PN-AAY-142
ISN-51953

THE BRINES OF SUA PAN

REPUBLIC OF BOTSWANA

SUBMITTED TO:

TRADE AND DEVELOPMENT PROGRAM
U.S. GOVERNMENT

CONTRACT No. AID/SOD PDC-C-0407

NOVEMBER 24, 1980

Human Resources Management, Inc. • 1101 30th Street, N.W., Suite 301 • Washington, D.C. 20007

Human Resources Management, Inc.
1101 30th Street, N.W., Suite 301, Washington, D.C. 20007 (202) 338-9071

November 24, 1980

Mr. Raymond Dinkin
TRADE AND DEVELOPMENT PROGRAM
Room 220
1400 Wilson Boulevard
Rosslyn, Virginia 20523

Ref: Botswana Soda-ash Study
Contract No. AID/SOD/PDC-C-0407

Dear Ray:

Pursuant to the above referenced contract, we are pleased to submit to you herewith ten (10) copies of the Final Report on the study we conducted on Botswana's brine prospects. The report is entitled

THE BRINES OF SUA PAN
REPUBLIC OF BOTSWANA.

It has been our pleasure conducting this study for your office, and we look forward to being of further assistance to TDP in the future.

Sincerely yours,

George

George A. Doumani
Vice President for
Technology Transfer

GAD/sd
Enclosure: Ten (10) copies.

TABLE OF CONTENTS

I.	SUMMARY	1
II.	INTRODUCTION	3
III.	GENERAL DESCRIPTION	5
IV.	TERRAIN AND GEOLOGY	9
V.	CLIMATE AND EVAPORATION	14
VI.	BRINE	17
VII.	PROCESSING	29
	Solar Evaporation	29
	Marketing and Inexpensive Transportation	30
	Impermeable, Flat, Pond Areas	30
	Adequate Evaporation Rate	31
	Phase Relations	32
VII.	SUA SALT PLANT	33
IX.	FUTURE ACTION	37
	Market Survey	37
	Brine Analyses	38
	Processing	39
	Water Capture	41
X.	TECHNICAL TRAINING AND MANPOWER DEVELOPMENT	42
	Institutional Structure and Functions	42
	Manpower Development	47
	Training Programs	51
	Findings and Recommendations	52
XI.	PROPOSED STATEMENT OF WORK	53
XII.	BIBLIOGRAPHY	61

I. SUMMARY

1. Sua Pan in northeastern Botswana contains a substantial amount of brine in which sodium chloride or common salt is the main constituent. Other chemicals present are sodium carbonate, sodium bicarbonate, sodium sulfate, and a minor amount of potash.

2. The area appears very conducive to the operation of a solar salt plant as the net evaporation rate is very significant.

3. Potable water in the area is scarce. Thus, before a solar salt plant is built, other techniques to obtain both salt and water should be thoroughly examined.

4. Previous investigators have stated there is a potential for the sale of about 100,000 tons per year of salt in Botswana and the neighboring countries. This has to be verified by a detailed market study in order to determine the size of an economical operation.

5. Serious consideration should be given to the development of a salt plant utilizing Sua Pan brine. The size of the plant should be in some ratio to the size of the market as developed by the detailed market survey.

6. Serious consideration should be given to making the operation as labor intensive as possible, in keeping with the economics.

7. Additional holes should be drilled in other areas of both the Sua Pan as well as in the Ntwetwe Pan to insure the brine is consistent in quality and quantity sufficient to last for many years.

8. When the salt plant is operational, serious consideration should be given to the extraction of soda ash and perhaps other chemicals from the Sua Pan bitterns.

9. The Government of Botswana is anxious to accelerate the localization process, and looks favorably for cooperation and assistance in technical training and manpower development. It is recommended that the U.S. Government take this situation into serious consideration, especially toward the development of Botswana's mineral resources.

10. Chapter XI provides a detailed summary of our proposed statement of work. The proposal consists of four phases. Phase I suggests the need to conduct a definitive market survey. Phase II raises specific questions related to data needs on the consistency of the brines composition. Phase III covers the need for additional data on the physical chemistry of the Sua Pan brine. Finally, Phase IV discusses developing a feasibility study with sufficient detail from which an investor could decide whether or not to develop an interest in the Sua Pan.

II. INTRODUCTION

The Sua (Soa)(Sowa) salt pan in northeastern Botswana is one of the largest playa lakes in the world. It covers some 24,000 square kilometers (9300 sq. miles) with brine underlying an area of 915 square kilometers (353 square miles). Much work and many studies have been made on the pan. However, some of these studies have been inadequate or irrelevant and others in fact, are completely useless.

The composition of the brine is predominantly sodium chloride (common salt) with lesser amounts of soda ash, potassium chloride (potash) and sodium sulfate. As there appears to be market potential in southern Africa for these commodities, and the area is in need of industry, there are sufficient reasons to restudy the entire situation to determine if there isn't some way or manner in which the deposit can be economically exploited for the benefit of Botswana. Accordingly, a team from Human Resources Management of Washington D.C., spent September 14-23, 1980, in Botswana reviewing available data, discussing the project with knowledgeable people in the Botswana Department of Geological Survey as well as others and visiting the Sua Pan area. As the project is of economic interest to the area, steps are proposed for a study to systematically and economically develop the deposit. This report is a summation of our visit and includes recommendations for a feasibility study.

Field work, analyses, and report writing were performed by George A. Doumani and Stanley J. Lefond, representing Human Resources Management, Inc. (HRM). The project was supported by the U.S. Trade and Development Program (TDP) under Contract No. AID/SOD PDC-C-0407. The views and recommendations expressed herein are exclusively those of HRM, Inc., and do not necessarily represent those of TDP.

The authors acknowledge with gratitude the valuable advice, assistance and data given to them by John C. Brower, Economic Consultant at the Ministry of Mineral Resources and Water Affairs; G. Colin Clark, Director, and David Gould of the Geological Survey Department; and R. W. Jennings of the Mines Department. The staff of the U.S. Embassy, Gaborone, also provided valuable assistance which is deeply appreciated.

III. GENERAL DESCRIPTION

Sua Pan is the eastern arm of a large playa deposit in the Makgadikgadi Basin in northeastern Botswana (see Map 1). The Makgadikgadi Basin is about 200 kilometers (125 miles) long in an east-west direction and 120 kilometers (75 miles) wide in a north-south direction. Of this large area, the Sua Pan covers an area about 100 kilometers (62 miles) long from north to south and 50 kilometers (31 miles) in an east-west direction (see Map 2). Actually, only the eastern part of the Makgadikgadi, the Sua Pan, has undergone any type of investigation. The Ntwetwe Pan should be investigated to determine whether or not there is brine in this pan and if so, is it better than Sua Pan brine? does it contain a different suite of chemicals that might have more economic potential? etc.

The Sua Pan lies about 37 kilometers (23 miles) south of the village of Nata and about 158 kilometers (98 miles) west of the town of Francistown. The road from Gaborone to Francistown and Nata is paved (see Map 2). Sua Pan is accessible via an unmaintained road from a point about 30 kilometers (19 miles) north of Mosetse. This road runs almost due west for about 50 kilometers (31 miles) to the end

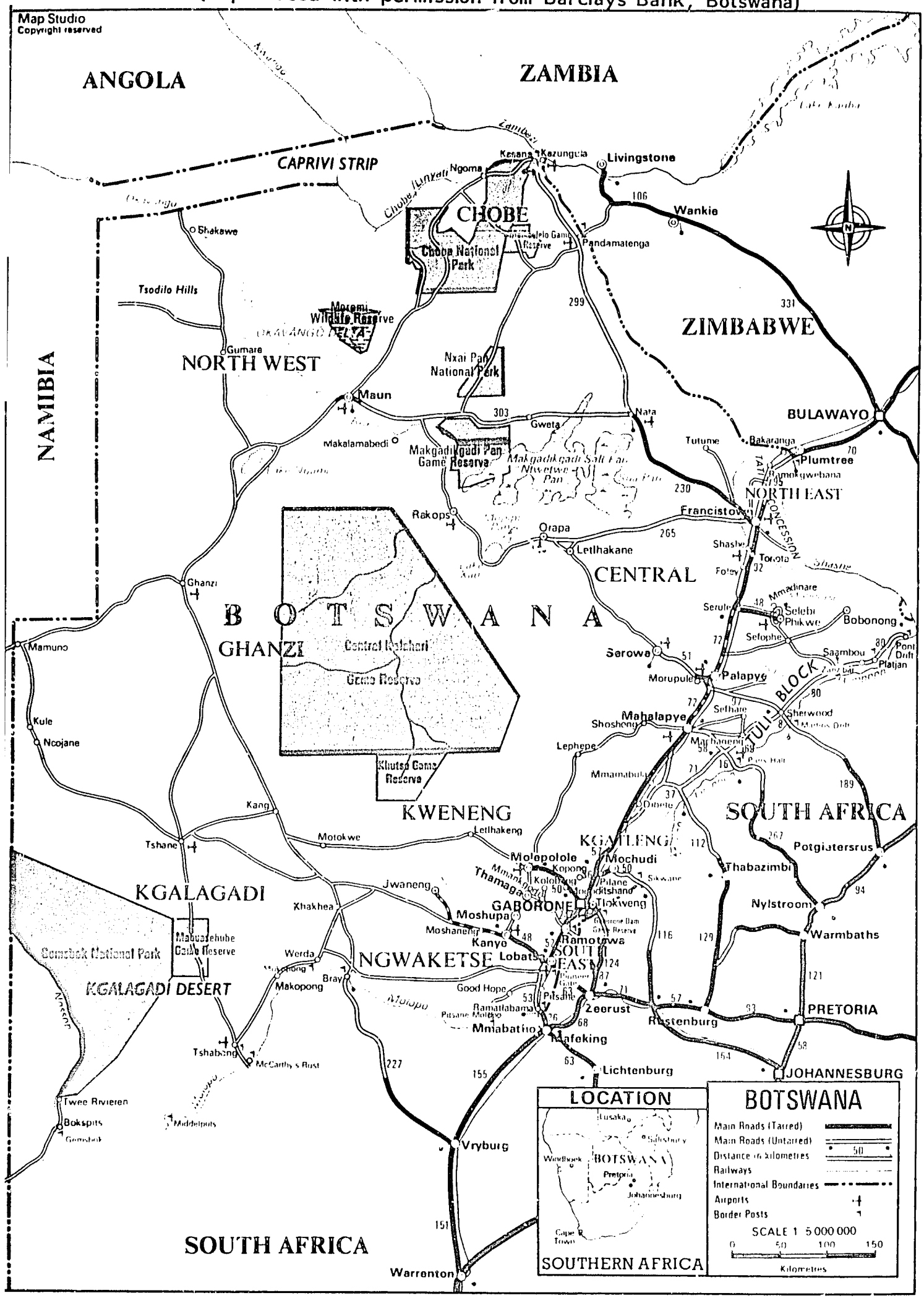
of the spit that extends into Sua Pan (see Map 2). Francistown is the nearest railhead and largest town in the area with a population of about 20,000 people.

