

**MAUN WATER SUPPLY  
HYDROGEOLOGICAL SURVEY**

**Interim report**

**VOL. 1 REPORT**



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## CHAPTER 5

### DETAILED GEOLOGY OF THE KALAHARI BEDS

#### 5.1 - LITHOLOGY OF THE KALAHARI BEDS AT MAUN

Of the thirty four boreholes constructed, seven penetrated 30 to 52 m down into the Kalahari beds which allowed a relatively exact idea of their lithology and structure.

Six of these so-called "deep" boreholes were set up along the Thamalakane River (see Figure 2). They are boreholes, numbers :

- 4800
- 4807 to 4811

to which n° 4801, located in the Shashi River, must be added.

All the detailed facts concerning these boreholes are given in the files and sections found in volume II "APPENDICES".

Drawing a typical lithological section of the Kalahari beds formations is difficult for the 2 following reasons :

- they are fluvatile or lake formations which, by definition, present numerous variations of both vertical and horizontal facies,
- the system of faults, especially Thamalakane fault, causes numerous displacements of the beds, therefore it is difficult to make correlations.

Nevertheless, the lithology of the Kalahari beds can be put roughly as :

- a - On the surface, silty or even distinctly sandy, grey to greenish, clays. These clays are nearly always altered over a thickness of ten metres or so and are then more yellow in shade. They are also soft and powdery. When they are seen in depth and unaltered, they have a more compact appearance. They are still, however, easy to drill. This formation is relatively homogeneous but a few soft sandstone and loose sand beds, about a metre-thick, are sometimes intercalated in the mass.

b - Below this lies a formation which is lithologically very varied but where grey plastic clays dominate. In this clayey mass are numerous intercalations of decimetre-thick beds of :

- "silcrete"
- "calcrete" (or limestone)
- fine sands and silts
- quartzous sandstones.

The total thickness of this unit is around 30 to 40 metres.

A word here on the exact petrographic nature of the rocks making up this formation.

- The "silcretes" : these are either isolated flint kidneys in the clay mass or, more commonly, thin (15 to 30 cm) bands of flint with a very irregular surface (strong vibrations of the drill string when these are crossed). These flints are usually of a light to dark brown colour. They are very hard but drilling through them does not set too many problems as they are never thick.
- The "calcretes". The rock so called is actually :
  - either a sandstone-limestone changing into a quartzitic sandstone with a limestone cement,
  - or a fine-grained, lacustrine-type of limestone, white or yellowish in colour.

These limestone beds are about a decimetre thick (maximum - 50 cm).

- The sandstones : They are quartzitic sandstones with a limestone cement, usually soft and friable. They are not very compact and, during drilling, they crumble into sands. This explains why they were never mentioned earlier by the drillers.
- The sands and silts. These are formed of white, translucent, relatively well-rounded quartz grains.

- c - At the bottom is a thick sandstone and loose sand layer with intercalations of silcrete, calcrete and clays. During this campaign, they were crossed over 20 to 25 m only but, according to the section the old borehole n° 3393, their total thickness must reach almost 80 m under MAUN. Moreover, the percentage of sands and sandstones and their grain size would seem to increase downwards.

It is these "running sands" which have given Maun its bad reputation for drilling. Collapsing took place on several occasions. Morphologically, these sands resemble those encountered in layer B above (fine grain-size, white, translucent, rounded quartz grains). Some authors use the term "dune field" for this formation.

