may actually reduce the marginal product of labour.

5. Alternatively we may consider water as the most important constraint on production. In this case, water should be used where its marginal product is greatest. On this criterion, irrigation would come near the bottom of a list of priorities for water use. Domestic users, industrialists and livestock owners can all afford to pay more for water than the irrigator, basically because water represents a much smaller proportion of total costs for these other users.

6. High priority is placed on reducing the country's dependence on the agricultural sector, i.e. expanding industry at the expense of agriculture.

Hence the order of priority for water use in Botswana is:

- A. Domestic
- B. Industrial, commercial and mining
- C. Livestock
- D. Irrigation.

#### 8.(vii) THE PLACE OF IRRIGATION IN THE DEVELOPMENT OF BOTSWANA

1. From the foregoing it is apparent that the place of irrigation in the development of Botswana is likely to be limited.

2. The growth of industry and the social infrastructure will have priority over agriculture in the development plans. These users will also take priority over agriculture in their claims to available water supplies.

3. Within the broad field of agriculture the limited evidence available does not suggest that irrigation is a more promising approach to development than livestock production or dryland arable cropping. Its benefits in reducing risk may be questioned. (See Section 4 (ii)).

4. This does not mean however, that there is no place for irrigation in Botswana's development. The following possible areas of expansion look particularly promising.

A. The Tuli Block - is an area of profitable irrigation which is expanding, subject to limitations imposed by competition for water by South Africa.

B. Private small scale irrigation schemes - established by African farmers in many parts of the country are promising where there are relatively cheap water supplies and good management.

Specific agricultural extension and credit programmes aimed at extending and improving this kind of irrigation development could be justified.

C. The Okavango - if practical methods of controlling the swamp waters can be devised and accepted, the potential development of irrigated agriculture from this source is very great. Irrigation could be introduced on such a scale as to justify the construction of new roads and other communications with the East of the country and the resettlement of population.

POSTSCRIPT

WATER CONSERVATION

In conditions where there are periodical water shortages there are two possible approaches to improving the water supply to crops:

1. The provision of extra water i.e. irrigation
2. Making better use of the natural rainfall i.e. water conservation.

The second approach is often ignored yet in some circumstances may prove to be the most desirable method of increasing crop production.

Various techniques may be used of which the following are examples:

1. Reducing run-off by mulching, regular cultivation, keeping the soil surface covered, contour ploughing, tied ridges, strip cropping, drains, terraces or grass strips. (See "Farming as a Business" by Upton and Anthonio 1965, Chapter 6).

2. Making use of run-off by planting crops below a catchment area (See Series IV trials at Radisele. I.T.D.G. Report 1969).

3. Tapping a greater depth of soil by growing trees. (Again see I.T.D.G. Report).

4. Using the soil as a reservoir by growing crops only once every two years - protecting the soil surface from evaporation in the intervening years. This method is used in parts of the wheat belt of America.

5. Reducing evaporation by mulching, both artificial (e.g. P.V.C) and organic, (See Series I and II trials at Radisele).

As an example of what might be achieved by cultural treatments, trials in Northern Nigeria have shown that a combination of tied contour ridging and mulching has enabled yields of seed cotton of the order of 2000 lb. per acre to be produced annually. This level of yield is about eight times the average for the country and about three times the yields obtained on the experimental farm without water conservation treatments. (See Lawes, 1961, 1964). This is, of course, in an area which is wetter than Botswana (annual rainfall between 35 and 60 inches) but this might suggest that the benefits could be even greater in Botswana.

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## APPENDIX I

### CROP WATER REQUIREMENTS

1. Individual crop water requirements are not known. It was therefore assumed that for any given month, the water requirements are the same for all crops.

2. Total annual water requirements to maintain plant growth uninterrupted throughout the year were estimated as follows:-

- A. Ivemy - Irrigation Agronomist  
60" per year 40" summer, 20" winter  
including rainfall
- B. Jackson - Agricultural Economist (irrigation)  
40" per year 25" summer, 15" winter  
plus rainfall
- C. Weare - Chief Agricultural Officer (research)  
36" per year 24" summer 12" winter  
plus rainfall

Since mean annual rainfall in the East of the country is around 20", estimate A is similar to the other two.

The following assumption was therefore adopted.

Annual water requirement net of rainfall 40" per year.

Peak requirement may go up to 2" per week.