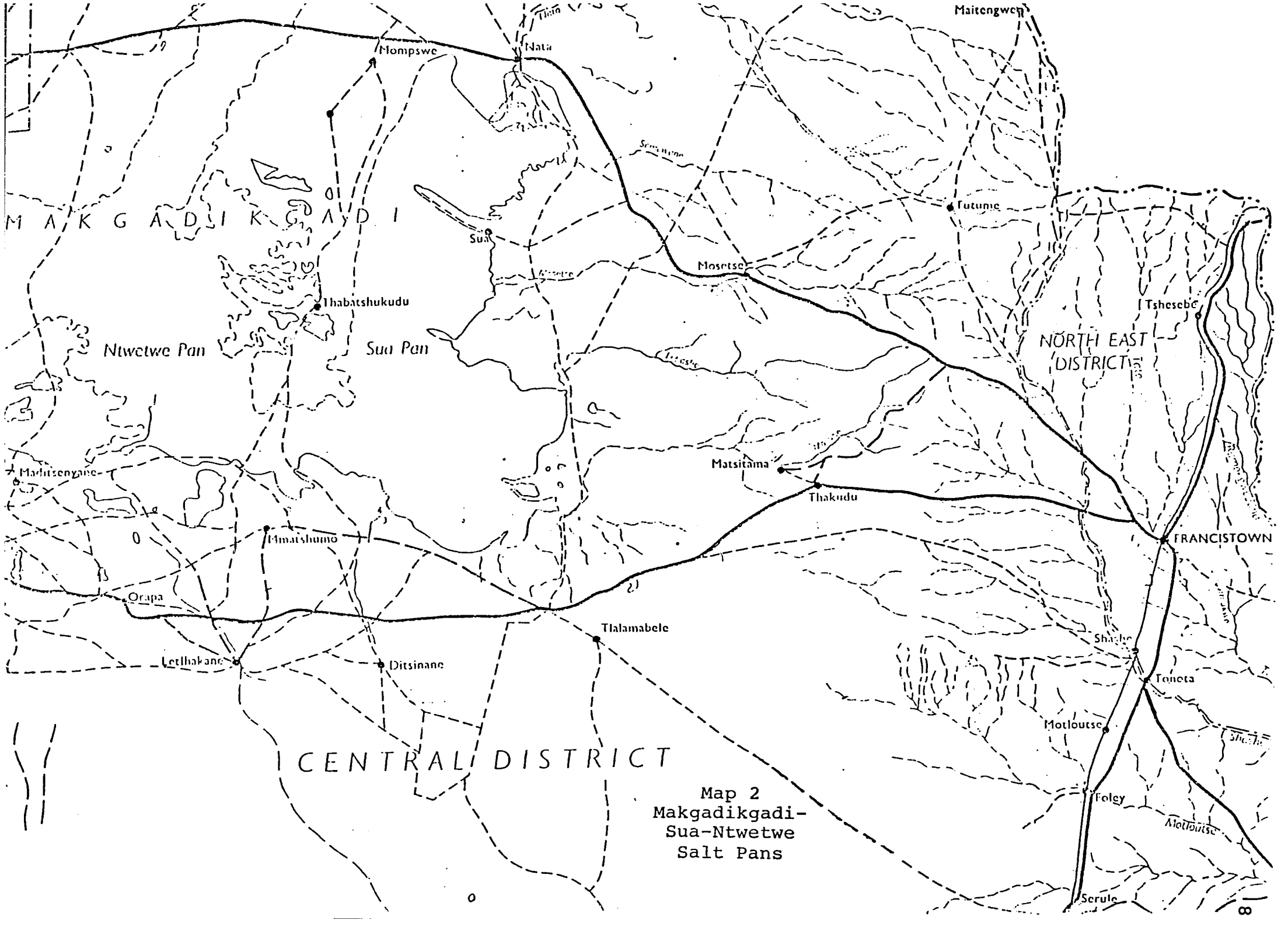
The towns in the area are capable of only supplying labor and perhaps making minor repairs. All significant supplies would have to be obtained from Gaborone, which is also inadequate in many respects. Technical people would have to be imported and extensive training programs conducted for middle and lower management personnel as well as for most laborers. Actually, most people in the area do not have a 'mechanical inheritance' and would have to be taught the rudiments of mechanical work. This does not imply they are ignorant, but just that they have not been exposed, in most instances, to this type of work.

There is also a scarcity of technical and professional manpower. A chapter is included in this report, which addresses specifically the subject of technical training and manpower development in the geosciences.

Map 1

(Reproduced with permission from Barclays Bank, Botswana)





Map 2
Makgadikgadi-
Sua-Ntwetwe
Salt Pans

IV. TERRAIN AND GEOLOGY

The Makgadikgadi Depression is a large flat area that lies at the center of a basin of interior drainage. All waters falling onto this large area eventually either evaporate or flow to the lowest point of the basin. It is these waters that, over geologic time, have carried dissolved material into a lake in the pan. As the water evaporates the dissolved material is left behind to accumulate. Today we find a large area underlain by a brine containing dissolved salts that have accumulated over the years in the basin.

The basement rocks of the area are a series of Precambrian (Archean) metamorphics. This series is in turn overlain by post-Cretaceous rocks collectively known as the 'Kalahari' beds. These beds are a group of aeolian sands and sandstones, calcretes, silcretes and various fluviatile and lacustrine deposits. The bedrock for the brine aquifer is believed to be a consolidated sand of this series (Ntane(?) sandstone). However, as yet, this has not been definitely decided.

The aquifer consists of sands with a medium grain size of 0.15 - 0.55 mm with a sorting coefficient ranging from 1.25 - 1.73. The porosity is estimated at 20-25% with a permeability of 2-3 darcys. It has a coefficient of

transmissibility of 20,000 gpd/ft. and a storage capacity of .005. These data suggest there should be no great problem in producing sufficient brine for any reasonable-sized plant.

The sequence overlying the Kalahari beds consists of an upper sand/clay succession, averaging 30 meters (100 feet) in thickness, overlying an unconsolidated fine grained sand (the aquifer) which in turn overlies a sandstone bedrock.

The surface of Sua Pan is covered with a mixture of salts from the brine, fine wind blown sands and clay (Fig. 1&2). In times of floods, the soluble material is dissolved and carried with the water to the center of the basin. The salts are either carried with the water down to the brine aquifer or, if the water evaporates, the salts are redeposited on the surface of the pan.

The regional geology of the Makgadikgadi is shown on Map 3 (Gould, 1980). Cross-sections through the pan are shown on Map 4 (Gould, 1980).

The geology of the area is much more adequately treated in Gould (1980), Lamont (1951), Van Straten (1958), Mazeretal (1977) and other.

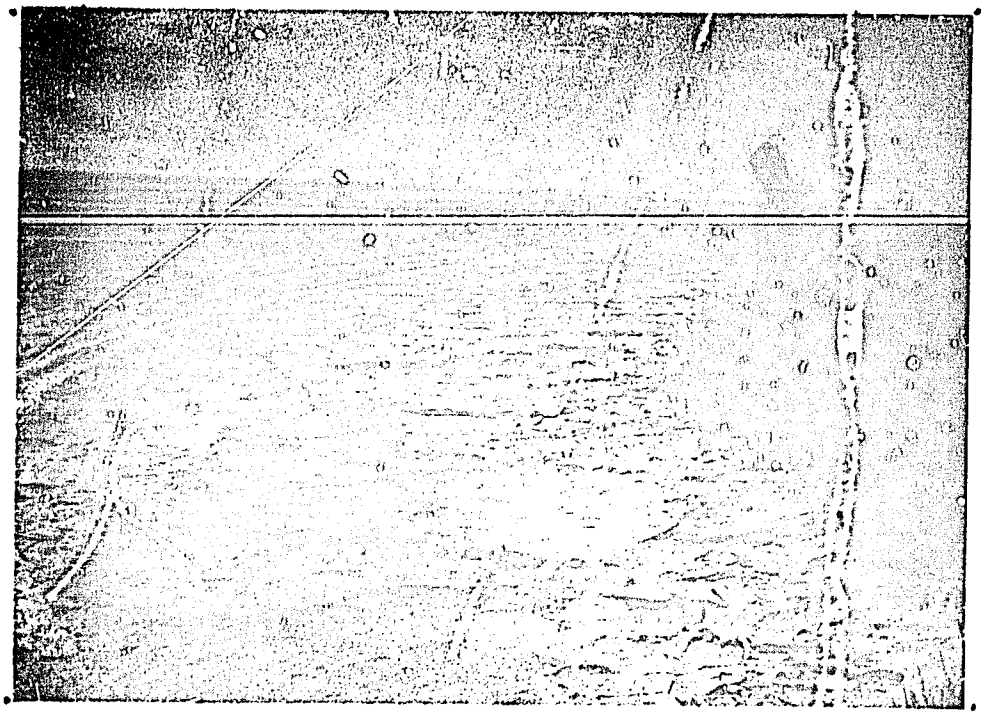


Figure 1. Typical surface appearance of Sua Pan, Botswana.

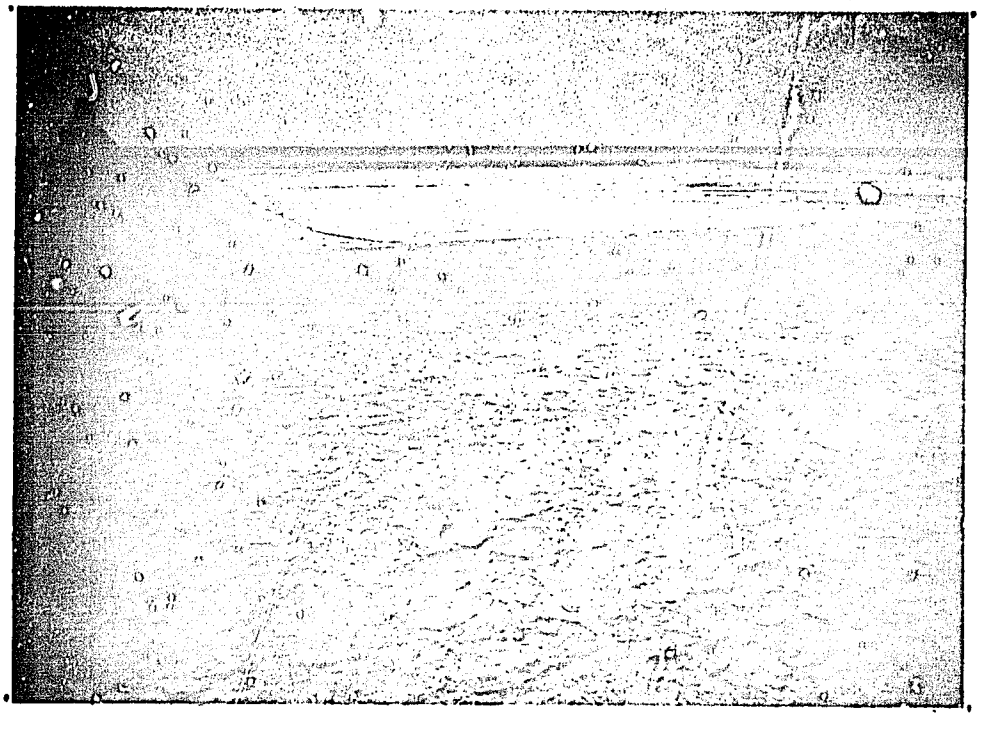
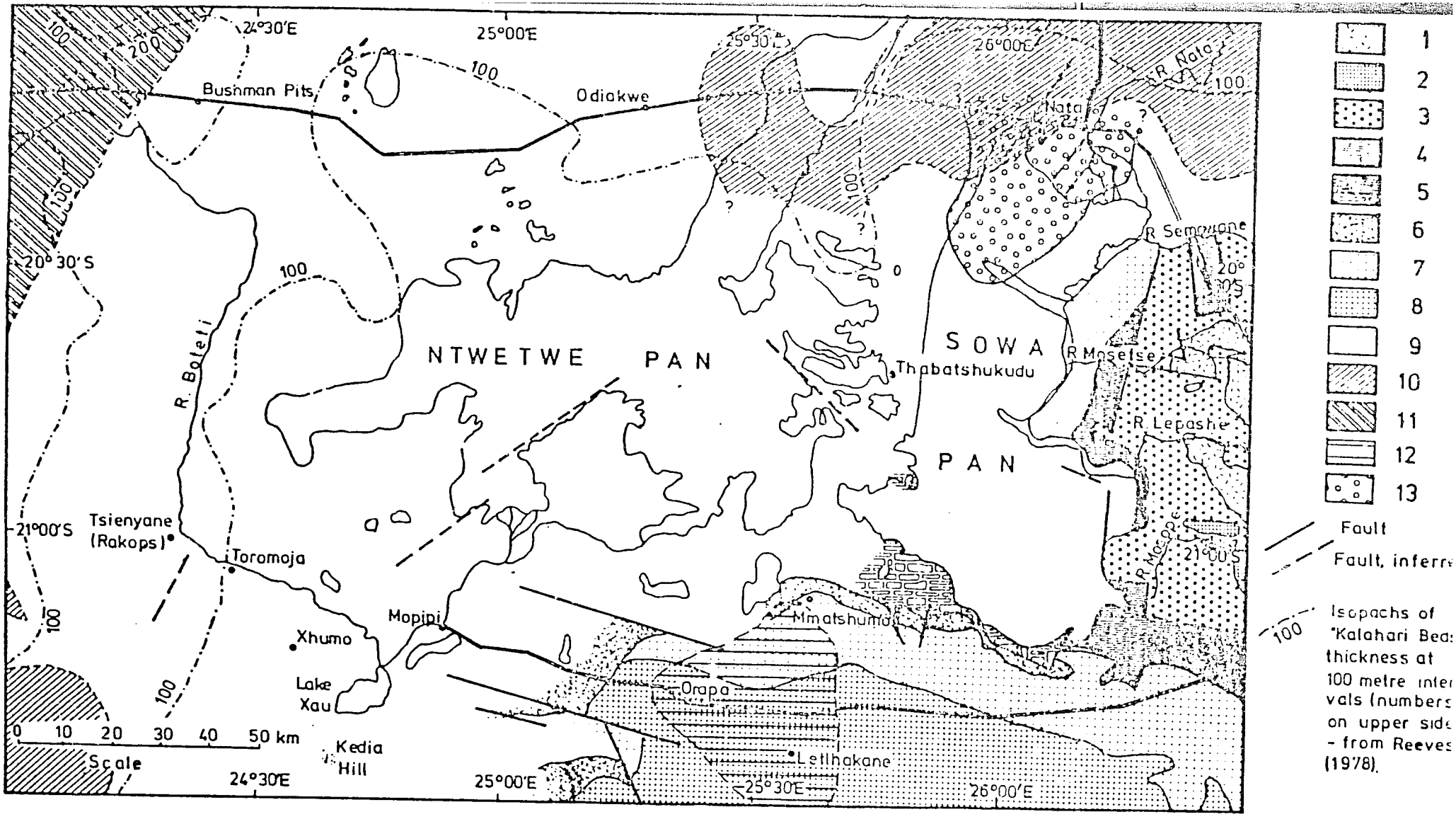
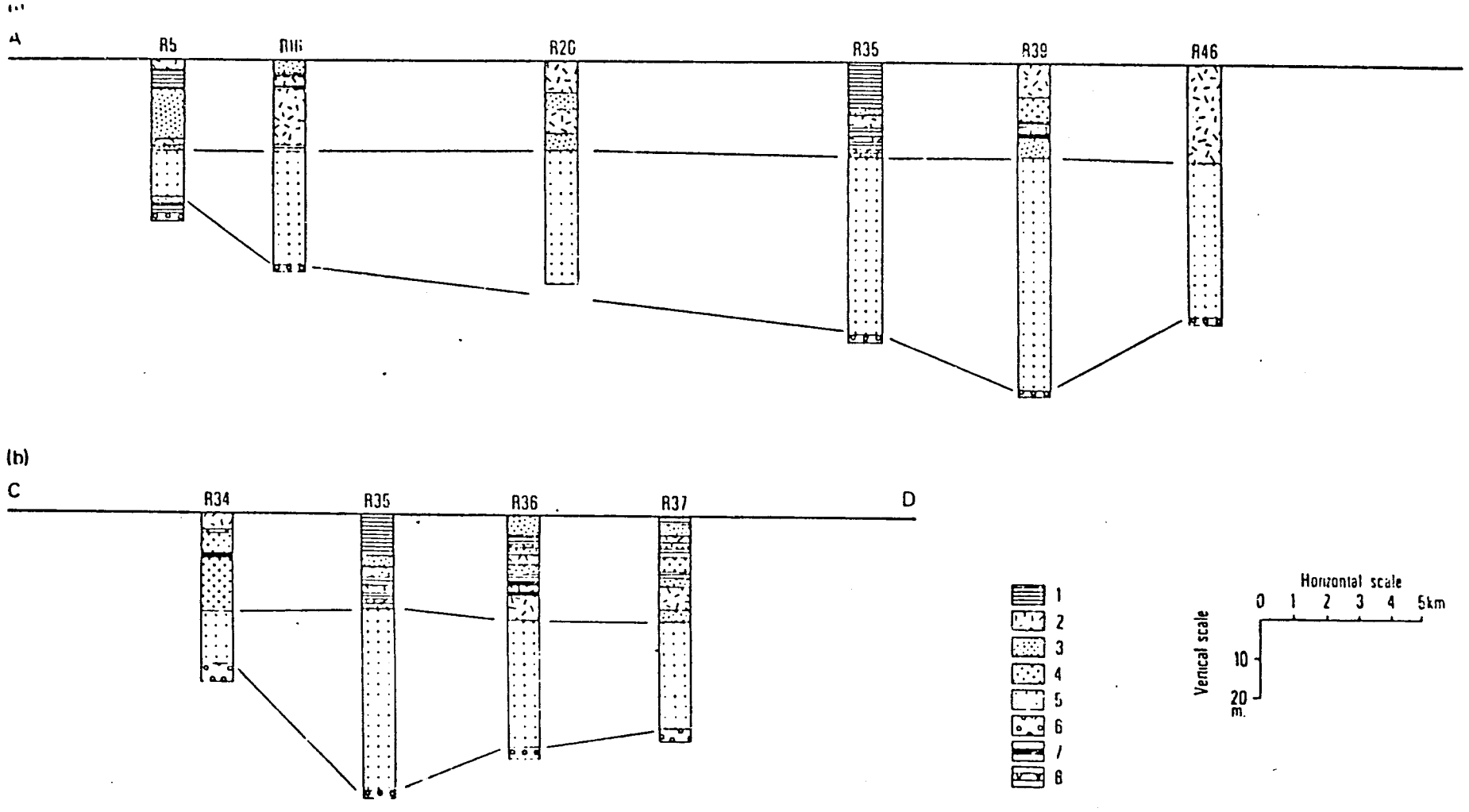