## 5.2- DETAILED STRUCTURE OF THE MAUN SUB-SURFACE

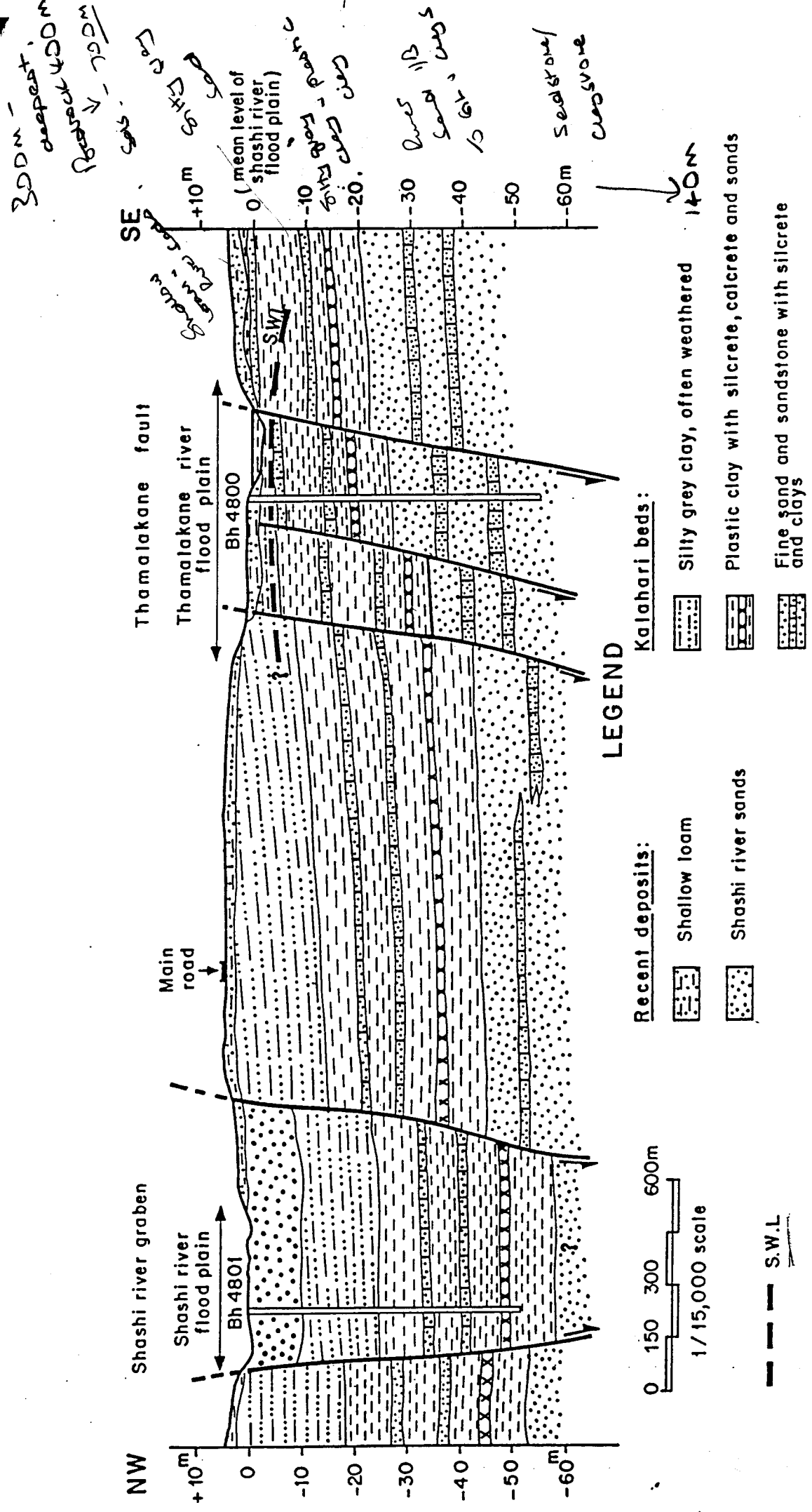
The diagrammatic and interpretative section enclosed (figure 6) shows the probable arrangement of the Kalahari beds south east of Maun, between the rivers Thamalakane and Shashi.

It brings to the fore the following main structural features :

- the almost horizontal beds,
- the role of the Thamalakane fault which causes the sinking of the beds towards the north-west (formation of the Okavango Rift),
- the Shashi river graben and the exceptional accumulation of alluvium resulting from it.

It is impossible to take the interpretation of the structure further, in the present state of knowledge.

Fig.6 - SCHEMATIC CROSS SECTION BETWEEN SHASHI AND THAMALAKANE RIVERS



## CHAPTER 6

### HYDROGEOLOGY OF THE KALAHARI BEDS

#### 6.1 - AQUIFER RESERVOIR

The following are the main hydrogeological characteristics of the 3 formations making up the Kalahari beds.

##### 6.1.1 - The silty clays

These must be taken as being impermeable even when altered. The few intercalated limestone-sandstone beds are permeable but enclose some saline water (e.g. the bed between 35 and 40 m depth in borehole 4811).

##### 6.1.2 - The grey plastic clays with sandstone and loose sand intercalations

This extremely heterogeneous formation may be considered as impermeable taken as a whole. However, when the sandstone-loose sand intercalations are thick enough and in the right structural position to be recharged, they may hold fresh water. This is the case at Maun where the boreholes, 25 to 35 m-deep, tap thin layers of running sands and sandstones intercalated between the clays.

The existence of this sandstone and loose sand reservoir is uncertain for, out of the twenty eight old boreholes, only thirteen are productive. Moreover, the productivity varies greatly and is usually mediocre (yields of 1.6 to 18 m<sup>3</sup>/h for a drawdown of 20 to 30 m). For that matter, it can be wondered whether this heterogeneous productivity and chemical quality of the water (two old boreholes produce briny water) is not more or less connected with the fracturing (Thamalakane fault).

This aquifer is put into head by the clays. The static water level is usually situated between 6 and 7 m below the river's water level, including in the boreholes installed very close to the low-water channel. This difference of level between the river and the aquifer proves the impermeability of the upper clays and the small seepage of surface waters.

### 6.1.3 - The bottom sands and sandstones

Despite the fine grain-size of the sands and the numerous clay and silcrete intercalations, this formation is the best potential aquifer of the Maun region. Indeed, its great thickness (almost 80 m) guarantees a good transmissivity and considerable reserves. Unfortunately, these sands are filled with saline water. It would appear that, sometimes, a thin lens of fresh water (5 to 10 m) might exist above the saline water mass. Exploiting this last resource is chancy because of the risks of saline water arrivals.

