## PAPER No. 152.

# TUBE WELLS ON ZHOB VALLEY RAILWAY BALUCHISTAN.

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### Introduction.

During the past decade considerable interest has been evinced, by engineers in all branches of the Service, and particularly in the Punjab, in tube well problems.

The writer has during the past four years submitted two papers on the subject to this Congress. Their reception, and the considerable number of references from engineers in the Punjab and other Provinces, has encouraged him to present what is likely to be his last paper on tube wells.

The previous papers of 1929 and 1930, dealt almost entirely with tube wells in the Punjab plains, where the strata conditions present no difficulties, and where wells may be installed with an almost absolute assurance that the supply required will be obtained, provided the job is handled intelligently.

This paper deals with a set of conditions very different from those in the Punjab plains, and it is felt that a detailed description of each of the 6 wells installed in this section, may be of assistance to engineers in the Punjab, and elsewhere, in solving their problems, when similar conditions are encountered.

The paper is illustrated by the diagrams listed below :—

Plate 1. Map of Zhob Valley Railway.

Plate 2. Section of tube wells on Zhob Valley Railway, showing general fall of country and water levels found at each of the tube wells.

Details of tube wells :—

Plate 3. Kila Saifulla.

Plate 4. Alozai.

Plate 5. Shinkai.

Plate 6. Simzai.

Plate 7. Badinzai.

Plate 8. Fort Sandeman.

Perhaps the most gratifying results obtained by the tube well division of the North Western Railway, since its formation in 1924, are on the Zhob Valley Railway Extension, where every watering station on the section has a tube well supply, sufficient to meet normal demands in the regulation 8 hour period of pumping, and mobilization needs by doubling or trebling the pumping hours.

It has taken just over 5 years, from the time work was first started, to complete the provision of a tube well supply at each of the 6 watering stations on this section, all of which are provided with air lift cum centrifugal pumping plants. The total cost of these works amounts to Rs. 1,16,060. The time taken and the expenditure incurred appear excessive, but a perusal of the detailed description of each of these wells provide, in the writer's opinion, ample justification for both.

The Zhob Valley Railway is a 2'—6" line, of which 46 miles from Khanai (30 miles beyond Quetta) to Hindubagh, were built in War time to obtain chrome from the mines in that vicinity, an extension from mile 46 to mile 174, Fort Sandeman, being constructed later to serve the Zhob Valley.

The following significant comments are extracted from the Project Report of the Zhob Valley Railway Extension :—

1. The Zhob Valley Railway runs along the south of the Zhob river, almost parallel to it throughout its length, and at an average distance of 2 miles from it.

2. The alignment lies on a somewhat gentle slope, composed chiefly of gravel, below which is a flatter slope of clay.

3. The valley being bounded by hills on each side, at a distance varying from about one to five miles, there is an enormous amount of cross drainage into the Zhob. The country is subject to cloud bursts. The absorption of the soil being very slight, and the hills being steep, there is a very rapid run off and in general this water spreads itself over wide shallow *Nallas.*

4. Water-supply for locomotives is a big problem, and in face of the great objections to the use of travelling water tanks, they are recommended for the Hindubagh Fort Sandeman Railway.

5. Time did not permit of borings being made, so as much information as could be obtained from observing local conditions was recorded. Details of water levels, geological sections, etc., of any existing wells were noted and the opinion arrived at was that sufficient water will be obtainable by sinking wells almost anywhere along the alignment between Killa Saifulla and Fort Sandeman at a depth varying from 40′ to 90′.

6. The question of water-supply is a crucial one and there are no data available from which definite deductions can be made. Reference was made to the Geological Survey of India department, who were willing to assist, but were unable to throw any light on the subject.

7. At some places karez water-supply would be available, but at others there is no alternative but to sink a well, or make use of travelling water tanks. It is very strongly advocated that wells should be sunk at all watering stations, if the results of borings show that an adequate supply is available.

