DEPARTMENT OF WATER AFFAIRS.
Hydrological Research Institute

Technical Note No. 39

WATERSUPPLY FROM RIVERSAND LIMPOPO RIVER AT MESSINA

M.P. Mulder.
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G.P.-S (L).

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WATER SUPPLY FROM RIVER SAND. LIMPOPO RIVER AT MESSINA.

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Division of Hydrology.

I. Introduction.

The Messina (Transvaal) Development Co. Ltd., referred to as MTD, abstracts all its water from sand wells in the bed of the Limpopo River, both for mining operations and for domestic supply to the township of Messina which in 1971 had a population of 3500 whites and 9000 bantu. During times of drought when flow and replenishment may cease for long periods, the supply is endangered.

Before a storage reservoir is contemplated to supply future increased requirements, it is advisable to investigate the possibility of increasing the yield from the sand in the river bed, at a cost far lower than that of the construction of a dam, more especially in view of the complications arising from the fact that the Limpopo is an international boundary river.

The CE(P) approached the C/DH to ascertain whether the Hydrological Division could assist with this investigation (Reg. 170, 73/8 of 30/4/71).

Two short surveys were carried out, in May 1971 and in November 1971. The crucual hydrological pumping tests could not be done with good result due to the existence of some surface flow. Since then, for once, the river has never ceased to flow, except for a few weeks in October 1972 and no tests could be made. It was decided not to postpone the interim report any longer, and to collate the available data without pump test results.

II. Method of abstraction.

The MTD Co. has sunk 9 abstraction points in the sand of the Limpopo River bed over a stretch of 12½ km from a point 4½ km downstream of Beit Bridge to a point 2½ km upstream of the confluence of the Sand River (see fig. 1). Of these, seven wells are fully equipped and five in constant use.

The abstraction points are of varying design. No. 7 is a caisson sunk to the rock bottom in the middle of the riverbed, with radiating perforated pipes. No. 2 is a pump shaft on the river bank with an addit 3 m under the river bed, from which perforated pipes are raised into the sand. No. 8 also has a pump shaft but just off the riverbank in the sand (see fig. 2 and 3). A buried feed pipe across the riverbed has at its other end a crossmember of unknown length with a number of perforated down pipes as well points. Other abstraction points are of simpler design. The system with a pump shaft on the riverbank with a central feeding line and cross members with down-well points is the most effective and economical design.

The water is pumped, unmetered, from each abstraction station to small reservoirs at a central pumping station, from where it is pumped through a 30-cm pipe to reservoirs and distribution pumps at Messina. The rise in time of the water level in the small reservoirs is the only way to measure the yield of individual abstraction points, when the others are closed off. The actual combined yield of the operational abstraction points is 7850 m^3/day. The capacity of the turbo-pumps is considerably in excess of this figure, the limitation being the narrow feeding pipelines to the central pumping station.

III. Previous investigations.

In February 1962 the acting Chief Surveyor of MTD, Mr. A.A. le Roux produced an excellent report entitled "Limpopo River Hydrological Survey". However, certain essential hydrological conclusions are debatable (hydrological investigations being still in their infancy at that time). Some of the more important statements and conclusions in this report are as follows:

The optimum/.......

The optimum pumping rate per well point is 300 gpm (1964 m^3/day). The zone of influence of each extraction point extends half a mile up and down stream, therefore extraction points should not be spaced closer than 1 mile ($1\frac{1}{2}$ km) apart.

The "subsurface flow" under the natural gradient was only 7 ft (2,1 m) per 24 hours and even during pumping the induced flow velocity did not increase materially.

Abstraction from a tunnel under the riverbed did not increase the yield above that obtained from well points.

Careful surveying of the bedrock is essential.

Mill slimes carried down the Malalaspruit will eventually raise the silt content of the river sand and seriously reduce permeability and water yield.

Over 40% of the water supply is **unmetered** and wastage can be expected.

A storage dam is not recommended. The "present" 8 abstraction points should be sufficient for mine and township use, but citrus irrigation should be abolished.

The amount of water pumped from the river during the summer of 1961/62 averaged 188 200 m^3 per month (6273 m^3/d).

IV. Investigations by the Division of Hydrology.

1. Methods.

Soon after the request of the CE(P) a team was sent out in May 1971 to start preliminary work under the guidance of the Chief Technician and the writer. The site selected for the investigation was at pumping station No. 8, being representative of the average river bed conditions and relatively free of surface water over a large expanse of sand.

The work sequence comprised the following:-

establishment of Bench Marks (BM); accurate surveying of probing stations and sand surface; determination of the sand thickness with mechanical probing (small drill on a 4-wheel drive vehicle); determination of the water level in the sand in cased probing holes; an experimental geophysical survey with electrical resistivity measurements to determine sand depth, and with a magnetometer in an attempt to trace the buried well points; probing of the Sand River bed.