On the other hand, when the faults and step structure are considered, this sandy layer might be locally just below the surface and therefore in a good structural position to be recharged by seepage of surface water. In this case it might be a good fresh water aquifer.

## 6.2 - CHEMICAL QUALITY OF THE WATER

Chemical analyses were carried out on water samples taken from the thirteen existing production boreholes at Maun and from the river. These analyses were carried out by the Geological Survey Laboratory at Lobatse.

The analysis files are given in appendix with the borehole files.

The following main conclusions can be drawn from these analyses :

### a - Field measurements

**pH :** The measurements taken in the field are between 7.2 and 7.8 whereas those of the laboratory give slightly higher results (7.5 to 8.1). The waters are not corrosive.

**Conductivity :** The field and laboratory figures agree here. Nine boreholes have a conductivity of between 450 and 560 microsiemens/cm. Two others (n° 3983 and 3876) are distinctly more mineralized (1400 to 3000 microsiemens/cm). The last two boreholes (n° 4493 and 4494) have a lower conductivity (270 to 300 microsiemens/cm).

**Temperatures :** They lie between 22° and 25° whereas the air temperature is between 30° and 35°.

## **b - Laboratory analyses**

**T.D.S. (Total Dissolved Solids) :** The same distribution is, of course, found as for the conductivities. Nine boreholes have a T.D.S. of approximately 400 mg/l ; two have between 1160 and 2000 mg/l. The last two have a T.D.S. of between 230 and 270 mg/l.

**Dominant ions :** Two different chemical families can be seen distinctly :

- firstly, the eleven weakly mineralized samples which have a predominant calcium bicarbonate content,
- secondly, the two boreholes, number 3876 and 3983 which give water with a predominant sodium chloride content.

This chemical evolution is illustrated by the "Schoeller-Berkaloff" logarithmic diagram enclosed (figure 7). From the water of the River Shashi to that of borehole n° 3876 the increased mineralization is clearly seen.

- 1 - An enrichment in Ca + Mg carbonates and bicarbonates,
- 2 - Then an increase in the Na and K sulphates and chlorides.

This tends to confirm that all the water has the same origin : seepage of river water.

## **6.3 - CHEMICAL POTABILITY**

Apart from boreholes n° 3876 and 3983 which produce a distinctly too mineralized water, the eleven others produce water which is in agreement with the generally accepted potability standards (e.g. E.E.C. standards). Their water can, therefore, be distributed without any treatment. The total hardness, however, is often close to the maximum accepted (300 ppm). The inhabitants of Maun complain, in fact about the clogging of water pipes by limestone deposits. This excess hardness might be corrected by mixing this water with softer water, such as that of the Shashi River.