3. It should be noted that the assumption that water requirements are the same for all crops is a somewhat arbitrary one. Crops do vary considerably in their water requirements especially at different stages of growth.

However, in planning an irrigation scheme it is generally not possible to arrange for the irrigable area to vary from season to season, because of the high capital costs of land preparation and water distribution. Plans must therefore be based on generalised or average water requirements for all crops that might be grown. This argument only really applies to surface irrigation, furrow or basin. The area irrigated by an overhead sprinkler system may be varied over the year according to water needs, but presumably the year still has a maximum spread.

4. Total water supplies must also provide for water losses both in storage and distribution. In the absence of any objective measures of irrigation efficiency for Botswana, the following figures from Swaziland are used.

Furrow irrigation - efficiency 50%  
Sprinkler irrigation - efficiency 70%

3. Therefore total annual water requirements net of rainfall

A. For furrow irrigation =

$$\frac{40'' \times 100}{50} = 80'' \text{ per year}$$

B. For sprinkler irrigation =

$$\frac{40'' \times 100}{70} = 57'' \text{ per year}$$

and total peak requirements per week

C. For furrow irrigation =

$$\frac{2'' \times 100}{50} = 4'' \text{ per week}$$

D. For sprinkler irrigation =

2" no allowance for waste or inefficiency for the following reason.

As noted under para. 3 above - a sprinkler system allows greater flexibility. Thus peak requirements might be met by transferring sprinklers from an area where requirements are below the peak. There is therefore some justification for ignoring waste and inefficiency in this case.

6. For surface water total irrigable acreage is determined by total requirements. Generally surface water can be stored so peak requirements are met by storing water from a period of low requirement.

(i) Therefore for furrow irrigation (see A above) the total need is  $\frac{80}{12}$  acre feet per acre per year.

= 1,810,667 gallons per acre per year

or 4960 gallons per acre per day on average. This equals about 0.2 inches per day.

(ii) Therefore for sprinkler irrigation (see B above) the total need is  $\frac{57}{12}$  acre feet per acre per year

= 1,290,100 gallons per acre per year

or 3534 gallons per acre per day on average or 0.16 inches.

7. For underground water from boreholes and sand extraction units the maximum rate of water supply is fixed by the characteristics of the pump. The peak water requirement must therefore, not exceed this maximum yield.

(i) Therefore, for furrow irrigation (see C above) the maximum yield must be

$\frac{4}{12}$  acre feet per acre per week

or 90,533 gallons per acre per week.

Assuming a 7 day week, pumping 10 hours per day at peak requirement this equals

1293 gallons per acre per hour

(ii) Therefore for sprinkler irrigation (see D above) the maximum yield must be

$\frac{2}{12}$  acre feet per acre per week

or 45,267 gallons per acre per week

or 647 gallons per acre per hour.

APPENDIX II

IRRIGATION COSTINGS

General Notes

1. In all cases, where applicable, the irrigable acreage has been determined on the basis of estimated water requirements given in Appendix I. The only two exceptions occur, as noted in the Tables. The first is the Shashi siding dam where B.G.A. Lund and Partners estimated the specific water requirements of the crops to be grown.

The second is the Irrigation Demonstration Unit Lobatsi which was planned on the basis of continuous pumping from the borehole on an experimental basis by the Geological Survey Department. It is therefore, completely atypical since the Geological Survey Department recommend farmers to allow a safety margin against exhaustion of the aquifer, by pumping at  $\frac{2}{3}$  of measured yield for only 10 hours per day.

2. In all cases annual costs of capital investment have been calculated as an annual sinking fund annuity at 8% standard rate of interest on agricultural loans charged by the National Development Bank spread over 10 years except in the case of dams. The cost of the Gaberones and Shashi dams are spread over 50 years and the cost of small dams over 20 years.

Table 1

<u>Land preparation costs</u> (Capital	<u>R</u>
Bush clearing per acre	10
Levelling per acre	<u>12</u>
<u>Total per acre</u>	<u>22</u>
Annual annuity at 8% over	
10 years =	R3.3

Table 2

Furrow irrigation costs

Main furrows - based on costs for irrigation demonstration unit

Lobatsi original (i.e. capital) cost per acre R40  
Annual annuity of 8% over 10 years = R5.9

In addition there will be annual costs of drawing irrigation furrows but this will form part of ordinary annual costs of cultivation.