For a hydrological pump test it is essential that no boundary effects interfere, like recharge from surface water within the cone of depression. This condition was not met, for on the left bank, opposite the pumping station, a fairly wide stream of water was present (see section on fig. 2). Furthermore the water abstraction should be from one central point and not from a row of buried well points of which the position could only be guessed. In fact the test should be carried out after a few months of no flow to establish pumping draw-down over a sufficiently long period. In spite of this a test was carried out. Two rows of holes were drilled at right angles to each other, intersecting over the presumed well points. Drilling was done with hydraulic jetting. The 22 holes were temporarily supplied with perforated casing, half of which was made and supplied by the MTD workshops. The collarheights were accurately surveyed. Soundings of the waterlevels were done electrically. It was arranged with MTD to stop the pumps at No. 8 at a predetermined time (10h30 on 26th May) and not to resume pumping for 48 hours (the maximum period that the mine could do without this water supply). The pump had been in constant operation for at least 3 weeks prior to 26th May. Water levels were measured continuously day and night for the whole of the "recovery test". Pumping was resumed at 10h35 on the 28th, but until 10h50 with many interuptions, which virtually nullified the crucual first part of the drawdown test. Readings were taken continuously until midnight on the 30th May when the pump stopped due to mechanical failure. Drawdown by that time had not reached the level measured at the beginning of the test sequence. At the central pumping station the yield was measured accurately during the drawdown test in the small storage reservoirs.

It varied/....

It varied from 1606 m^3/d (245,3 gpm) to 1689 m^3/d (258,0 gpm), average 1650 m^3/d.

Laboratory tests were carried out at the Hydrological Research Institute on samples of the river sand. Specific yield, retention, specific porosity and grading tests were done by Mr. P. Reid.

After a period of no flow of more than a month's duration was reported a team was sent out hurriedly in November 1971. But as fate would have it, on the day of their arrival the river came down. It was a trickle, but sufficient to vitiate the pumptest. A resurvey was carried out to rectify some errors of the previous survey, and additional traverses done, e.g. at station No. 3. The team was withdrawn after 10 days. Since then, the river has never ceased to flow except for a few weeks in October 1972.

2. Results.

a. Sand depth. Over the width of river bed the sand surface is reasonably level, there being less than 1,5 m variation. The rock bottom, however, is extremely irregular, with troughs and pinnacles rising to within 2 m of the surface (see fig. 2). This greatly reduces the flow to deep well points, the flow at low waterlevel being impeded by ridges. The average depth of the sand cover is about 4,5 m, and the depth to water rest level was from 0 m to 1,80 m at the time of observation (May 1971). For practical purposes, (allowing for impedence of flow by ridges) the depth of water saturated sand, not long after surface replenishment, is 3,5 m, the upper 1 m being subject to rapid evaporation and drainage to lower levels of the sand surface.

In tributaries of the Limpopo River, such as the Sand River, the rock-bottom is more uniform in shape and considerably deeper, up to 20 m in places.

b. The geophysical survey proved in general to be inconclusive and inaccurate. Mechanical probing is faster and more accurate than a resistivity survey. The attempt to trace the buried pipes with the magnetometer was unsuccessful; the instrument was probably not accurate enough.

c. Physical and hydrological characteristics of the river sand. The sand is coarse to very coarse grained and remarkedly free of any silt (see fig. 4). The grading curves show a rather wide variation in grain size, with a uniformity coefficient of 2,036. More than 50% of the sand falls in the fraction 0,6 - 1,2 mm. There is little variation in composition with depth, only a slight increase in the coarser fractions.

Full saturation (porosity) varied from 33,6 to 36,0 percent by volume, the lower value being from a sample at a depth of 2 m. Specific retention (field capacity) varied little, from 9,3 to 9,9 percent. Specific yield (effective porosity) ranged from 23,7 to 25,3 percent by volume, averaging 24% for all the samples.

The permeability, without hydraulic head, under gravity, was found to vary between 4,75 m/h and 5,6 m/h. This is considerably more than the values reported by Mr. le Roux, who carried out tracer tests and found a velocity of only 7 ft (2,1 m) per 24 hours. The laboratory results are, however, more in accord with the distance-drawdown curves obtained with the pumptest. It is intended to arrange for field tests with isotopes to be carried out at first opportunity.

It can be concluded that the sand of the Limpopo River is a near-ideal aquifer, but unfortunately of quite shallow depth.

The probing in the Sand River revealed numerous silt lenses. This was found also in other tributaries of the Limpopo, like the Mogol River, where the amount of silt increased markedly near the confluence with the Limpopo.

d. Hydrological pumptest.

As expected, the time-drawdown curves showed anomalies due to boundary effects and lack of a single abstraction point. As the test will be repeated under/........

under better conditions, the tentative results and calculations for specific transmissivity and capacity will not be included in this report. From the distance-drawdown curves (see fig. 3) it can be concluded that the cone of depression is shallow (maximum depth 0,67 m) and very wide, as is to be expected in such an excellent aquifer. The plotted radius extended to 300 m after 48 hours pumping, and was therefore well within the zone of recharge from the surface water. After 3 weeks of pumping the plotted radius extended to 550 m. From the results of the measurements by MTD in 1962 and these more recent results the slope of the depression cone after prolonged pumping approaches 1:700.