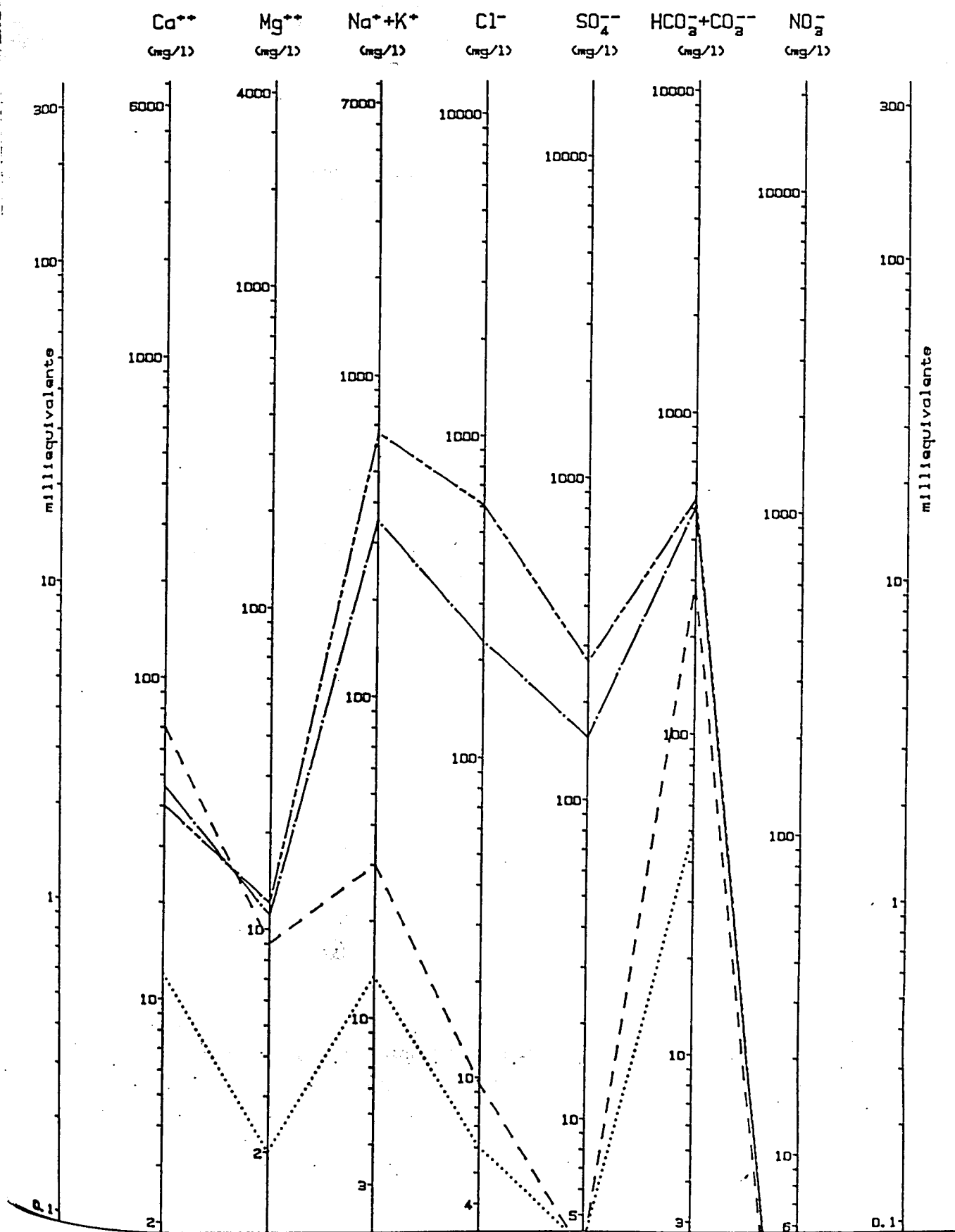


LOCATION	Bh. Number	Repres.	Field Ph	El.C (μei/cm)	TDS
MAUN	1234	---	7.7	450	380
MAUN	3983	---	7.5	1400	1160
MAUN	3876	---	7.6	3000	2000
MAUN	SHASHI RIV	0	7.8	75	108

MAUN  
AREA

BRGM

WATER ANALYSIS  
LOGARITHMIC DIAGRAM  
'SCHOELLER BERKALOFF'



#### 6.4 - BACTERIOLOGICAL POTABILITY

Stress has often been laid on the risk of bacteriological pollution, especially for the five boreholes of the "Centre town wellfield". In actual fact, to this day, the analyses carried out have never shown up pollution of this type. This appears logical enough now that we know that an upper clayey layer exists protecting the reservoir from seepage.

In fact, the boreholes which seem to us to be the most vulnerable are the last two to be put into operation (n° 4493 and 4494). These two are only a few metres from the River Thamalakane's low water channel and direct seepage from the river along the casing is to be feared. These boreholes, like all those constructed up till now, have no "sanitary casing".

Moreover, as was seen above, both these boreholes produce water which is distinctly less mineralized than the others. The explanation for this could be direct seepage of Thamalakane river water.

#### 6.5 - CONCLUSIONS ON THE HYDROGEOLOGY OF THE KALAHARI BEDS

This borehole campaign has greatly modified the ideas accepted up to now on the geology and hydrogeology of the Maun region. The main element was the discovery of a thick homogeneous impermeable clayey formation out-cropping almost over the whole region under a very thin layer of loamy sands (2 to 3 m). It explains the extreme rareness of fresh water in the sub-surface due to lack of seepage. The contrast between the abundance of surface water and the insignificant economic role of the groundwater can thus be better understood.

This study confirmed, moreover, the existence of a sandstone-loose sand reservoir at the bottom of the Kalahari Beds. It is of no economic value at Maun for it is full of saline water. It may well, however, be an interesting objective for research in other zones where it is in a structural position favouring surface water seepage (outcropping or almost outcropping).

Lastly, there exists at Maun, between the top clays and the bottom sands a mainly clayey formation in which are intercalated a few sandstone-loose sand lenses. This reservoir possesses mediocre hydraulic characteristics but is, nevertheless, of high economic interest.

It is from this reservoir indeed, that the town gets its drinking water supply. The large number of negative boreholes proves the geological complexity of this zone, a complexity linked both with the facies variations of the fluvio-lacustrine series and with the Thamalakane fault's activity. It can, moreover, be assumed that fracturing plays a part in the presence of fresh water by aiding river water infiltrations. This hypothesis of the existence of fracturing is also borne out by the very heterogeneous production of boreholes situated close to each other, for instance a yield which jumps from 1.6 to 12 m<sup>3</sup>/h within a distance of 200 m.

The uncertain deductions on this aquifer, its mediocre productivity and the risks of saline water invasion, saline water having been found both in depth and on the sides, encouraged us to look for other aquifer types. It was thus that we turned our interest towards the River Shashi alluvium.