Table 3

Sprinkler irrigation costs

1. Capital cost - pump, piping and sprinklers

e.g. (a) Irrigation demonstration unit Lobatsi

- 5 acres irrigated for capital cost of R850 = R170  
per acre

e.g. (b) Tuli Block - Gesond Ltd.

420 acres irrigated for R55,000 investment = R130  
per acre

2. Annual running cost per acre

(a) Irrigation demonstration unit Lobatsi

Annual sinking fund annuity on investment  
at 8% for 10 years on say R170 = R25.3

Operating - fuel and oil/acre R30

Total - R55.3

(b) Tuli Block - Gesond Ltd.

Annual sinking fund annuity on R130 = R19.4

Operating - fuel and oil/acre = R10

Total 29.4

Table 4

Pumping costs - surface water

(i) Tuli Block - with storage weir - e.g. Riggs of Dovedale

1. Capital cost R4,000 for 60 acres for furrow irrigation =  
R66 per acre

2. Annual running cost/acre

(a) Annual sinking fund annuity at 8%  $\frac{R}{}$   
for 10 years on say R66 = 9.8

(b) Operating - fuel and oil/acre  $\frac{25}{}$   
Total =  $\frac{34.8}{}$

3. Cost per 1,000 gallons approx. 1c

(ii) Afgate Sprinkaan pumps - Thamalakane River

1. Capital cost

Model R2 delivering 2,000 galls/hour cost =  $\frac{R}{150}$   
Hose = 54  
Sprays = 8  
Total =  $\frac{212}{}$

Should be possible to irrigate 3 acres  
therefore Capital cost per acre = R71

2. Annual running cost/acre

(a) Annual sinking fund annuity at 8%  $\frac{R}{}$   
for 10 years on R71 15.8

(b) Operating - fuel and oil per acre  $\frac{30}{}$   
Total =  $\frac{45.8}{}$

3. Cost per 1,000 gallons - - - - - approx. 1c.

Table 5

Small Dams

(Costing provided by L.U.P.O)

Small Dams constructed by Dam Building Unit

1. Capital Cost:

<u>Earth Moving:</u>	<u>R</u>
25,322 cub.yds. placed and compacted on earth wall	
i.e. Machine costs: 625 hrs. @ R7-55 per hour	4,718-75
210 hrs. @ R4-25 " "	892-50
Cut off wall	708-00
Outlet pipe	291-90
Fencing materials	150-00
Stock watering facilities	125-00
 <u>Preparation of Dam Site</u>	
10,700 cub.yds. rubble removed from site and burrow area	
219 machine hours @ R4-25 per hour	930-75
Hand clearing	152-00
Retaining wall - 150 cub.yds. concrete	1,050-00
Depreciation:	
625 hours R3-25 per hour	2,031-25
210 " R2-30 " "	483-00
219 " R2-30 " "	503-70
	<hr/>
	12,036-85
	<hr/>

/continued

Table 5 cont'd.

Water Supply

(1) <u>Irrigation:</u>	<u>R</u>
1,400 ft. x 3" Class A plastic piping & fittings	570-00
40 x 5" Reservoir to hold a supply of 70,000 galls.	350-00
3,000 ft. Canal (if necessary)	720-00
(2) <u>Domestic Supply:</u>	
1,300 ft. x 1" Plastic piping	42-00
Fittings for 12 houses @ R3-50 per house	42-00
(3) <u>Stock Watering</u>	
1,600 ft. Plastic piping x 2 plus fittings	290-00
Drinking trough	34-00
	<hr/>
	2,028-00
	<hr/>

Storage capacity 72 million gallons  
(assured draft 2/3 of this i.e. 48 mill.galls.)

Capital cost to irrigate 25 acres -

12,036-85 + R1,640-00 = R13,676-85

Cost per acre =  $\frac{R13,676-85}{25}$  = R547.07

25

Capital cost to provide 48 million gallons = R13,677

Cost per 1,000 gallons = R 0.28

2. Annual Cost

Annual sinking fund annuity at 8% for 20 years = R55

Annual cost per 1,000 gallons = 2.9 cents

Table 6

Big Dams

e.g. (1) Gaberones Dam - Estimates by W.B. Calder - Hydrological Engineer.

(1) <u>Capital Cost</u>	<u>R</u>
Total of contracts for dam	554,070
Consultants fees - say	<u>33,244</u>
	587,314
Cost of land acquisition	45,669
Fencing - say 12 miles @ R250	<u>3,000</u>
	<u>635,983</u>
Total, say, <u>R636,000</u>	

Economic life of dam 50 years at 8% interest rates.