Figure 2. View of the solar evaporation test pond at Sua Spit.



Map 3 Geological map of the Makgadikgadi.

1. acid gneisses.
2. intermediate to basic volcanics and metasediments of the Matsitama schist belt. 3 - 8 Karoo
3. Mea Arkose.
4. Tlapana Mudstone.
5. Kautse Beds.
6. Mosu Sandstone, "Toatshaa mudstone", "Toatshaa sandstone" and sandstone of Kedia Hill.
7. "Ntana sandstone"
8. basalt
9. "Kalahari Beds" overlying undifferentiated Karoo sediments.
10. "Kalahari Beds" overlying basalt.
11. "Kalahari Beds" overlying Proterozoic Ghanzi Group sediments.
12. Orapa - Letlhakane kimberlite province.
13. Area underlain by brine aquifer. N.B. The WNW - ESE trending post-Karoo dykes which occur throughout the area have not been shown.



MAP 4

(a) SSW - NNE section through northern part of Sowa Pan.
(b) WNW - ESE section through northern part of Sowa Pan.

LEGEND:

1. Clay
2. Sandy clay
3. Clayey sand
4. Sand (other than aquifer).
5. Aquifer sand (unconsolidated).
6. Basal sandstone (?Ntane).
7. Sandstone (other than basal).
8. Chalcedony. N.B. Apart from that in borehole R34, the chalcedony layers are too thin to be shown at this scale. Borehole R46 was not logged in detail.

V. CLIMATE AND EVAPORATION

The climate is classified as semi-arid with short dry winters (May-August) and summer from September to April. Rains usually commence in October or November with an increasing intensity and frequency until the end of December, after which it starts to decline and stops in March or April. There also appears to be a progressive reduction in precipitation from northeast to southwest. Rainfall averages about 19 inches/year at Maun (178 miles WNW of the Sua spit) with an annual minima of 9.5 inches and a maxima of 27.5 inches.

Rainfall varies greatly from year to year and there is a tendency for excessively wet and dry years to cluster together. For example, the five years from 1961/1962 to 1965/1966 had less than 75% of the average rainfall while 1973/74 - 1977/78 had over 150% of the average rainfall. However, there was a failure in the 1978 summer rains and the country was faced with a drought. In 1979 the president issued a proclamation declaring the republic a drought-stricken country.

Winds are usually light to variable except from August to October, when steady easterly winds are the rule. Winds are a necessity for a solar-evaporation operation to blow away the moisture-laden air from over a solar-salt pan. The moisture-laden air has to be blown away or it will set over the pan and retard evaporation.

Little definitive work has been done on the solar evaporation of the Sua Pan brine. The meager data available suggest water in the Sua Pan area has an evaporation of about 74 inches/year. However, brines do not evaporate as fast as water. Thus, the evaporation rate for the Sua Pan brine could be on the order of 40-50 inches/year.

Cremer and Warner, in their report of January 1976 stated:

"The average net evaporation data after allowing for rainfall estimated from four weather stations in Rhodesia is quoted as 90 in. (2.286m) per annum for a standard tank. A factor of 0.7 was used to convert this figure to apply to large areas (without quoting any authority) and a further factor of 0.85 to give a rate applicable to brine of 54 inches (1.37m) per annum, subject to confirmation in test pans."

Elsewhere in the same report, the results of experiments in a 250 square-foot test solar evaporation pond indicated the net evaporation of raw brine per year was 54 inches and the rate of evaporation of a saturated brine was 50 inches. The annual rainfall in the Makgadikgadi Depression was between 10 and 15 inches. Thus, there is a net evaporation of about 40 inches.

Other tests showed a variation from month to month, but evaporation does exceed the average rainfall in every month.

With our present information, albeit limited, there is no reason why a small solar salt plant could not be installed and operated somewhere in the Sua Pan area. Of course, the economics of such an operation have to be carefully considered, but the physical parameters appear favorable.

VI. BRINE

Some 49 holes have been drilled in the Sua Pan area, whose locations are shown on Map 5 (in pocket). Depths, aquifer thickness, etc., are shown in Table 1. The aquifer varies in thickness up to about 260 feet and is overlain by a varying thickness of clay and/or sand/clay.

The Sua Pan brine is contained in the pores of the aquifer sand and overlying sand/clay sequence. While a good portion of the area and configuration of the Sua Pan are known, the extension of the brine body to the north is still open. Brines similar to those of the Sua Pan have been encountered in water well boreholes under a thin layer of fresh water in areas west of Nata.

The brines are believed to underlie an area of at least 915 square kilometers. If this is so, the brine reserves in the aquifer are at 8,012,000,000 cubic meters. An additional 5,502,000,000 cubic meters are believed to be stored in the overlying sand/clay sequence.

Analyses of the brine taken at various times and places are tabulated in Tables 2 - 6. Many of the analyses listed are duplicates or analyses of brine samples taken at different times from the same drillhole.

Table 1

Availability Of Basic Data

Hole	Core Log		Sieve Analyses		Aquifer	
No.	From	To	From	To	From	To
R1	Believed Not Drilled					
R2	None		101	169	101	169
R3	0	162	102	138	102	136
R4	0	140	None		Not Present	
R5	0	161	90	140	90	140
R6	Believed Not Drilled					
R7	0	155	100	115	100	115
R8	Believed Not Drilled					
R9	Believed Not Drilled					
R10	Believed Not Drilled					
R11	0	180	90	174	90	174
R12	0	165	90	128	85	128.5
R13	Believed Not Drilled					
R14	Believed Not Drilled					
R15	Believed Not Drilled					
R16	0	215	90	210	90	210
R17	0	201	102	191	102	191
R18	0	161	90	150	90	149
R19	0	225	90	215	85	220
R20	0	227	90	227	89	227
R21	Believed Not Drilled					
R22	Believed Not Drilled					
R23	0	227	90	220	81	220
R24	0	40	None		Not Present	
R25	0	110	None		11	102
R26	Believed Not Drilled					
R27	Believed Not Drilled					
R28	Believed Not Drilled					
R29	Believed Not Drilled					
R30	None		0	140	50	140
R31	Believed Not Drilled					
R32	Believed Not Drilled					
R33	0	206	96	196	96	196
R34	0	160	20	150	20	150
R35	0	285	90	278	96	278

Table 1 cont.

Hole	Core Log		Sieve Analyses		Aquifer	
No.	From	To	From	To	From	To
R36	0	266	110	236	110	236
R37	0	230	110	217	110	220
R38	None		25	185	95	255
R39	0	72	35	60	95	333
	72 and	340	80 and	333		
R40	0	186	53	150	52.8	149.5
	186 and	240				
R41	0	70	34	64	126	287
	70 and	305	126 and	287		
R42	None		0	190	75	193
R43	Believed Not Drilled					
R44	None		0	275	100	275
R45	None		20	285	100	270
R46	None		40	260	100	260
R47	0	205	67	72	20	185
			85 and	180		
R48	None		0	200	72	187
R49	0	190	0	195	72.5	130
R50	None		0	175	Not Known	
R51	0	92	None		Not Present	
R52	Believed Not Drilled					
R53	0	180	78	197	78	197
	200 and	215				
R54	None		0	175	90	175
R55	None		0	165	75	175
R56	0	180	59	67	40	151
			84 and	160		
R57	0	100	None		Not Present	
R58	Believed Not Drilled					
R59	None		0	160	90	160
R60	0	120	28	35	26	97
			38 and	73		
R61	0	124	None		Not Present	
R62	None		0	205	90	195
R63	None		0	270	Not Known	
R64	None		0	295	35	280
R65	None		None		40	165

Apparently either not all the brines from the various boreholes were analyzed or they are not available. Analyses of brine samples from Holes R2, R20, R39, the ditch and a few miscellaneous ones appear to be the only ones available. However, while the analyses are not identical, they do suggest the brine to be fairly constant in composition. The consistency over the entire brine body has to be verified.