## CHAPTER 7

### GEOLOGY OF THE RIVER SHASHI ALLUVIUM

#### 7.1 - GEOMORPHOLOGY

Initially, it was the geomorphology which attracted our attention to the Shashi River Valley and made us choose it as a priority prospecting zone in the Preliminary Report of August 1984. Indeed, examination of the 1/50,000 scale aerial photos showed the existence of an alluvial plain, 12 km long by 0.6 to 1.5 km wide. Moreover, traces of recent floods which had drowned this valley over a width of several hundreds of metres gave hope of very favourable recharge conditions.

Later, we concentrated our interest on the downstream section of this valley, this being the only zone covered by the 1/15,000 aerial photos (photos taken in 1983 for the urban study of the nearby town of Maun).

#### 7.2 - TECTONICS

A detailed examination of the aerial photos and field checks later showed up the graben structure of the River Shashi Valley. This graben structure is particularly clear in the lower course but seems to exist more or less upstream also (see figures 2 and 6). This type of structure led one to expect a thicker amount of alluvium than elsewhere and this was immediately checked on the 2nd borehole constructed during our study (n° 4801). This exploration borehole did, in fact, cross 12 m of fine to coarse quartzitic sands, well-graded and very clean (no clay) lying on a thick series of impermeable silty clays (Kalahari beds).

Having made this very interesting discovery we turned our efforts to finding out the size of this reservoir.

## 7.3 - GEOLOGY OF THE SANDY ALLUVIUM OF THE SHASHI RIVER

### 7.3.1 - Size and shape of the reservoir

The extent of the alluvia was first estimated approximately on 1/50,000-scale photos, then with more precision on 1/15,000 scale photos, lastly checked with the help of electric soundings (resistivity) and exploration boreholes.

The map in figure 8 shows the positions of the fifty eight resistivity soundings and the twenty eight boreholes.

One of the special features of this prospection was the simultaneous geophysical and borehole investigations. This made it possible, firstly, to gage the resistivity soundings or the first boreholes constructed and, secondly, to check the interpretation of certain electric soundings by an exploration borehole. This method proved very efficacious. Moreover, the geophysicist took advantage of the resistivity measurements taken in the exploration boreholes by the logging unit for his interpretation.

The geological sections of figure 9 show up the geometry of the alluvium. Sections A, B and C were drawn with the help of both the geophysical prospecting and the boreholes. Section D, on the other hand, was drawn on the basis of the electric soundings alone.

It is seen that the sands vary in thickness according to the throw of the faults. The average thickness is around 10 m. The reservoir's width varies from 0.6 to 1.5 km.

### 7.3.2 - Geological nature of the alluvia

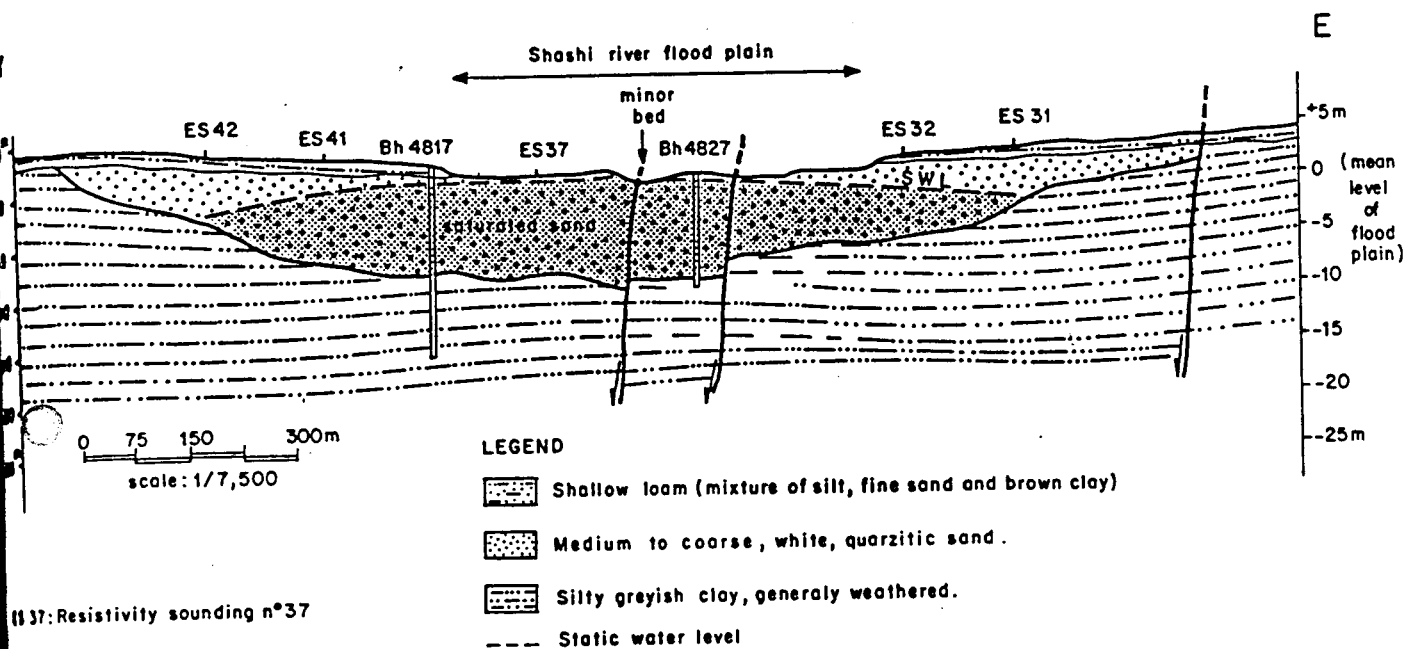
The geological nature of the reservoir was discovered in detail thanks to the permanent follow-up of the boreholes by a geologist and the taking of sand samples, for grain-size analyses. It is very homogeneous, both horizontally and vertically.