(2) <u>Annual Costs</u>	<u>R</u>
Sinking fund annuity	51,991
Annual maintenance, say 1% of 554,070 + 3,000	<u>5,570</u>
	<u>57,561</u>

Assumed daily supply 5 m.g.d. - 1825 mg./year

Cost per 1,000 gallons 3.15 cents

Assume consumption increases from 1 m.g.d. at beginning increasing to 5 m.g.d. at end of 25 years and remains at 5 m.g.d. thereafter.

$$\text{Average daily consumption over 50 years} = \frac{\frac{1+5}{2} + 5}{2} = 4 \text{ m.g.d.}$$

$$\text{Utilisation factor} = \frac{4}{5} = .8$$

$$\text{Adjusted cost} = \frac{3.15}{.8} = 3.94 \text{ cents}$$

Add 10% for contingencies 4.33 cents

/continued

Table 6 cont'd.

	<u>R</u>
<u>Cost per acre per year</u>	78.41
Plus pipeline to cost R24,000 (estimate by A.Ivemy, Irrigation Agronomist) to irrigate 400 acres i.e. R60 per acre at 8% for 50 years.	4.91
Total annual cost per acre	83.32
(3) Total cost per acre inch = R1	
"      "      " thousand galls. = 4 cents.	

(2) Shashi Siding Dam

<u>Capital costs</u>	<u>R</u>
<u>Dam</u>	950,000
+ 15% Contingencies	<u>142,500</u>
	1,092,500
+ 10% fees and supervision	<u>109,250</u>
	<u>1,201,750</u>

This cost must be distributed between the treated supply and irrigation supply in the ratio of water supplied to each, the former being weighted due to the fact that its supply is 100% assured.

Treated supply 2,700 acre ft/annum

\*Irrigation supply 15,000 acre ft/annum

This ratio of 1:5.5 is modified by weighting to 2:3

Irrigation Supply

	<u>R</u>
Proportionate cost of dam	901,750
Main canal	530,000
Distribution system	160,000
Land preparation	<u>240,000</u>
	930,000
+ 15% contingencies	<u>139,500</u>
	1,069,500
+ 10% fees and supervision	<u>106,950</u>
	1,176,450
	<u>1,176,450</u>
	<u><u>R2,078,200</u></u>

This to be used to irrigate 4,000 acres  
Therefore capital cost per acre = R500 approx.

\*See foot of next page.

Table 6 cont'd

- (2) Annual costs  
Assuming economic life of investment 50 years at 8%  
Annual sinking fund annuity - per acre per year R40.9
- (3) Cost per 1,000 gallons water = 4.17 cents.

Table 7

Catchment Tanks

- (i) A 10,000 gallon tank lined with multiple layers of polythene, puddled mud and cement 'sausages'.
1. Capital cost of materials  
Polythene tubing, polythene sheeting,  
gauge 8 wire, D.D.T. and cement R25  
Assume labour available for construction  
at slack times free of charge - self help
  2. Annual Cost - ignoring maintenance  
Economic life of tank 10 years at 8% interest  
Sinking fund annuity for tank R3.72  
10,000 gallons should water 37.5 square yards or .008 acres.  
Therefore annual cost per acre R479.9.
  3. Cost per 1,000 gallons stored = 37.2 cents.
- (ii) A 10,000 gallon tank lined with .03" butyl
1. Capital cost of material - butyl sheet - R200
  2. Annual cost  
Physical life indefinite - economic life  
10 years at 8%  
Sinking fund annuity for tank - R29.8  
Annual cost per acre - R3844.5
  3. Cost per 1,000 gallons stored - R2.98

\*Note: The water requirements for irrigation in this instance are based on estimates by B.G.A.Lund & Partners of individual crop requirements. Using estimates in Appendix I the irrigation water requirement for 4,000 acres would be about 25,000 acre feet. i.e. 2/3 higher.

Table 8

Boreholes

(i) Irrigation demonstration unit Lobatsi

Mean depth of pumping 240 ft.