Further results are incorporated in Section V.

V. Water consumption and probable water reserves.

1. Probable water reserves.

(a) An estimate has been made of the extractable water reserves in the sand of the Limpopo River bed, based on previous information and the field and laboratory results obtained so far. The estimate pertains to the stretch of river 15½ km long from a point 3½ km downstream of Beit Bridge as far as the confluence of the Sand River. Above this reach the sand cover is shallow, with many rock outcrops in the river bed. The average width of the sand bed is 300 m and the average thickness of water saturated sand is taken at 3½ m (see par. IV.2a). The specific yield is 24% by volume.

(b) Further upstream the sand cover is shallow and there are many rock outcrops in the river bed. The amount of available water at specific yield is estimated to be 4,07 x $10^6 m^3$. Allowance should be made for the "remnants" between abstraction cones with a calculated slope of 1:700. With 14 abstraction points at 1 km interval the amount of extractable water is estimated to be 3,7 x $10^6 m^3$.

(c) It is realized that at 1 km spacing of abstraction points there will interference (Par. IV.2d). However this should not be a serious disadvantage with a judicious pumping schedule. Only alternate pumps should be used simultaneously, and when draw down at individual well points has proceeded to 1,5 m below starting rest level the other alternate series should come into operation, and so on.

(d) Calculations were made to establish the extent to which a "sand weir" would increase available water supply. By a "sand weir" is meant a watertight barrier built to a height just above the sand surface, say 0,5 m, to accumulate sand and not silt. The weir would then be systematically raised as the accumulated sand level rises. The natural gradient of the river is 1:1000; the specific yield 24%. With an eventual height of the sand level at the weir of 3 meter above original level the additional amount of abstractable water would be 337 500 m^3. This is not a substantial amount of water (20 days supply at estimated consumption levels of 1985). Also with the low gradient it might take very long for sufficient sand to accumulate. As a water storage dam - for induced recharge in times of drought - the weir would serve little purpose. Evaporation on such a shallow large water surface would be very high indeed.

It is therefore not recommended.

2. Water consumption.

From information supplied by the Town Council of Messina (letter 156/2 of 27/9/71 on file 1/170) consumption graphs were drawn (see fig. 5) for the period 1950 to 1971, and two estimates of future use. It appears that the future requirements are rather under estimated. By 1990 the total consumption, according to the Council's estimate, will be 13700 m^3/day, but is more likely to be nearer 21 000 m^3/day.

Total water consumption for Township and Mine at present (1972) is around 9000 m^3/day. The reserves of "pumpable" water would therefore be sufficient for 410 days (14 months) with no flow in the River.

By 1985 the total consumption is estimated to be 17 000 m^3/day and the probable reserve would last 218 days, or 7 months, without replenishment from surface water.

No-flow periods of 6 months are not uncommon, the longest period was 8 months. For a 6 month no-flow period the maximum daily consumption may not exceed 20 500 m^3. This is estimated to be reached by 1989/90.

According to information from the Mine management the water consumption of the mine is not likely to increase much, and after the commissioning of the new mill in 1974 to remain virtually static due to more efficient water use. It is also unlikely that the mining activities at Messina will extend much more in the future, due to diminishing ore grade. These considerations have been incorporated in the estimates of future use.

VI. Summary of Conclusions and Recommendations.

1. The sand of the Limpopo River bed is a near ideal aquifer, but unfortunately of relatively shallow depth (average 4 m). Siting of abstraction points should be preceded by a detailed mechanical probing survey of the irregular rock bottom to select troughs of sufficient depth and open water access to surrounding areas.

2. It is suggested that the present system of 9 abstraction points be extended to 14, at approximately 1 km distance apart (depending on suitable sites). Due to the high specific transmissivity of the sand, interference of adjoining abstraction points is unavoidable, but should not be a serious disadvantage with a judicious pumping schedule (simultaneous use of alternate pumps only, in rotation). Pumping rate per point should not exceed 2000 m^3/day.

3. The available, extractable water is calculated to be 3,7 x $10^6 m^3$ over a $15\frac{1}{2}$ km stretch of river course controlled by the Mine Co. This reserve should be sufficient to meet requirements during periods of no flow of 6 months duration as far ahead as 1989.

4. A "sand weir" would not increase the water reserve substantially and is not recommended.

5. Abstraction points should be of the vertical, multiple well point type with a common feeder and cross members in a fish bone pattern. The whole system should be at least 2 m under the sand surface with the well points extending to rock bottom. The well points should be gravel packed.

M.P. MULDER
Chief Hydrologist.

December, 1972.