The lithological series of the Shashi River is :

- a - On the surface -over a thickness of 1 to 2 m, loams, formed of a mixture of fine sand and quartzitic silts, mixed with clays and organic matter. This gives a blackish colour to the whole. This formation covers the whole region and is either powdery in aspect or crusted over.

Fig.9 - SHASHI RIVER AQUIFER SURVEY  
GEOLOGICAL CROSS SECTIONS

SECTION A



SECTION B

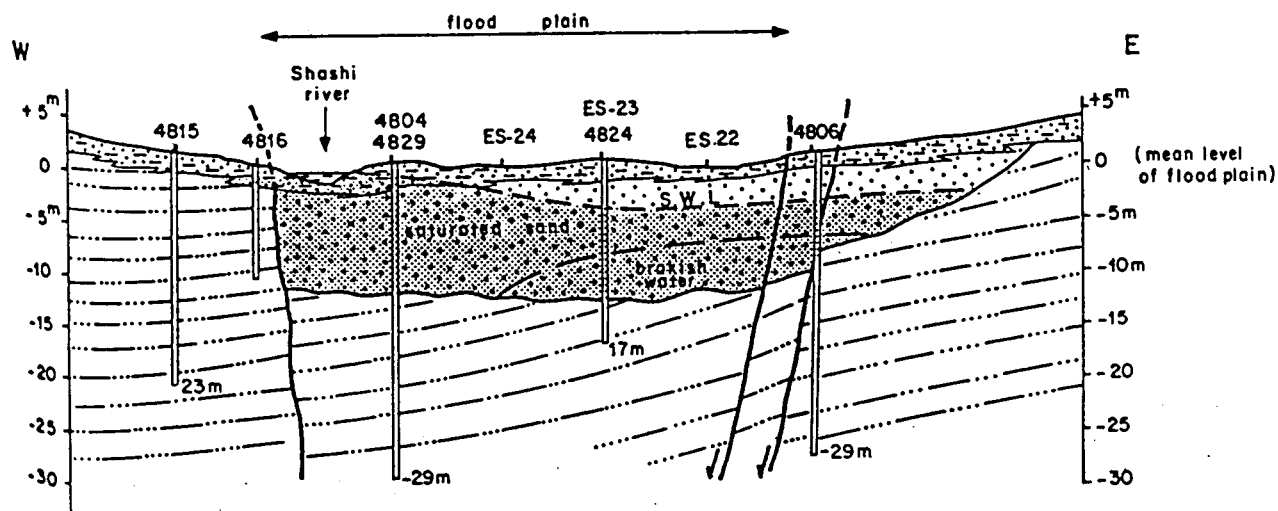
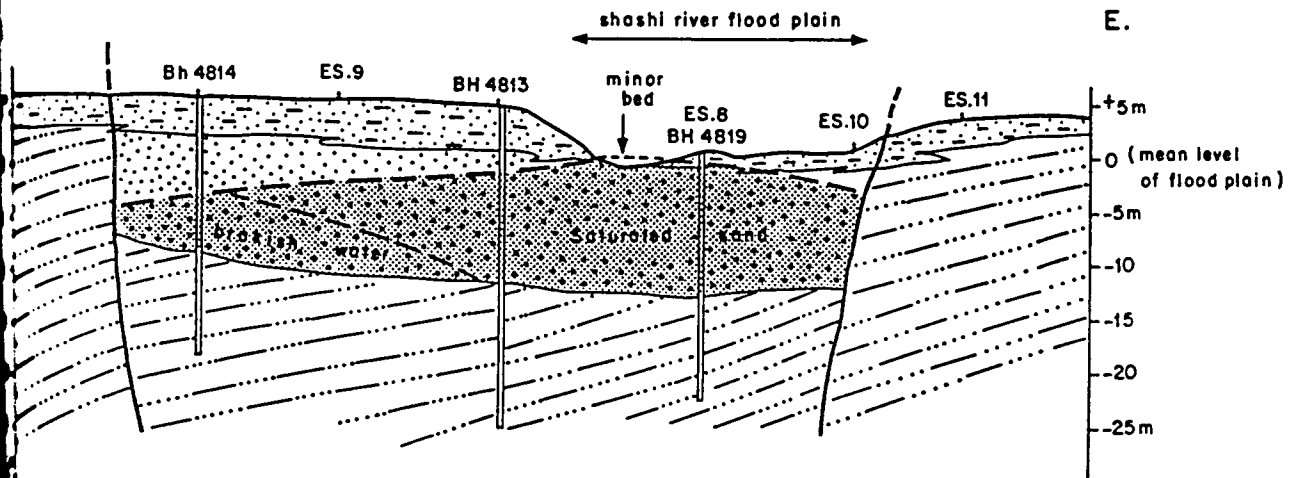
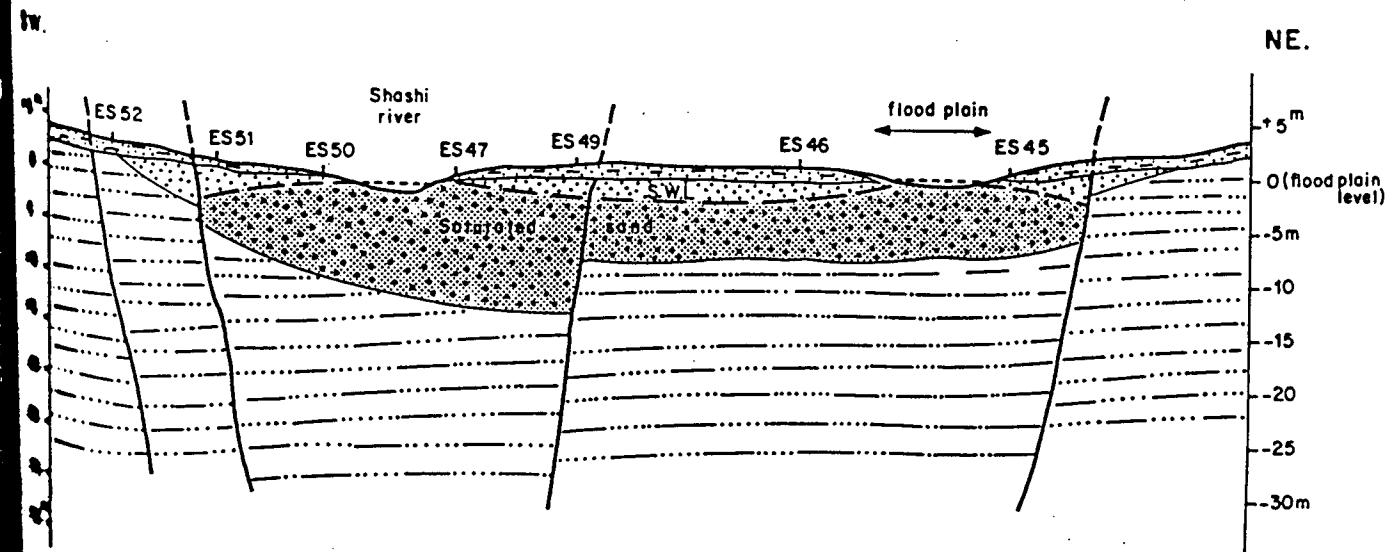