1. <u>Capital cost</u>	<u>R</u>
Drilling and casing	1,500 *
Equipping - pump etc.	<u>2,000</u>
Total	<u><u>3,500</u></u>

\*\*To irrigate 10 acres - hence capital cost per acre = R350

2. Annual costs

Assuming economic life of investment 10 years at 8%

Annual sinking fund annuity	R521.6
Operating costs - fuel, oil & maintenance	<u>R300</u>
	<u><u>R821.6</u></u>
Cost per acre	R82.16

3. Cost per 1,000 gallons

Mean daily yield  $\frac{2}{3}$  of tested yield 3,000 gallons

for 10 hours per day = 20,000 galls/day.

365 days gives 7,300 thousand gallons per year.

Hence cost per 1,000 gallons = 11.3 cents.

\*Note: It will be noted that drilling and casing form the smaller part of the total cost, hence depth of borehole has only a limited effect on total capital cost. In fact the next costing on a high yielding shallow depth borehole - overleaf shows a higher total capital cost. Yield has a far greater influence on the cost of water.

\*\*Note: Using estimates given in Appendix I a borehole yielding 2,500 gallons/hour could only water 2.6 acres not 10. However it is assumed that this borehole will operate for more than the specified 10 hours especially during peak requirement periods.

Table 8 cont'd

(ii) Tuli Block - Gesond Ltd.

On alluvial soil beside Limpopo River - exceptionally shallow depth of 90 ft. and high yields.

1. Capital Cost

Drilling and casing	<u>R</u> 500
Equipping	<u>5000</u>
Total =	<u><u>5500</u></u>

2. Annual costs

Assuming economic life of 10 years at 8%

Annual sinking fund annuity	<u>R</u> 820
Operating costs, fuel oil and maintenance	<u>1000</u>
Total =	<u><u>1820</u></u>

Yield 45,000 gallons per hour, 10 hours per day -  
should water 69.6 acres

capital cost per acre = R79

Hence annual cost per acre = R26

3. Cost per 1,000 gallons - 1.5 cents.

Table 9

Sand Extraction

(i) Information on costs received from Kingsley Butler (Senior Agricultural Officer, Animal Husbandry).

1. <u>Capital cost of unit</u>	<u>R</u>
Labour (hired)	32
2,000 bricks at R10 per thousand	20
4 pockets cement at 80 cents per pkt.	3.2
Mould - metal sheeting	<u>7</u>
Sub total cost of hole	<u>62.2</u>
Equipping with centrifugal pump, engine, pumphousing etc.	<u>1,200</u>
Total capital cost =	<u>1,262.2</u>

2. <u>Annual cost</u>	<u>R</u>
Sinking fund annuity for 10 years at 8%	90
Operating costs - fuels, oils and maintenance	<u>500</u>
Total =	<u>590</u>

Yield

22,500 gallons per hour

On the assumptions given in Appendix I, assuming furrow irrigation this could water 20 acres.

Capital cost per acre = R63

Annual cost per acre = R29.5

3. Cost per acre inch = 2.6 cents

Table 10

Summary

	Capital cost per acre	Annual cost per acre	Cost per 1,000 gallons
	<u>Rands</u>	<u>Rands</u>	<u>cents</u>
1. Land preparation	22	3.3	-
2. Irrigation furrows	40	5.9	-
3a. Sprinkler irrigation Lobatsi	170	52.3	-
b.   "           "       Tuli Block	130	52.3	-
4a. Pumping costs Tuli Block	66	34.8	1.0
b.   "       "       Thamalakane River	71	45.8	2.0
5. Small dams	547	55.7	2.9
6a. Gaberones dam Tlokweng Perhaps only 8 years in 10		83.3	5.0
b. Shashi Siding Dam Perhaps only 8 years in 10	500	40.9	4.2
7a. Catchment tanks - polythene lined	3,225	480.0	37.2
b.   "       "       - butyl lined	25,800	3844.5	298.0
8a. Boreholes Lobatsi	350	82.2	11.3
b.   "       Tuli Block	79	26.0	1.5
9. Sand extraction	63	29.5	2.6

Table 11

Some Irrigation Costs from Swaziland

(provided by T. Brook, Agricultural Officer, Irrigation  
now with Water Department, Swaziland)

Irrigation Schemes	Capital Cost (R) per acre			Annual
	Average	Low	High	Running Cost (R) per acre
1. River gravity schemes no storage	54	25	90	15
2. River gravity schemes plus storage	82	40	260	18
3. Pumping from rivers no storage	180	50	350	40
4. Pumping from rivers plus storage	230	?	?	50
5. Pumping from rivers (sprinkler) no storage	250	?	?	65