The analysis of Wellfield 10, Hole E2 on Chart 5, is a complete enigma. Why the Na and Cl content is so high is unknown. However, if the analysis is correct, then the area around hole Wellfield 10 should be investigated further.

Incidentally, brines tend to stratify with the lighter brines lying on top of brines with successively higher specific gravities. Thus it is not unusual to find fresh water on top of a brine. Actually, this layering often causes sampling problems. One has to be especially careful in sampling such brines to insure that an equal amount of each layer is considered in the sample. One technique is to pump from the entire section until the specific gravity of the brine remains more or less constant before taking a sample of the brine.

There are devices on the market which permit sampling at various depths. Care has to be used in the use of such devices as not to cause too much mixing between the layers. In this respect, brine samples should be taken from the top down.

Table 2

Brine Analyses in Ratio Form

Location	Date	Na/SO_4	K/SO_4	CO_3/SO_4	HCO_3/SO_4	EQ CO_3/SO_4	Cl/SO_4
Northern Edge of Pan	1960	13.7	0.72	1.1	3.6	2.9	15.7
	"	11.5	0.61	1.2	3.3	2.8	13.2
	"	10.3	0.51	2.0	1.5	2.7	12.3
	"	8.1	0.32	1.9	1.1	2.4	8.8
	"	9.2	0.32	1.7	1.1	2.2	11.0
	"	10.7	0.50	1.8	1.9	2.7	13.1
	"	9.5	0.39	2.2	1.0	2.8	11.5
106-114 (32.31-34.74m) Sua Spit	1961	9.4	0.33	1.8	0.6	2.1	11.3
91 (24.7m) Sua Spit	"	7.6	0.25	1.4	0.7	1.7	9.1
Sua Spit	"	7.9	0.17	1.3	0.7	1.7	8.8
112 (34.14m) North of Pan	"	9.2	0.33	1.9	0.8	2.3	10.5
R2	Mch '63	7.1	0.19	1.1	1.0	1.5	8.3
R2	June '63	7.1	0.12	1.1	0.9	1.6	8.6
11:00 R20	14/3/68	7.3	0.25	1.3	0.6	1.6	8.7
12:00 R20	"	7.2	0.25	1.3	0.6	1.6	8.7
R20	Mch '68	7.3	0.25	1.3	0.7	1.7	8.8
R39	June '72	7.3	0.29	1.8	0.6	2.1	8.3
R39	"	7.3	0.27	1.8	0.6	2.1	8.3
R2	20/9/72	8.8	0.23	1.5	1.0	2.0	10.8
Ditch 1.	July '72	6.6	0.25	1.9	0.6	2.2	7.0
2.	"	7.3	0.27	2.2	0.5	2.5	7.9
3.	July '72	9.5	0.35	2.9	0.6	3.2	10.4
4.	"	5.8	0.21	1.7	0.4	1.9	6.1
5.	"	7.2	0.27	2.2	0.5	2.4	7.7
6.	"	6.2	0.23	1.7	0.6	2.0	6.6
7.	"	6.5	0.25	1.9	0.6	2.2	6.9
8.	"	6.7	0.26	2.0	0.6	2.2	7.2
9.	"	7.4	0.30	2.1	0.8	2.5	8.1
10.	"	6.9	0.27	1.9	0.9	2.3	7.5
11.	"	7.7	0.30	2.1	1.0	2.6	8.4
12.	"	13.2	0.51	3.8	1.5	4.5	14.6
13.	"	13.9	0.57	4.3	1.1	4.9	15.5
14.	"	9.9	0.43	3.3	0.7	3.6	11.5
	July '72	7.6	0.32	2.0	0.5	2.2	8.7
	"	7.7	0.30	1.9	0.5	2.1	8.9
	7	7.3	0.25	1.3	0.8	1.7	8.8

Table 3

Brine Analyses in Ionic Form (g/l)

Description	Date of Sampling	Na	K	CO_3	HCO_3	EQ CO_3	Cl	SO_4	S.G	pH
Boreholes made on Northern edge of Pan	1960	33.8	1.76	2.7	8.9	7.1	38.7	2.46		
	"	36.7	1.95	3.9	10.6	9.1	42.3	3.20		
	"	51.9	2.57	10.0	7.7	13.8	61.8	5.04		
	"	44.5	1.78	10.3	6.0	13.3	48.5	5.51		
	"	26.3	0.91	4.8	3.1	6.3	31.7	2.87		
	"	46.7	2.18	8.0	8.1	12.0	57.5	4.38		
	"	72.7	3.02	17.2	8.0	21.1	88.3	7.68		
Sua Peninsula 106 - 114' (32.31-34.74m)	1961	71.32	2.50	13.5	4.6	15.76	85.36	7.58	1.125	
Sua Peninsula 81'	"	69.0	2.24	12.7	5.9	15.6	82.6	9.10	1.125	
Mid Test (24.7m)	"									
Sua Peninsula	"	72.33	1.54	11.9	6.2	14.95	80	9.14	1.123	
North of Pan 112' (34.14m)	"	74.19	2.66	15.4	6.6	18.65	84.3	8.05	1.132	
Pump Tests on Well R2	March 1963	70.7	1.87	10.8	9.45	15.4	82.3	9.98	1.125	9.0
	June 1963	71.4	1.20	11.4	8.54	15.6	85.7	10.0	1.125	9.0
R20 Pump Test 11:00	14/3/68	69.2	2.4	12.4	5.8	15.3	82.8	9.5		
12:00	"	68.7	2.4	12.6	5.6	15.4	82.9	9.5		
R20	March 1968	69.0	2.41	12.5	6.97	15.9	82.9	9.46	1.125	9.0
R39	June 1972	62.3	2.49	15.5	5.18	18.0	70.8	8.54	1.122	9.4
R39	June 1972	62.4	2.32	15.6	4.88	18.0	70.9	8.54	1.122	9.4
R2	20/9/72	72.6	1.92	12.0	8.39	16.1	88.7	8.22	1.128	9.35
Pump Tests from narrow ditch 1.	7/9/72	62.0	3.10	9.75	20.55	19.9	77.55	3.93		
2.	"	65.0	3.15	10.10	20.55	20.2	79.75	1.40		
3.	"	64.0	3.25	9.75	20.55	19.9	78.63	3.93		
4.	"	65.0	3.15	10.45	19.85	20.2	79.75	1.40		
5.	"	65.0	3.15	9.75	21.25	20.2	79.75	1.25		
6.	"	62.5	3.15	9.40	21.25	19.9	79.05	1.50		
7.	"	60.0	3.00	9.05	20.55	19.2	74.90	1.40		
8.	"	58.5	2.90	9.40	17.70	18.1	72.15	1.50		
9.	"	58.5	2.75	9.40	17.70	18.1	71.45	1.25		
10.	"	60.0	2.90	9.40	19.15	18.8	75.25	1.25		
11.	"	60.0	2.80	10.15	17.70	19.2	79.05	1.40		
12.	"	60.0	2.80	9.05	19.15	18.5	70.03	1.57		
Ditto 1.	July 1972	68.7	2.62	19.95	6.41	23.1	73.24	10.41		
2.	"	72.56	2.66	21.99	4.88	24.4	78.56	9.94		
3.	"	71.64	2.66	21.99	4.58	24.2	78.59	7.58		
4.	"	73.83	2.66	21.81	4.76	24.2	78.20	12.82		
5.	"	71.64	2.66	21.45	5.06	23.9	77.17	9.98		
6.	"	70.36	2.62	19.59	7.32	23.2	75.01	11.38		
7.	"	67.57	2.58	19.95	5.80	22.8	71.86	10.41		
8.	"	63.37	2.50	18.48	5.18	21.0	68.06	9.50		
9.	"	63.48	2.54	17.94	6.40	21.1	68.91	8.54		
10.	"	65.96	2.58	17.76	8.24	21.8	71.22	9.50		
11.	"	66.12	2.58	18.30	8.42	22.4	71.43	8.54		
12.	"	62.51	2.42	18.12	7.01	21.6	69.55	4.75		
13.	"	59.43	2.42	18.36	4.76	20.7	66.19	4.27		
14.	"	56.16	2.46	18.69	3.78	20.5	64.94	5.66		
Ditch	July 1972	72.1	2.99	18.6	4.4	20.8	82.5	9.48	1.132	
Ditch	July 1972	71.9	2.82	17.9	4.3	20.0	83.0	9.34	1.128	
R2	?	72.6	2.52	13.1	7.52	16.8	87.2	9.95		

TABLE 4

Raw Brine Analyses

	R2 March 1963	R2 June 1963	R20 March 1968	R39 June 1972	R39 June 1972
NaCl	137.70	138.20	132.90	112.90	113.30
Na_2CO_3	19.03	20.13	22.10	27.29	27.56
$NaHCO_3$	13.02	11.76	9.60	7.14	6.72
Na_2SO_4	14.46	14.80	14.00	12.64	12.64
KCl	3.58	3.82	4.60	*	4.43*
S.G.	1.125	1.125	1.125	1.122	1.122
pH	9.0	9.0	9.0	9.40	9.40

Results are in g/l

* The original calculation of KCl values was incorrect. A corrected figure is available for the second R39 sample, but not apparantly for the first.

TABLE 5

Raw Brine Analyses

Taken from the report "Nata Road Project. Underground Water Supply Potential" by Tona Earth Resource Associates (Pty.) Ltd., submitted to the Roads Department, Botswana.

	Wellfield 9 Hole E2			Wellfield 10 Hole E2
	45m.	63m.	75m.	20m.
CO_3	72	76	66	890
HCO_3	867	1,024	933	6,275
Cl	1,492	1,841	1,708	20,375
SO_4	309	330	306	2,730
F	4	1	2.5	4
K	50	50	50	600
Na	1,320	1,600	1,500	16,250
Ca	15	18	15	3
Mg	50	46	40	10
pH	8.90	8.30	8.70	8.20

Results are in p.p.m.

Table 6

Chemical Analyses of Sowa Pan Brines

	R2	R20	R39	Average
Na^+	70,88	69,0	62,35	67,41
K^+	1,94	2,41	2,41	2,25
Cl^-	85,48	82,9	70,85	79,74
$CO_3^=$	11,10	12,5	15,55	13,05
HCO_3^-	9,00	6,97	5,03	7,00
$SO_4^=$	9,90	9,46	8,54	9,30
Br^-	0,22	*	*	*
Li^+	0,02	*	*	*
NaCl	138,0	132,9	113,1	128,0
Na_2CO_3	19,61	22,10	27,43	23,05
$NaHCO_3$	12,39	9,60	6,93	9,64
Na_2SO_4	14,63	14,00	12,64	13,76
KCl	3,70	4,60	4,60	4,30
Total	188,33	183,20	164,70	178,75
S.G.	1,125	1,125	1,122	
pH	9,0	9,0	9,4	

All concentrations in g/ℓ.

* - no analysis available.

The temperature of the brine should also be taken immediately upon taking the sample as the specific gravity will vary with the temperature.

Analyses of those samples that are available while not exactly identical are essentially similar. Variations could be caused by differences in sampling techniques, depth of sampling, types of containers used, temperature of brine, time elapsed between sampling and analyses - or many other factors. Apparently, no total analysis for minor constituents of the brine has been made. However, the few data on trace elements present are shown in Table 7.

It is interesting to note there are plans to solar-evaporate a brine containing 0.12-1.4 g/l of lithium from the Solar de Alacama in Chile. This is in contrast to Sua Pan brine which has a lithium content of 0.020-.093 g/l. At Clayton Peak, Nevada, a playa lake brine with 0.68 g/l is being processed by solar evaporation for lithium.

The Smackover brine in Arkansas, U.S.A., with a bromine content of 4.5 g/l is processed to recover the bromine in contrast to the Sua Pan brine which only has a bromine content of 0.22 g/l.