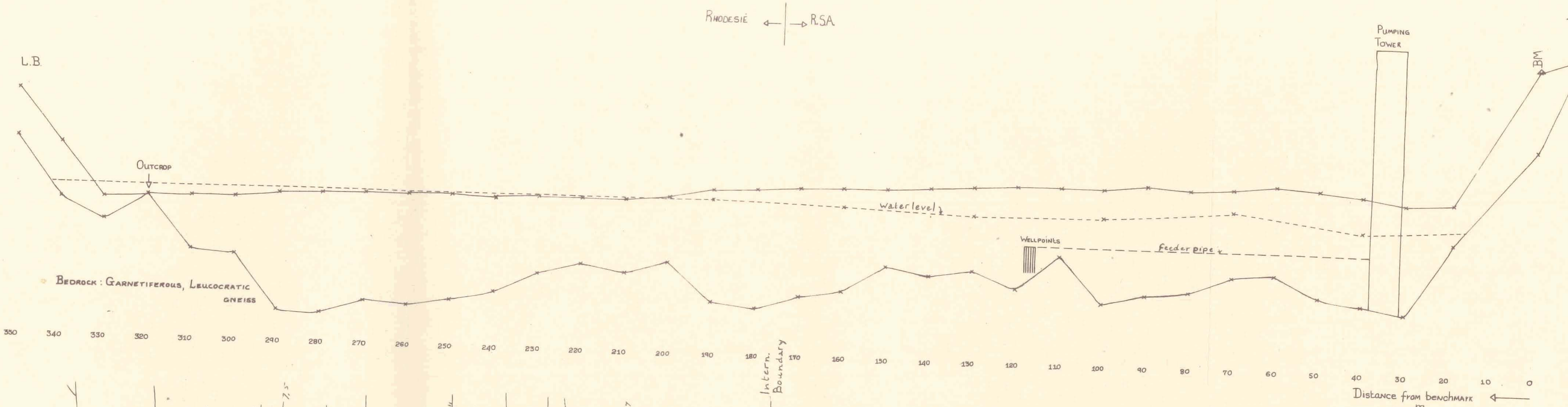
Fig. 1

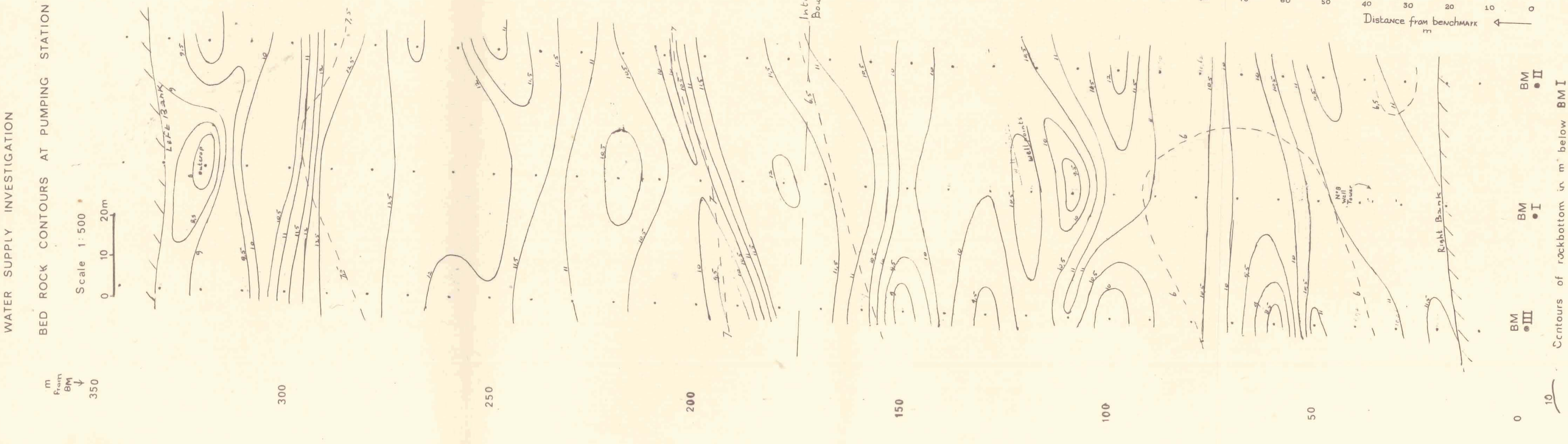
Wellpoints of M.T.D. Co. Ltd., in the Limpopo River

Scale 1:50 000

SECTION THROUGH NO. 8 PUMPING STATION.

Nov. 71.





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Nov 71.