Fig.9 bis - SHASHI RIVER AQUIFER SURVEY  
GEOLOGICAL CROSS SECTIONS

SECTION C



SECTION D



b - Underneath are white, quartzitic sands with translucent, rounded and well-graded grains. This sand grain grading from fine to coarse, with medium-size predominating, is remarkable. In actual fact, the thirteen sand samples taken carefully from several boreholes and at varying depths all lie between the extreme granulometric curves plotted on figure 10 enclosed. Such a granulometric curve can only be explained by certain successive gradings :

- by the wind (dune sands of the Okavango)
- by water (fluvial deposition by the river).

This grain-size distribution led one to suppose a high porosity and permeability and this has actually been confirmed by the borehole results as will be shown later.

c - The bedrock, formed of silty clays of the Kalahari beds, several tens of metres thick. This impermeable formation surrounds the sands on the sides as well as underneath, completely isolating the aquifer.



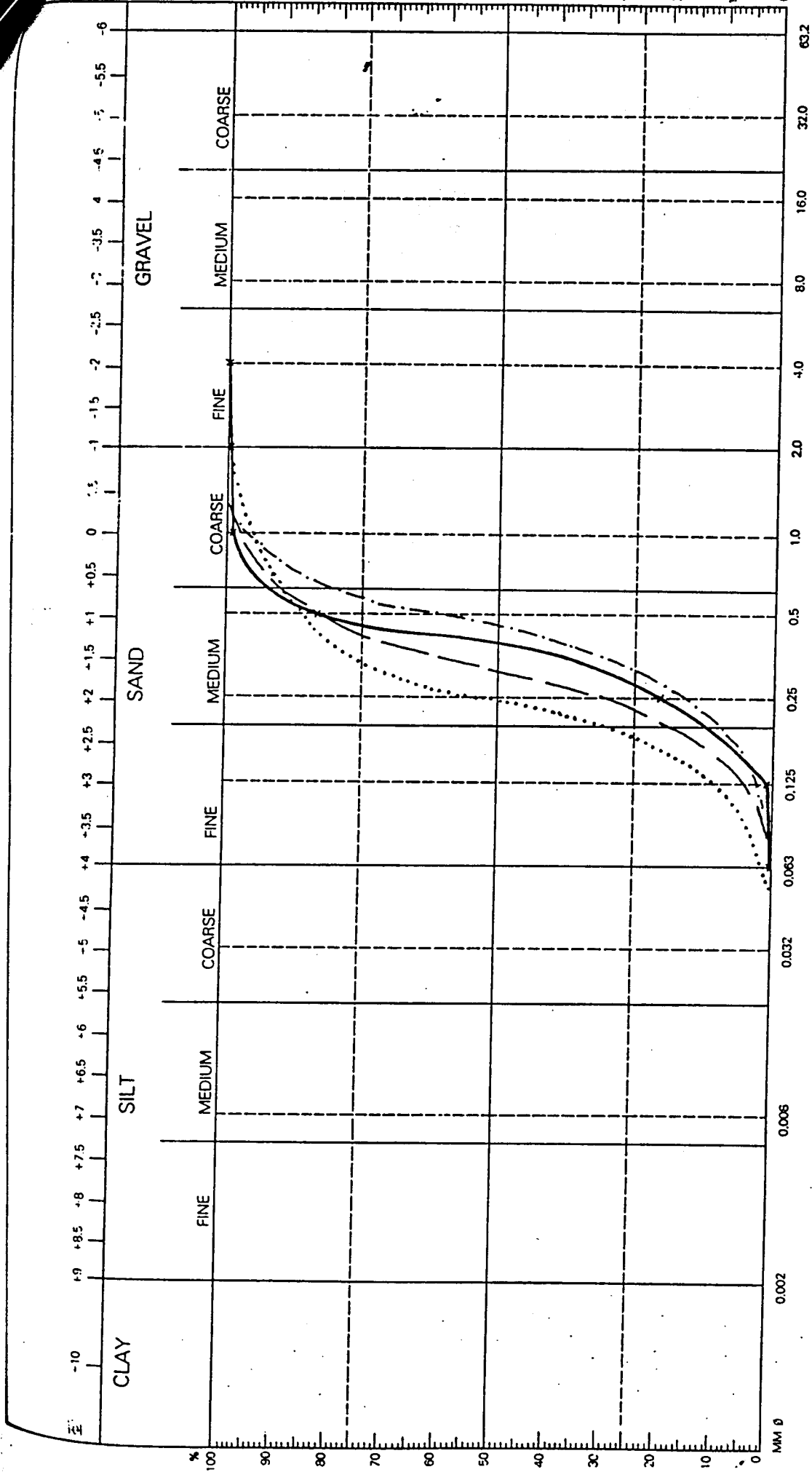


FIG. 10: GRAIN SIZE DISTRIBUTION OF SHASHI RIVER SANDS

Bh N° : 4804 ..... Bh N° : 4814 — — — Bh N° : 4813 — — — Bh N° : 4806 — — —

## CHAPTER 8

### HYDROGEOLOGICAL STUDY OF THE SHASHI RIVER ALLUVIAL GROUNDWATER

#### 8.1 - PIEZOMETRY

The map in figure 11 shows the position of the twenty eight boreholes drilled in the Shashi river region. Out of these, fifteen were equipped as piezometers to have a permanent piezometric measurement network. All the detailed information concerning these boreholes is given in the files and sections enclosed in appendix (volume II).

Of the fifteen observation boreholes, thirteen were fitted with metal casing and Hydrotec screens of 50 mm diameter and 0.15 mm slot size. The other two (n° 4822 and 4824) have steel casings ("spiral welded casing") of 152 mm diameter to make it possible to fit automatic water level recorders. All these observation boreholes were cemented and protected on the surface by casings of 152 mm diameter requiring a special pipe wrench for unscrewing the caps. The official borehole number is engraved in the cement or painted on the casing. The installation of such a large observation borehole network was necessary firstly because of the complete lack of already existing dug wells or boreholes and secondly, because of the need to draw up a precise piezometric map of the groundwater. A local surveying (no connection with mean sea level) was carried out by a Water Affairs team in November 1984. It is planned to have level measurements taken on this network twice a month by the Maun Department of Water Affairs.

The first complete series of measurements was carried out on November 7th, 1984 and from these the first piezometric map was drawn (figure 12). This map was drawn at the end of the annual flood when there was still a small trickle of water in the bottom of the low-water channel of the river. As could be expected, this map confirms the essential role played by the river in the recharging of the aquifer. This was, in fact, already visible on the sections of figure 6. At this time of the year the groundwater flow takes place from the bed of the low-water channel towards the edges of the aquifer with a gradient of 0.006 to 0.007.

It is probable that the general appearance of the piezometric map changes with the time of year depending mainly on the flow of the river and perhaps also on the rainy season.

Fig:11 - LOCATION MAP OF SHASHI RIVER BOREHOLES