Table 7

TRACE ELEMENTS IN THE BRINE (g/l)

C&W No.	Description	Date	Li	Ca+Mg	B	Soluble SiO_2	PO_4	F	I	Br	S Other than SO_4	NO_3	As
1.	Northern edge of Pan. Composite of 7 Samples given for B, SiO_2, PO_4, F and NO_3.	1960	.093	Negligible	)								
		"	.093		)								
		"	.117	"	)								
		"	.103	"	) .01	.07	.027	.011				.01	
		"	.075	"	)								
		"	.103	"	)								
		"	.224	"	)								
2.	Borehole (1) 106-114' (Sua Spit) (32.31-34.74 m)	1961	.0215	< .05			.035	.014	<.001	.22	$<6\times10^{-5}$		
	130-135' (39.62-41.14 m)	"	.021	< .05		.003	.037	.013			$<6\times10^{-5}$		
	151' (46.03 m)	"	.0226	< .05			.040	.014			$<6\times10^{-5}$		
	Borehole (2) 81' Sua Spit (24.7 m)	1961	.026				.054	.019	.01	.22	$<6\times10^{-5}$		
	261' (79.55 m)	"	.026				.054	.022	.01	.22	$<6\times10^{-5}$		
	Borehole (3) 171' Sua Spit (52.12 m)	1961	.020				.052	.018			$<6\times10^{-5}$		
	Borehole (4) 112' (34.14 m)	1961	.026	.05	.01		.031	.011	.01	.22	$<6\times10^{-5}$		
	North edge of Pan 195' (59.43 m)	"	.028	.05	.01		.054	.012	.01	.25	$<6\times10^{-5}$		
3.	Well R20 (?)	14/3/68	< .01	Could not detect		.027			<.006	< .006	.123*		<.001
		"	< .01			.03			<.006	< .006	.113*		<.001

* These figures include .04 g/l H_2S
.11 g/l Na_2S

In any event, known brines in sufficient quantity are believed to be available to suggest that Sua Pan contains a tremendous tonnage of various salts. For example, Gould (1980) calculated tonnage of salt in the Sua Pan brine to be as follows:

Compound	Tons
Salt (NaCl)	1,026,000,000
Soda Ash (Na_2CO_3)	233,000,000
(including bicarbonate equivalent)	
Salt Cake (Na_2SO_4)	110,000,000
Potash (KCl)	34,000,000
Bromine (Br_2)	1,760,000
Lithium Chloride (LiCL)	970,000

It should be firmly emphasized that perhaps not all these commodities can be economically recovered from the brine. It should also be emphasized these tonnages are based on data from only a few holes that are close together and have been extrapolated to include all of Sua Pan.

VII. PROCESSING

Several schemes have been considered to recover the salts from brines at Sua Pan. In fact, several proposals suggest the construction of extremely large chemical complex operations. However, all proposed schemes so far have started with a solar salt plant. There are other processes available which should be considered and their investment and operating costs compared with solar plants before any final decision is made. Perhaps a combination of several techniques will be the answer.

Solar Evaporation

Solar evaporation salt plants have been known since man's early history and, today, just about every country with a sea coast and a nominal amount of sun shine has some type of a solar salt industry. Plants range from small one- or two-man operations with a production of 10,000 t/year to extremely large modern operations that can produce 3-4 million tons of salt per year.

Theoretically, salt can be made by solar evaporation in any region of the world where the rate or amount of evaporation of water from a brine is greater than the amount of rainfall.

There are many factors which have to be considered in the location of a new solar salt plant - and any one of them can be controlling. However, if the plant is to be both technically and economically successful, all the following factors must be at least reasonably favorable.

Marketing and Inexpensive Transportation

With today's world-wide competition in the salt industry, it is doubtful that any new large salt plant could be successful unless it was close to markets or adjacent to favorable transportation facilities. Many of the other factors can be compromised or designed around, but not sales and this of course is basically dependent upon the delivered price of salt.

Impermeable, Flat, Pond Areas

Ideally a solar salt plant should be located on a large area of comparatively flat, impervious soil. Large plants require thousands of acres, and leakage must be reasonably low. If these conditions are not possible there are many compromises that can be made. First, the solar salt pond does not have to be adjacent to the brine supply. With an efficient conduit system, pumping or flow by gravity, reasonable distances can be traversed.

While the ponds must be fairly leak free, there are techniques of diking or sealing that can inexpensively use soil that is apparently porous. These, of course, add to the capital costs but may still allow the operation to be viable.

Adequate Evaporation Rate

Although apparently the most important factor in the success of a solar system, the annual net evaporation rate can be acceptable over a wide range. The method of working within greater varying climatic conditions varies greatly and alters the efficiency of the operations. Solar evaporation is conducted in areas such as Taiwan and East Pakistan where they have extreme rainfalls and short evaporating seasons. They shorten the evaporation cycle and work in between rainstorms in the border months and throughout the dry season. In Panama, they produce salt by solar evaporation of sea water in only 5 or 6 months of the year. In other areas such as San Francisco and New Zealand, they accept the yearly net evaporation rate and keep their ponds flooded all year.

Thus, one can work around the rainfall or learn to adjust the operation to the variations in climatic conditions.

Phase Relations

To completely understand the operation of a solar salt plant, it is necessary to know the physical chemistry that occurs in a brine during evaporation both in the crystalling phase relationships and in rates of crystallization and evaporation. These data are necessary so that a pan can be efficiently operated.

VIII. SUA SALT PLANT

Previous investigators have assumed a solar evaporation facility would be used to supply a concentrated brine to a soda ash producing facility. The soda ash plant has been variously estimated to have a capacity of 100,000 t/year of salt, 200,000 t/year of soda ash, up to as much as 500,000 t/year of soda ash.

Using an average brine composition of

	g/l	x	Factor	=	Pounds/1000 gallons
NaCl	128.0		8.345		1068.
Na_2CO_3	23.05		8.345		192.
$NaHCO_3$	9.64		8.345		80. = (50. Na_2CO_3)
Na_2SO_4	13.76		8.345		115.
KCl	4.30		8.345		36.
					1491.

thus we find that in every 1000 gallons of Sua Pan brine there are 1491 pounds of dissolved materials. This assumes the composition of the brine is fairly constant and is as widespread as predicted.

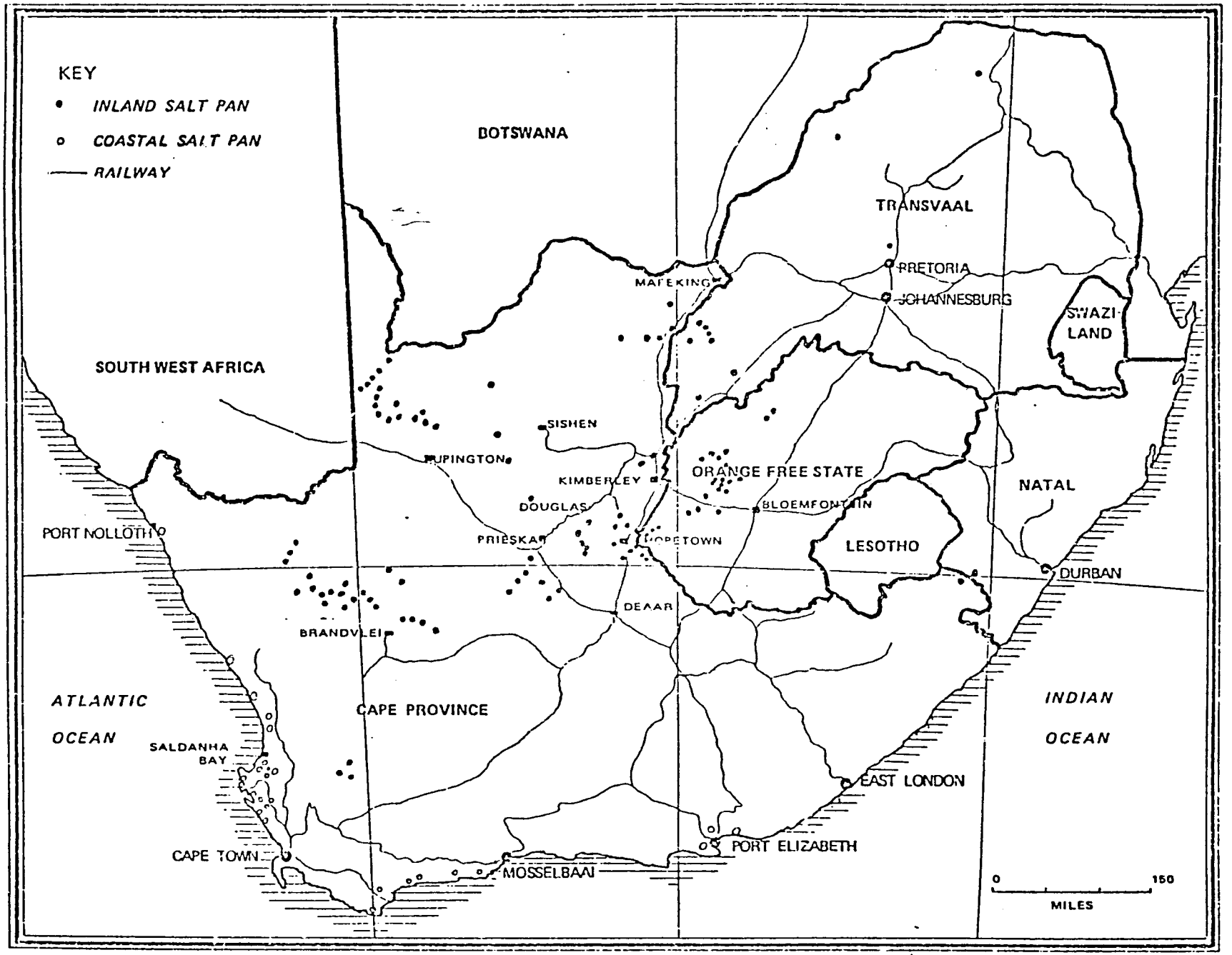
It is felt that insufficient attention has been paid to many of the factors involved in the establishment of a substantial or large chemical processing plant. First, a plant to produce 200,000 - 500,000 tons/year of soda ash is very large and would require many skilled chemical workers. Such

people are not readily available in Botswana and would have to be imported - at a cost. Such a plant is operated according to detailed and finite phase rule chemistry, and any deviations in temperatures and pressures or operating procedures would result in all types of process problems. Plants like this are usually highly automated with a minimum of labor. This means the operators have to be fully trained chemical technicians working under graduate chemical engineers.

A preliminary and rudimentary market survey suggests there is a possible market for about 150,000 tons/year of soda ash in southern Africa. Any excess over local requirements would have to be sold on international markets. Unless someone producing and marketing soda ash in the area or perhaps a broker undertook to sell this excess production, it would be necessary to have a sales organization to sell soda ash in the world market which can be very difficult.

To produce one ton/year of soda ash would require processing 8,300 gallons of Sua Pan brine. Thus to produce 200,000 tons of soda ash per year would require the processing of 1,660,000,000 gallons of brine - assuming no losses. An additional 886,000 tons of salt would be produced annually. This salt would either have to be sold or disposed of in some manner. The disposal of such a large amount of salt annually would be expensive and this expense would have to be born by the soda ash. In addition, over the years, this amount of salt, approximately 900,000 cubic yards annually, would create major ecological problems.

A preliminary survey suggests there might be a market for about 100,000 tons of salt in Botswana, Zaire, Zimbabwe and elsewhere in southern Africa. It is doubtful that much salt could be sold in south Africa as they produce about 500,000 tons/year of salt from many operations scattered throughout the country (see Map 5).



Map 5

SALT PRODUCTION IN THE REPUBLIC OF SOUTH AFRICA

IX. FUTURE ACTION

Market Survey

From the data available to us, it appears there is a good potential to develop a small plant to produce salt from Sua Pan brine. However, in order to develop definite economics, a series of studies has to be made.

Past investigators have suggested schemes for very large, multimillion dollar complex projects without the consideration of many important facets. We suggest, however, a project that starts small and, as time goes on, can be enlarged to take advantage of new techniques, markets, etc. This project would start with salt production at a rate that would satisfy the present and potential salt markets in Botswana, Zaire, Zimbabwe and other easily accessible markets. This salt consumption is reported to be on the order of 100,000 tons per year. However, in order to properly size the salt operation it is necessary to obtain a definitive idea of the market for salt, and particularly the type of salt. Thus a market survey of the areas that can economically be reached from a salt plant on the Sua Pan has to be made. This survey will require visits to each area to obtain the following data:

1. Present sources of salt.
2. Amounts produced and/or imported.
3. Types of salt with acceptable specifications.
   a. Animal feed
   b. Tanning
   c. Human food
   d. Miscellaneous
4. Costs of salt in the area.
5. Distribution Methods.

   Bags, sizes

   Bulk

Brine Analyses

While much detailed work has been done on the brine aquifer not all of it is definitive. For example, while some 49 holes have been drilled on Sua Pan, brine analyses are only available from a few holes. We need to know whether or not the chemical composition of the brine is consistent vertically as well as horizontally. Are there layers within the brine that contain more lithium, potash or bromine which can be recovered? Is the northwest corner of Sua Pan, as reported, the better area for development? All work to date has been done on the small area of Sua Pan. Several exploratory holes should be drilled outside the Sua Pan area, and brine samples taken for analyses.