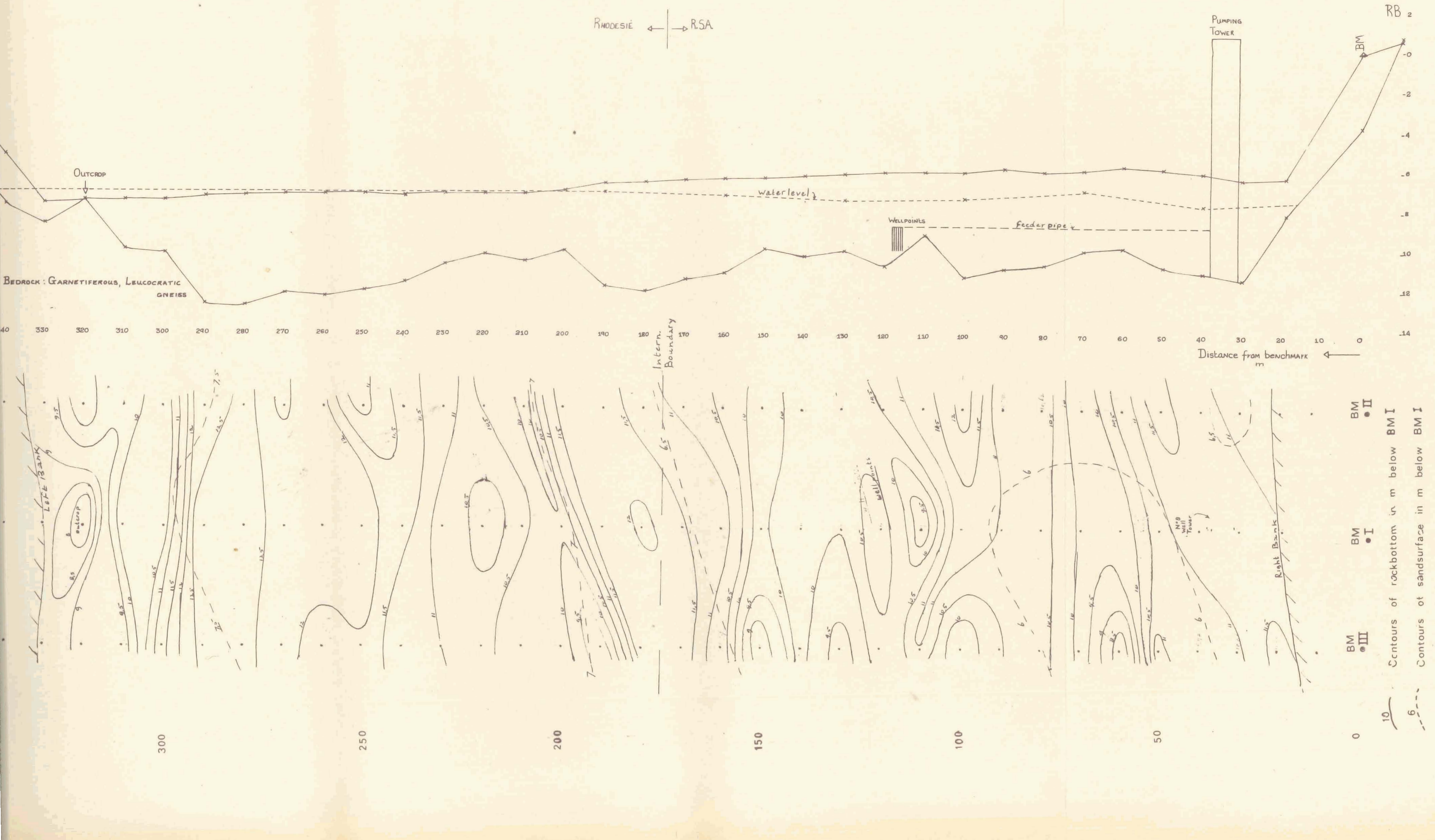

fig 2

LIMPOPO (MESSINA) PUMPTEST

DISTANCE - DRAWDOWN CURVES, MAY 1971.

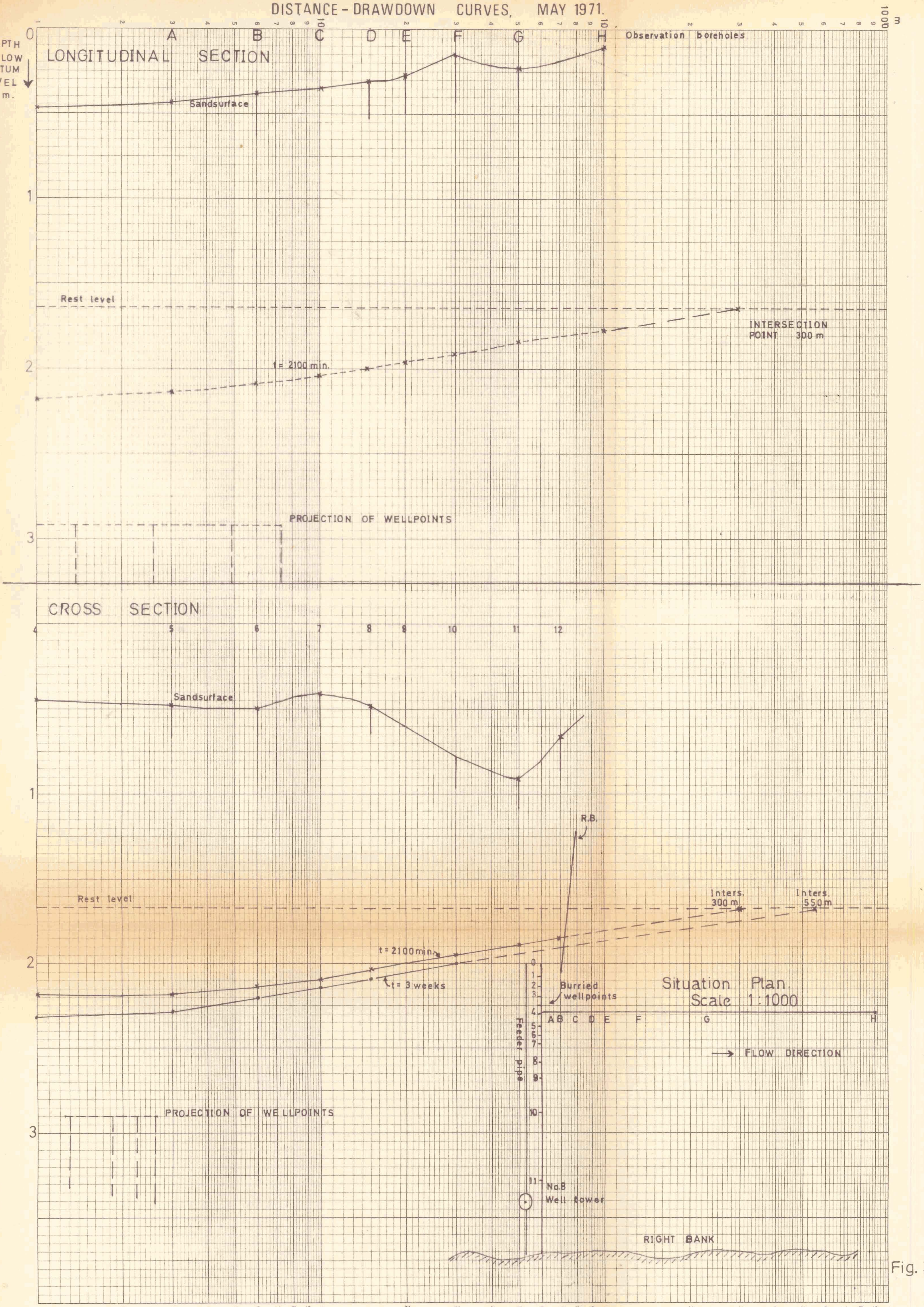

Fig. 3

MPM
9/12/72

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