Thus, concurrent with the market survey, we should:

1. Drill several widely spaced holes in both the Sua and Ntwetwe Pans, and carefully sample the brines vertically as well as horizontally.

2. Analyze the brine samples not only for major elements but also for trace elements.

3. Develop significant data on brine production by pumping tests or flow in an open ditch.

The data obtained from this program, coupled with usable data from previous programs should be sufficient to start to develop an area for a plant site as well as sizing solar salt pans, etc. for efficient and economical operation, developing a manning table and investment and operating costs.

Processing

Theoretically the production of 100,000 tons of salt per year from Sua Pan brine will require the processing of 200,000,000 gallons of brine/year. However, because of many components in the brine, it may be necessary to handle perhaps as much as 500,000,000 gallons of brine per year in order to produce 100,000 tons/year of a relatively pure salt. This can be done in a very carefully controlled series of salt pans.

Previous investigators have stated the salt precipitation sequence from a Sua Pan brine to be:

1. Salt
2. Salt + trona
3. Salt + trona + burkeite
4. Salt + trona + burkeite + hanksite

Salt will precipitate out when the original volume of the brine has been reduced to 47%. Salt and trona will precipitate out when the original volume of the brine has been reduced to 37% of the original.

Thus salt could be recovered in the first pond and a salt and trona mixture in the second pond. It might be possible to separate these two chemicals. If not, they could be discarded without allowing them to settle out in a second pond. The remainder of the concentrated brine could be discarded, as a liquid, at some place on the pan. This bittern would dissolve additional salt and soda ash from the surface and would eventually be more or less the composition as before processing.

A 100,000 ton/year solar salt operation is rather small and in this instance could be labor intensive. It is mentioned at one point in the Cremer and Warner report (1975), that a film of salt crystals formed on top of the evaporating brine. This is natural. Perhaps this salt layer could be skimmed off daily and processed to make an acceptable product. However,

regardless of the size, the operation, i.e. control of specific gravities, pond development, etc. has to be rigidly maintained.

In a small solar salt plant, much of the salt harvesting could be done manually. Laborers could rake up the salt into piles or long rows, which would also help it to drain.

Depending upon conditions, the salt then could be loaded onto trucks by laborers or picked up by a front-end loader.

Water Capture

In an area so devoid of water, it seems tragic to allow over 200,000,000 gallons of water/year to be solar evaporated and no attempt be made to reclaim the water.

There are many systems available that could be adapted for such use. Such equipment includes desalination stills, osmotic membranes, solar stills, flash distallation and many more. One technique that should be investigated is the so-called "Green-House" effect. In this method, the water is solar evaporated but the vapors are condensed on an inclined glass plate. The condensed water rolls down the plate into a collecting trough. In this way much of the water is saved.

Naturally before any decision can be made on any type of a mechanism for processing Sua Pan brines, a serious study, and perhaps even pilot-plant tests should be conducted to determine capital investment requirements as well as operating costs.

X. TECHNICAL TRAINING AND MANPOWER DEVELOPMENT

In the course of our fact-finding mission, we gathered information on the institutional structure and the availability of manpower related to mineral resources development. Hence, we confined our interests within the Ministry of Mineral Resources and Water Affairs in general, and conducted more detailed discussions with the Director of the Geological Survey Department in particular. Besides interviews with Ministry officials, the information contained hereunder was gathered from the National Development Plan V and a report by Barclays Bank (see Bibliography).

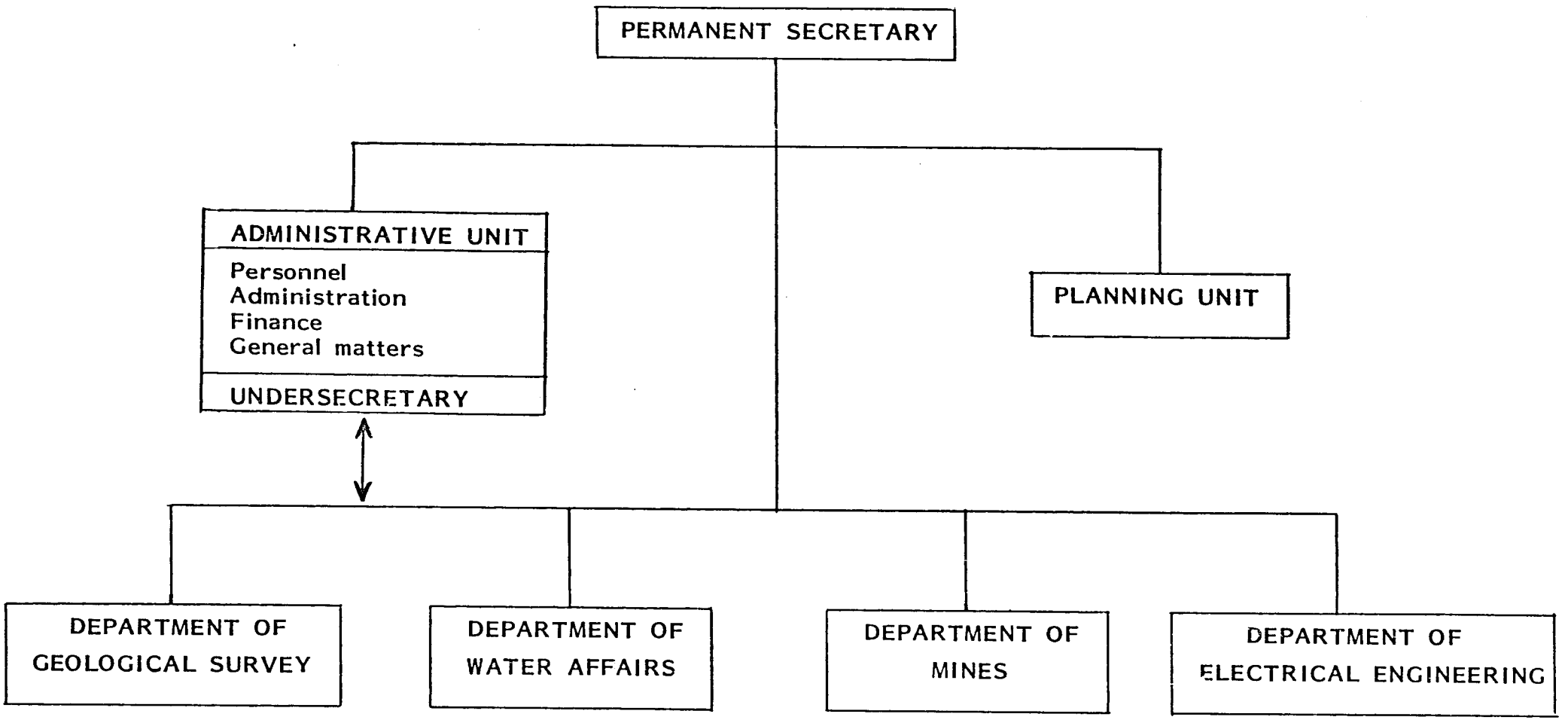
Institutional Structure and Functions

All matters concerned with the development of mineral and water resources in Botswana are grouped within the Ministry of Mineral Resources and Water Affairs. The Ministry is divided into four major Departments: (1) Geological Survey Department, (2) Department of Water Affairs, (3) Department of Mines, and (4) Department of Electrical Engineering (Figure 3).

Functions of the Department of Electrical Engineering are mainly those of providing engineering and maintenance services to the other departments in the Ministry. The Department of Mines is charged with implementing government policies as set in the Mines and Minerals Act (No. 30) of 1975. Its activities range from the initial negotiations and issuance of a mining lease, through monitoring the daily operations of the mines, to overseeing

FIGURE 3

MINISTRY OF MINERAL RESOURCES AND WATER AFFAIRS
ORGANIZATION CHART



the overall production. It is worth noting here that the Government of Botswana favors active participation in any mineral project, and insists on equity participation and direct board representation in a project. As a general guideline, government participation is in the range of 15% to 25% of the shares, issued free of cost. In some instances, the government may purchase additional shares.

According to Barclays Bank report (p. 16), royalties are payable on the gross market value of any mineral product at the following rates:

Mineral or Mineral Product	Rate
Building materials, industrial materials, oil shale.	3%
Coal, radioactive minerals, semi-precious stones, precious metals.	5%
Petroleum and natural gas, precious stones.	10%

Because of the existence of the Department of Water Affairs, activities of the Geological Survey in this area are confined to mapping, locating and evaluating underground aquifers, and maintaining records of the national water resources budget. The Department of Water Affairs, however, is responsible for developing groundwater resources by drilling. It has successfully mounted an accelerated borehole drilling program. It maintains a borehole data center and undertakes chemical analyses of groundwater. There is a data bank of all government drilled boreholes as well as several thousand privately drilled boreholes.

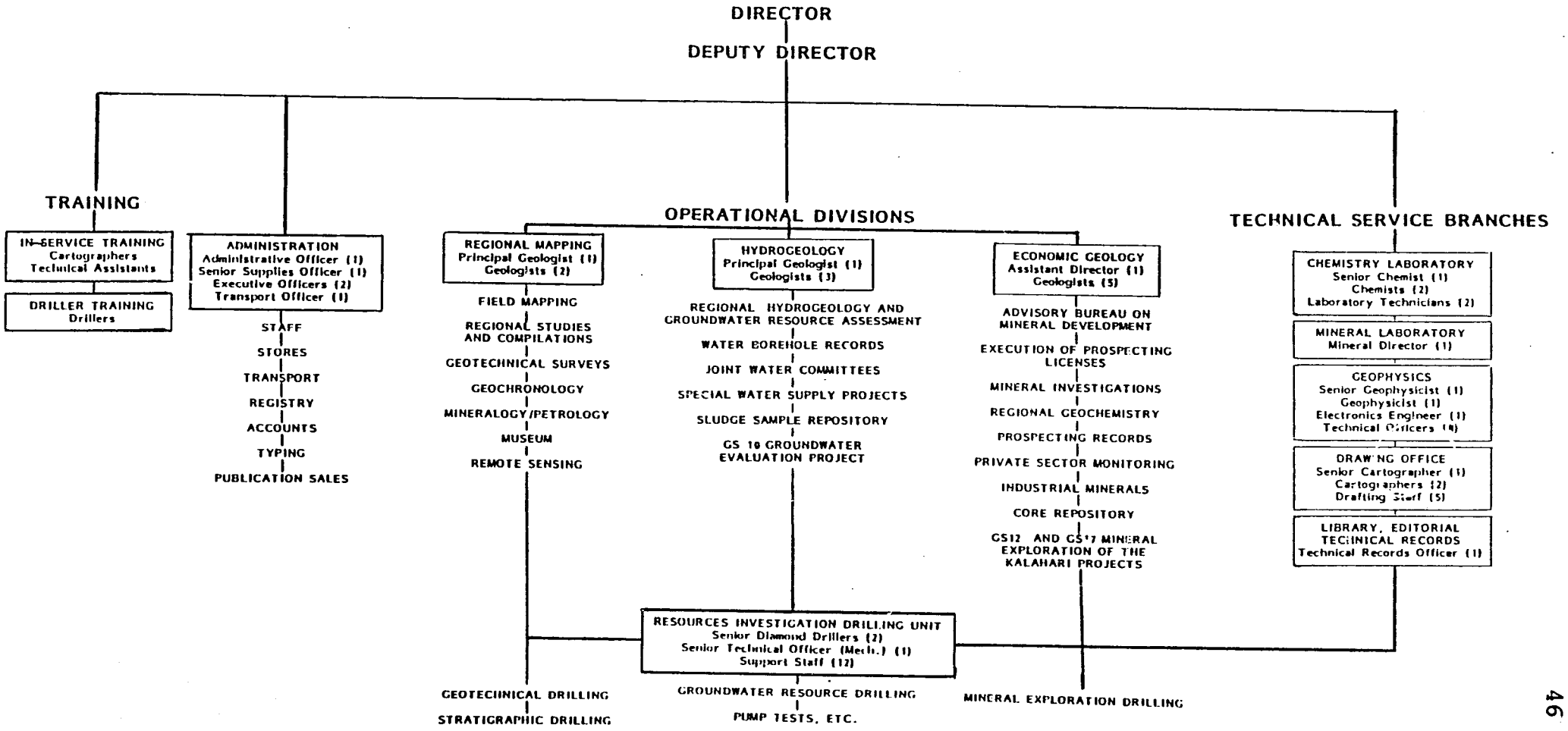
The Department of Geological Survey was established in 1948, and has its headquarters in Lobatse. The Department's main function is the compilation of an inventory of the mineral resources of Botswana, including ground-water reserves. It is responsible for the National geological resources inventory, the administration of private-sector prospecting and the provision of advisory and technical services to the government.

The Department also undertakes basic geological research, in-service technical training, the education of the public on Botswana's geology and mineral resources, and the dissemination of information abroad. The evaluation of ground-water resources is also undertaken with the preparation of geological and mineral resources maps.

Organizationally, the Department of Geological Survey is divided along three major functional lines: Training, Operational Divisions, and Technical Service Branches (Figure 4). While in Lobatse, we visited the different facilities and were impressed by the spartan but functional laboratories, library, drawing and map-making, and field equipment facilities. We were also assured of the desire of the Survey to participate in any feasibility study that we may recommend on the Sua Pan, the subject of our visit. The Survey is prepared to provide field vehicles and equipment, and technical manpower (field assistants), but will not be able to provide professional manpower because of shortage of such personnel.

FIGURE 4

GEOLOGICAL SURVEY OF BOTSWANA
ORGANIZATION CHART



Manpower Development

As would be expected, the Government of Botswana has set a national goal to derive the most benefits from the present and future development of the country's mineral resources. Several major objectives have been enunciated by the government in order to achieve its national goal. Of these objectives, the most relevant to this study is the objective of initiating and maintaining sound training programs to ensure the growth of local skilled labor force.

According to the National Development Plan V (pp. 8/23-8/24), the major existing mining operations at Selebi-Phikwe and Orapa are carrying out localization and training programs, while other existing operations already employ few expatriates. The opening of Jwaneng, however, will require a lot of foreign expertise, which will not be reduced in absolute terms during the next 5 years though it will fall steadily in relative terms.

Table 8 shows the estimated levels of employment of both Botswana citizens and expatriates in the mining sector to 1983.

Table 8. Employment and Localization in Mining

	1979		1981		1983	
	Botswana	Expatriates	Botsw.	Expat.	Botsw.	Expat.
BCL (Selebi-Phikwe)	3,710	420	4,240	360	4,320	280
Orapa	1,540	170	1,590	160	1,630	120
Jwaneng	440	60	970	130	1,220	130
Morupule	166	9	172	8	192	8
Construction Agg's	308	11	320	10	340	10
Asbestos-Ceramic	8	-	24	-	48	-
Gold Mine	-	-	-	-	170	30
Others	-	-	18	2	110	10
Total	6,172	670	7,334	670	8,030	588
Total Employment	6,842		8,004		8,618	
% Expatriate	9.8		8.4		6.8	

Source: Ministry of Mineral Resources and Water Affairs

Both the Department of Geological Survey and the Department of Mines have produced detailed localization and training programs. A steady flow of professional geo-scientists should be trained in Canadian universities and elsewhere. The current programs for training in Canada end with this year's input, but it is hoped that a new program can be established.

Table 9. Localization of Employment in the Geo-sciences

	1979 Employment			
Professional	Botswana	Expatriate	Total	To be trained
Dept. of Geol. Survey	3	18	21)	
Private Sector and UBS geo-scientists	2	26	28)	36
Technical				
Dept. of Geol. Survey	1	5	6)	
Private Sector and UBS geo-technicians	10	20	30)	20
	16	69	85	56

Source: Ministry of Mineral Resources and Water Affairs

The Department of Mines will also benefit from Canadian training. Again trainees will study a general science course before proceeding to study for a degree. By 1985 no more than five professional posts should remain to be localized, compared with eleven in 1979. Table 10 shows the planned training program.

Table 10. Training of Mining Engineers and Technicians

	1979	1980	1981	1982	1983	1984	1985
Finishing Basic Course	7	5	6	2	-	-	-
Transferring to University	7	3	3	1	-	-	-
Returning technicians of	-	2	3	1	-	-	-
which employed by Dept. of Mines	-	2	1	0	-	-	-
Returning engineers of	-	-	-	7	3	3	1
which employed by Dept. of Mines	-	-	-	4	2	1	1

The figures obtained from personal discussions with the Geological Survey indicate a professional staff of 17 geologists and three chemists currently employed at the Survey. Of the 17 geologists, four are local: three working on their M.Sc. degrees overseas (2 in South Dakota, U.S.A.; 1 in London), and the fourth will be doing graduate work overseas next year (1981). The three chemists include one U.S.A.I.D. and two British. The majority of the expatriates are British, either on secondment from the British Survey or on direct contract with the Botswana Government; three are West German, mainly in hydrology.

There are three hydrologists with the Department of Water Affairs, and seven mining engineers with the Department of Mines. The private sector, coal, diamond, and other mining concerns employ almost twice the number of professionals the government has--roughly 40 geoscientists and engineers.

Training Programs

The Canadian International Development Agency (CIDA) has had traditionally the most active training program in Botswana, especially geared toward prospective students in the geosciences. Students are selected for a two-year program in general instructions, usually resulting in the award of a diploma. If these students show promise and aptitude toward geology and mining, they would continue for two more years at Hailbury School of Mines.

In the first group, 12 native Botswana students were sent to Canada. Four dropped out, and the remaining are due back in 1984. The returning 8 will be divided between the Department of Mines and the Geological Survey. Low-level "technicians" are trained either on the job or at Botswana Polytechnic. All trainees are "bonded" to serve in the government at least three years.

Another country active in training Botswana citizens is Holland. Holland sponsored two instructors who were supposed to establish an Earth Science Department at the University of Botswana and Swaziland in Gaborone. However, The Mininstry of Education determined that no sufficient student cadre existed to justify a "Department", and the instructors (who had already arrived in Gaborone) will have to teach only an earth science "course".

There are also several bilateral aid programs in which the United Kingdom, Japan, West Germany, and the U.S. Geological Survey are or will be involved. Most of these projects almost always contain provisions for Botswana "counterpart" personnel. This, too, eventually imparts considerable experience to the local personnel participating in the project, and would include an element of training.

Findings and Recommendations

Our findings indicate that the Government of Botswana is anxious to accelerate the localization process, and looks favorably for cooperation and assistance toward that goal. The process of localization, however, is a slow and long-term process. At the present rate of activity, localization of personnel may reach 50 per cent of the total technical manpower by the late 1980s. Fully-local high-level professional personnel may not be achieved before the 1990s at the present rate of training.

It is our belief that ample opportunity currently exists in Botswana for U.S. assistance in training and technical manpower development, especially toward the development of the country's mineral resources. Renewed funding of the Canadian aid program at this time is undecided. But even if CIDA renews its program, the modesty of its scale and the absence of other vigorous programs still provide ample opportunity for participation and assistance by the United States. The needs of the Botswana Government are so diversified and acute that even the possible duplication of effort on the part of the aiding countries would produce favorable results.

XI. PROPOSED STATEMENT OF WORK

The Sua Pan in northwestern Botswana appears to contain a tremendous amount of a brine that contains significant quantities of salt, sodium carbonate, sodium bicarbonate, sodium sulfate with lesser amounts of lithium and bromine. It is not known what other elements, if any, are present. The potential for a plant to produce salt for local markets appears to exist. However, there are many factors which have to be determined first in order to develop an economical operation. It is entirely possible, as the data are developed, hitherto unknown information may develop that could cause curtailment of the project. Therefore, the following proposal is designed so that it contains several "go or no go" decision points. Thus, it can be curtailed when data develops that suggest the project will be uneconomic or technically unfeasible or, conversely, increased in scope if the new data justify such an increase.

PHASE I

In order to properly size the potential salt plant, one has to obtain fairly accurate ideas of the markets to be served by an operation at Sua Pan. Thus, a fairly definitive market survey should be conducted.

1. This survey should include those areas that can be economically served from a salt plant at the Sua Pan, and would naturally include Botswana as well as Zambia, Zimbabwe, South Africa and Zaire.

2. Visits will be made to various agencies such as major wholesalers, customs officers, brokers, agricultural agents, etc. Also, the economic officers of the U.S. Embassy (and others) often have valuable economic data which would undoubtedly be made available. Actually during surveys of this type, it is not unusual to have other agencies or people suggested who also might have pertinent data.

3. Obtain data on railroad and truck freight costs, as well as information on the markets and consumption of other chemicals such as soda ash, sodium sulfate, etc.

One commodity that could be made for the cattle industry are salt blocks for cattle licks. Specialized blocks containing such elements as iron, sulfur or other minerals could be added to salt blocks as they are being made. The blocks could be formed in a hand operated machine similar to those used in making bricks.

The data collected should include information on:

a. Present sources of salt for each country.

b. Amounts produced and/or imported.

c. Costs of salt in the area.

d. Types of salt with acceptable specifications.

- Animal feed
- Tanning
- Human food
- Miscellaneous

e. Transportation facilities and costs.

- Rail
- Trucks

f. Distribution Methods.

- Bags, sizes
- Bulk

g. Taxes, custom duties, etc.

4. Two senior specialists are required to conduct this phase. It is estimated the actual accumulation of the data will take approximately 3-4 weeks and another 2-3 weeks to tabulate, study, interpret and prepare a report for a decision on Phase II (see Timetable, page 60).

Data obtained during Phase I should give sufficient basis for making a "go or no go" decision. For example, if the data suggest the market for salt to be very small or uneconomic due to freight costs or other factors, the project can be dropped. If the data suggest that markets for salt exist and a plant at Sua Pan might be feasible, Phase II should then be inaugurated.

PHASE II

While upwards of 40 holes have been drilled on Sua Pan, analyses of brine are only available from 3 or 4 holes. The holes do indicate the brine to be widespread but there are no data on the consistency of the brine's composition. Information on the consistency of composition is necessary in order to develop techniques to process the brine. Some of the questions that have to be answered are:

1. Is the brine consistent in composition over the whole area both horizontally and vertically or is it layered?

2. If layered, are certain elements, i.e., bromine, lithium, etc. concentrated in certain layers?

3. Is there a brine in the Ntwetwe Pan? If so, is it similar to Sua Pan brine or does it contain a different ratio of elements; perhaps it is a more concentrated brine.

Phase II, designed to obtain answers to these questions, consists of :

1. Drilling a sufficient number of holes in Sua Pan to obtain brine samples for analyses and to determine the consistency of composition.

2. Brine samples would be taken with utmost care as the holes are being drilled to determine if there is any stratification in the brine.

3. Analyses will be made to determine the qualities and quantities of the major elements as well as the trace elements.

4. Permeability and porosity determination would be made on cores of the sand containing the aquifer.

5. Pumping tests would be made on different holes to determine the best area(s) from which to produce brine.

6. Large representative samples should also be taken for further testing in Phase III.

7. As there are no data on the brine potential of the Ntwetwe Pan, several holes should be drilled in the pan, and the brine sampled carefully both vertically and horizontally.

8. Manpower requirements for Phase II include two (2) technical specialists, two (2) drillers, and assorted laborers. It is assumed that the Botswana government will provide the drilling equipment and testing facilities. To properly drill, sample, and analyze the brines and conduct pumping tests in significant areas will require at least 7-9 months to collect the data and another 2-3 months for interpretation of the data. The results of this program should be sufficient to make a decision as to "go or no go" on Phase III.

PHASE III

Data on the physical chemistry of Sua Pan brine is almost completely lacking. We need to know how the various components will precipitate as the brine concentration increases. Can we get a relatively clean, usable salt by careful control or will we require a purification process?

Will pure trona precipitate in the second evaporation phase, and can we recover it - or will the second evaporation phase be burkeite ($NA_2CO_3 2NA_2SO_4$)? Will the residual bittern, left after the first salt is recovered, be concentrated enough to permit an economical recovery of the bromine and lithium?

The answers to these questions and the results of a definitive market study are needed to properly size the operation and develop a process to utilize the Sua Pan brine.

Only evaporation in salt pans has been considered as a process for Sua Pan brines. However, there are other techniques which can be developed not only to produce salt but also water.

Part of Phase III should consist of investigations of various processes not only to produce salt but also to recover the water that will be evolved during the process. Actually, in the area of Sua Pan, water is perhaps just as valuable as the salt. It is estimated that about 500,000,000 gallons of water will be involved in the process to produce about 100,000,000 tons/year of salt. The recovery of an acceptable water from the process would certainly be a major asset of the project.

It is difficult to estimate the time needed for Phase III, but it shouldn't take more than 7-9 months to develop the needed data to decide on Phase IV. While Phase II is in progress and positive results are indicated, Phase III could be inaugrated in order to save time.