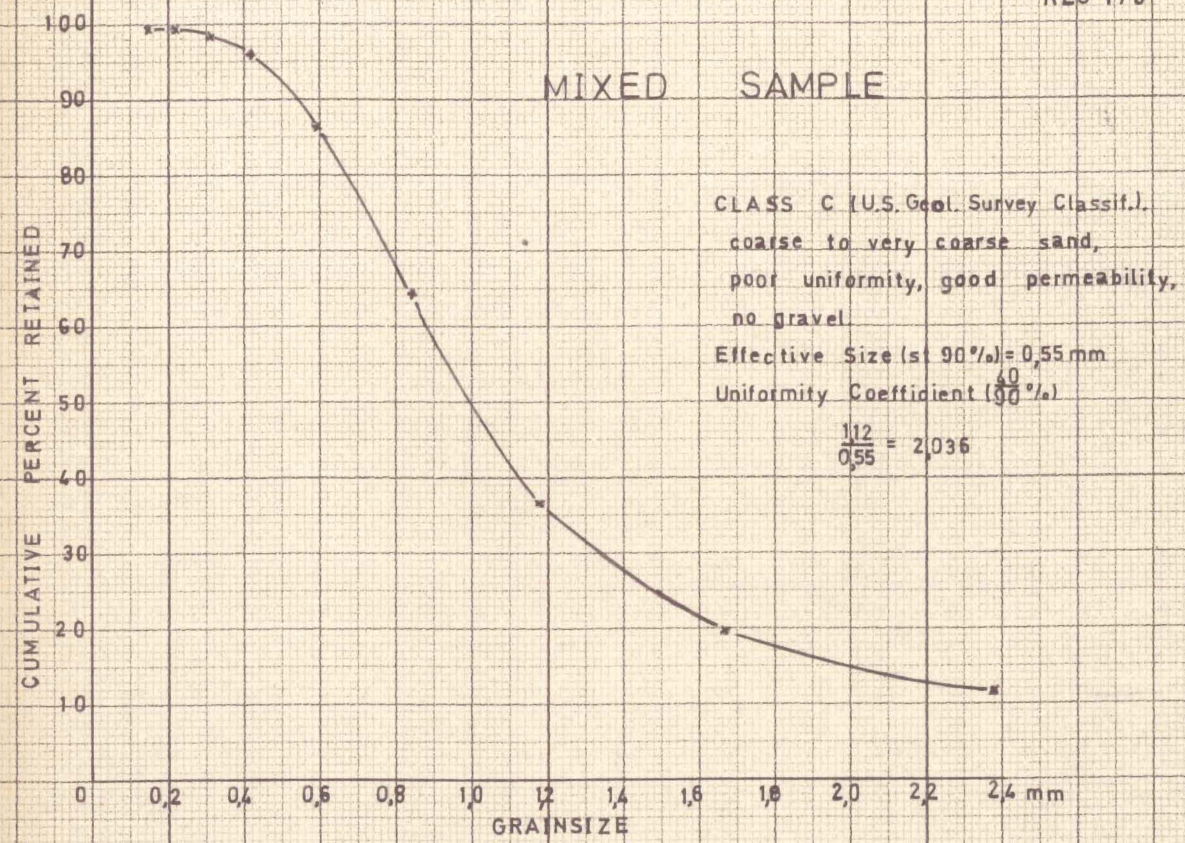
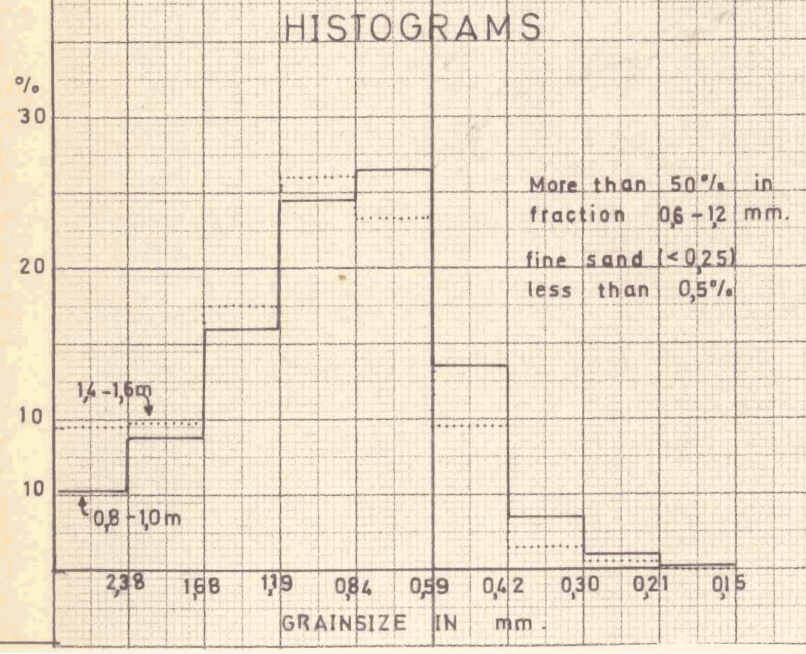
Fig. 4

LIMPOPO RIVER (MESSINA)
SANDGRADINGS.





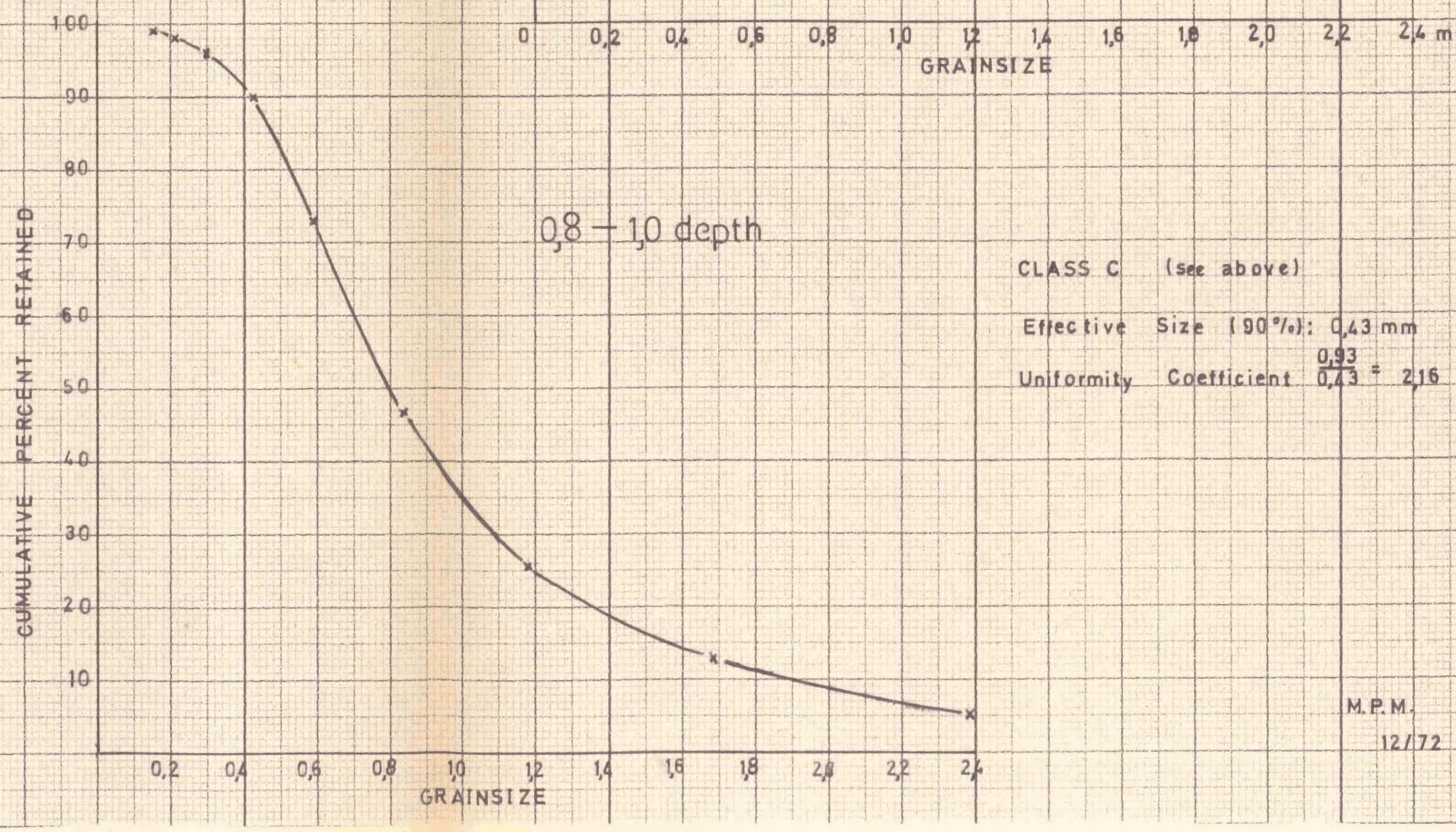


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Fig. 5

Water Consumption Messina Township and Mine.

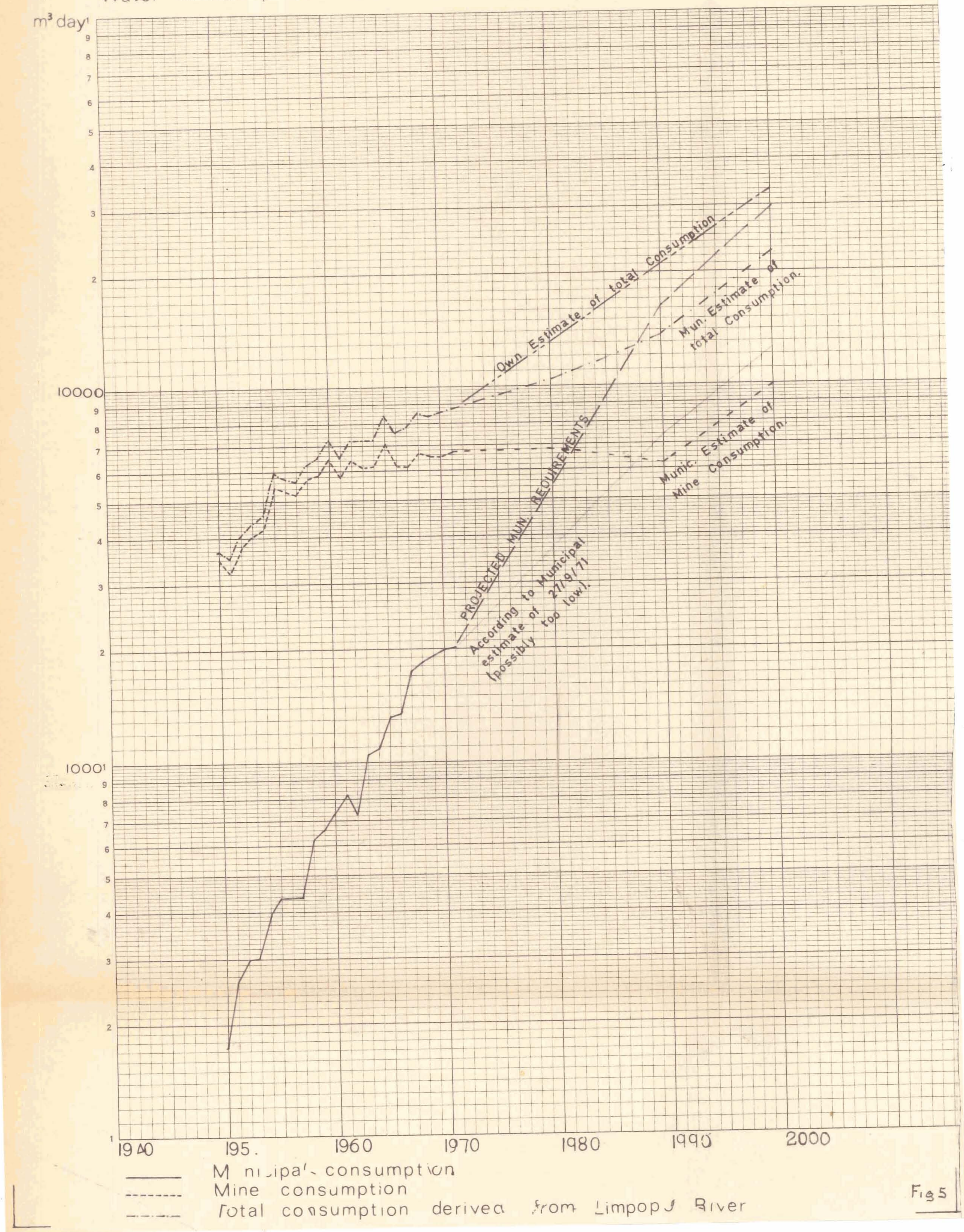

Fig 5