PHASE IV

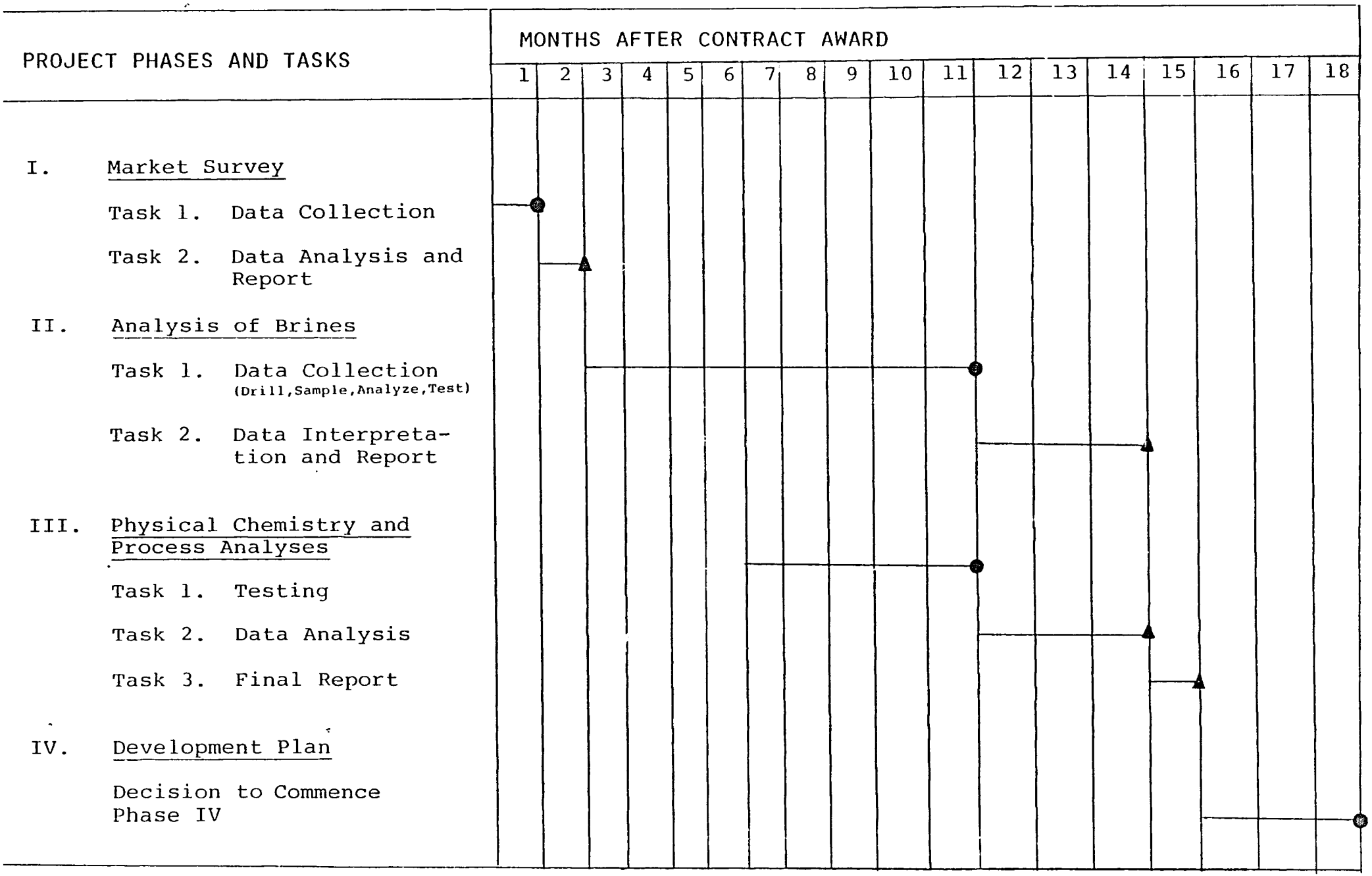
This phase would consist of developing a full scale plan to produce the desired quantity and quality of salt and perhaps other products. This plan would include a process designed to suit the market study and products to be produced, and tonnages, capital investment and estimated operating costs. The plan would also cover taxation, manning tables, production schedules, etc. In short, Phase IV would result in a plan with sufficient details which provide guidelines for decision makers of industrial firms to invest in developing the Sua Pan brines.

Requirements in time and technical manpower for conducting Phase IV cannot be determined at this time. These requirements will depend on the results of Phases I-III.

LEGEND

- ● Project Milestones
- ▲ Project Deliverables

PROPOSED TIMETABLE



XI. BIBLIOGRAPHY

Alderman, S. S. Jr., 1972. Results of the Sua brine ditch pump test. Agricultural and Industrial Minerals, Inc., (AIM), unpublished report.

Australian Groundwater Consultants (Pty) Ltd., 1974. Groundwater investigations and wellfield development, Wellfield 4, Orapa, Botswana. Report for De Beers Botswana Mining Co. (Pty) Ltd.

Baillieul, T. A., 1973. Reconnaissance sand survey, northeastern Botswana. Geol. Surv. Botswana, unpublished report no. TAB/12/73.

Baldwin, P. L., and Yuill, W. G., 1975. Review of the Sua Pan salt/soda project. Cremer and Warner, Consulting Engineers, Report no. C. 1053.

Butterworth, J. S., 1979. An investigation into the possibility of using low temperature crystallization for the production of pure sodium chloride from Sua Pan brine. Geol. Surv. Botswana, unpublished report no. JSB/6/79.

Gibb, Sir A. and Partners, 1969. Appendices to report on water supply to AK 1 (Orapa). I.B.R.D.-U.N.D.P.(S.F.) Bots. Shashi River Feasibility Studies.

Green, D., 1966. The Karoo System in Bechuanaland. Geol. Surv. Bech., Bull. 2.

Grey, D. R. D., 1976. The prospecting of the Mopipi area, north central Botswana, and associated Pleistocene studies. De Beers Prospecting Botswana (Pty) Ltd., unpublished report.

Jennings, R. W., 1979. A salt-only option for Sua Pan. Mines Dept., Republic of Botswana, unpublished report.

Lamont, G. T., 1951. Report on the Sua River salt deposit near Nata. Geol. Surv. Bech. Prot., unpublished report no. GTL/11/51.

Lund, B. G. A. and Partner, 1972. Makgadikgadi Soda Ltd. Preliminary report on proposed water supply system.

Mackay & Schnellman, Ltd., 1976. Geology of Sua Pan, Government of the Republic of Botswana, MS7604.

Makgadikgadi Soda Limited. Sua soda/salt project Shashe pilot plant, 1971-1972.

Mazor, E., Verhagen, B. Th., Sellschop, J.P.F., Jones, M.T., Robins, N.S., Hutton, L.G., and Jennings, C.M.H., 1977. Northern Kalahari groundwater: hydrologic, isotopic and chemical studies at Orapa, Botswana. J. Hydrol., 34, 203-204.

Patrick, D.H., 1980. Botswana: An economic survey and businessman's guide. Barclays Bank of Botswana Limited.

Paulsen, W.W., 1971. Review of investigations and research Botswana brine recovery - well-field studies. Agriculutral and Industrial Minerals, Inc., unpublished report.

Read, E., 1976. Sua Project: Dukwe New Town. Groundwater study. Inception report. SWECO (Swedish consulting group), unpublished report.

Read, E., and Berg, H., 1974. Sua Pan Project - Location and transportation study - Final report. SWECO (Swedish consulting group), unpublished report.

Reeves, C.V., 1978. Interpretation of the reconnaissance aeromagnetic survey of Botswana - Final report. Terra Surveys Ltd. Report - job no. 77-20.

Republic of Botswana, 1980. The National Development Plan V.

Rhodesian Selection Trust Exploration Ltd., 1964. Sua Pan soda salt project, parts 1,2,3, unpublished report.

Stansfield, G., 1973. The geology of the area around Dukwe and Tlalamabele. Geol. Surv. Botswana, Dist. Memoir no. 1.

Van Straten, O. J., 1958. A reconnaissance report on the salt deposits of the Nata River delta. Geol. Surv. Bech Prot., Records, 1956, 21-28.

REFER TO FICHE

2 OF 2

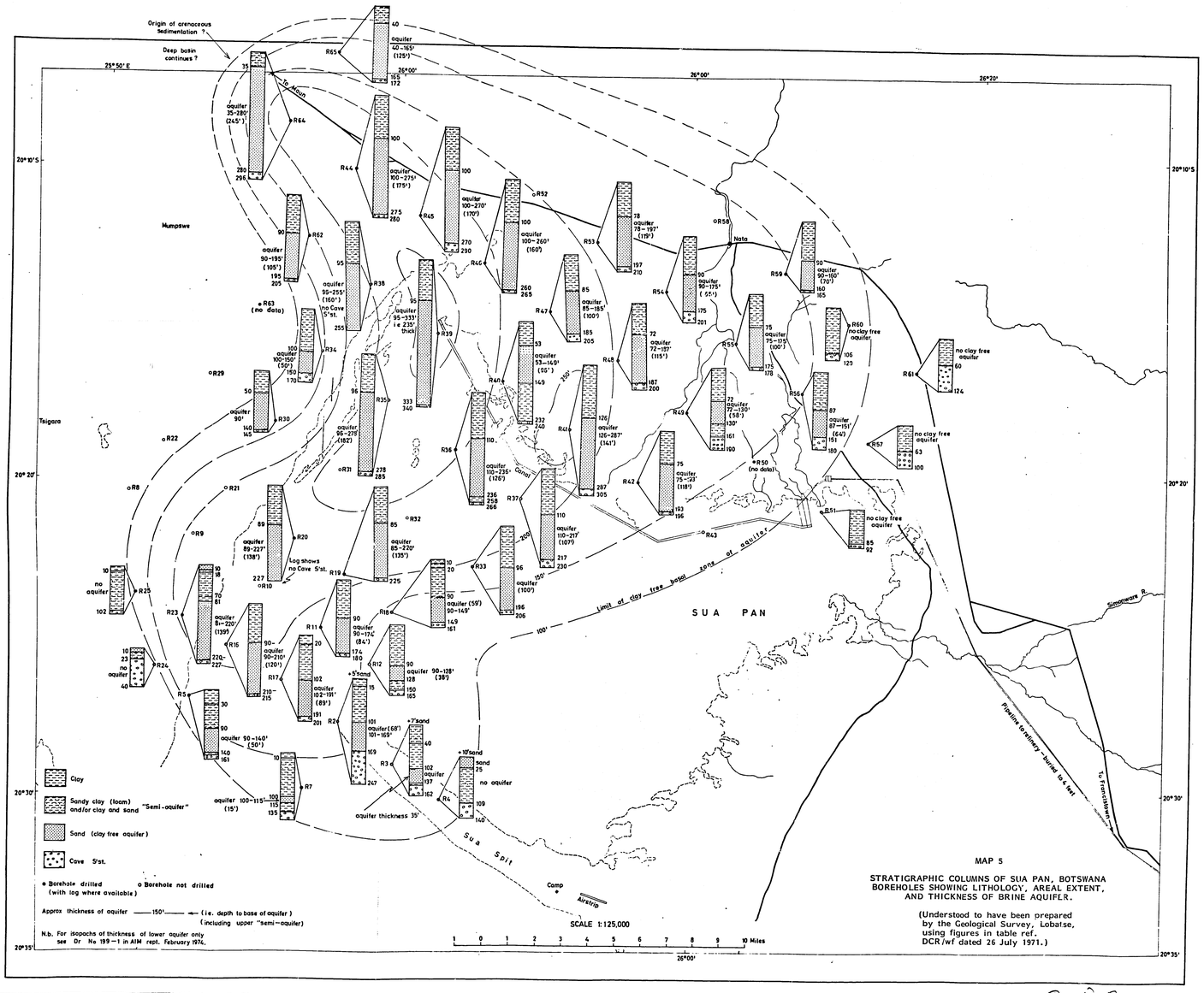
FOR

FIGURE(S):

MAP 5

STRATIGRAPHIC Columns of SUA PAN, BOTSWANA

63



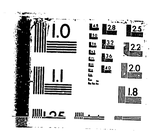
MAP 5

STRATIGRAPHIC COLUMNS OF SUA PAN, BOTSWANA BOREHOLES SHOWING LITHOLOGY, AREAL EXTENT, AND THICKNESS OF BRINE AQUIFER.

(Understood to have been prepared by the Geological Survey, Lobatse, using figures in table ref. DCR/wf dated 26 July 1971.)

2 of 2

PN-AAY-142



24 X