**Geology.**

The only reference to the geology of the country traversed by the railway, was found in the Baluchistan District Gazetteer, Volume I, from which the following is extracted :—

The broad plain of the Zhob occupied by alluvial formations of considerable depth, separates two mountainous regions of different character and constitution. That forming the northern and greater part of the District, beyond the left bank of the Zhob consists almost entirely of an extensive and monotonous series of calcareous sandstones and shales, known as "Kojak Shales," all of one geological age. The hilly regions situated beyond the right bank of the Zhob, only a comparatively small portion of which occurs in the District, forming a narrow fringe along its southern and eastern boundary, are far more varied in composition and structure. The most interesting rocks of this region are the carboniferous and triassic slates and the igneous intrusions occurring south of Hindubagh.

**Kila Saifulla. Elevation 5086.**

The first boring done by the Railway in the Zhob Valley was started in September 1926, with 6″ casing, as a trial boring, to investigate the possibilities of obtaining a tube well supply of water for locomotive requirements at Kila Saifulla, mile 85.

A hole was drilled up to a depth of 300′—0″ and water first struck at 24′—8″, but all samples taken up to a depth of 197′—0″, on analysis, were reported as "Unfit for locomotive boilers."

The next sample of water taken at 232′—0″ was reported on as "Not very good but may be used " and the last sample from a depth of 270′—0″ was passed as suitable for locomotive use.

From 232′—0″ where good water was first obtained to 300′—0″ the total depth of the boring, the following water bearing strata were encountered :—

| | | | |
|---|---|---|---|
| 229′—0″ to 239′—0″ | 10′—0″ | Boulders and gravel. |
| 245′—3″ to 255′—6″ | 10′—3″ | do. |
| 266′—3″ to 270′—6″ | 4′—3″ | do. |
| 271′—6″ to 285′—6″ | 14′—0″ | Big boulders and gravel. |
| 292′—0″ to 296′—3″ | 4′—3″ | Gravel boulders and sand. |
| | 42′—9″ | |

From an examination of the samples of the strata detailed above, it was considered that a tube well installed in this boring, with strainers kept below the 232′—0″ level, would provide the 3,500 gallons per hourt required for locomotive use at this station, and a tube well with fine slot Tej screens was duly installed.

Unfortunately during the extraction of the 6″ casing the pipes parted and could not be recovered. All the tube well material however was salvaged in a serviceable condition for use in another boring which it was decided to start.

Immediately afterwards the writer proceeded on long leave and during his absence this boring was carried down with 10″ casing to a depth of 302′—0″. The records show that 7″ Tej strainers were located as shown below :—

| | | |
|---|---|---|
| 230′—242′ | 12′—0″ | In Boulders, gravel and sand. |
| 270′—282′ | 12′—0″ | In Shingle, gravel and sand. |
| 292′—296′ | 4′—0″ | In Boulders, gravel and sand. |
| Total | 28′—00″ | |

On test the well yielded no water, and the reason ascribed for the failure, was, that the subordinate in charge of the work had kept incorrect samples, in as much as the strata he sampled as boulders, gravel and sand, actually contained a sufficiently large mixture of clay to make it impervious, and hence no water could flow into the well.

This was the position when the writer returned from leave and resumed charge.

A study of the history of the two failures and of the strata drilled through in these borings, suggested that there was a reasonable prospect of obtaining a tube well supply, if greater care was exercised in sampling strata and observing variations in the water levels during boring operations. Sanction was obtained to sink another bore with 13″ casing and work was started in August 1928.

By the end of the year the tube-well was lowered into position with 5″ Tej fine slot screens located as detailed below :—

| | | |
|---|---|---|
| 259′—0″ to 263′—0″ | 4′—0″ | Boulders, shingle and sand. |
| 267′—0″ to 283′—0″ | 16′—0″ | Boulders, shingle and sand with traces of clay. |
| 312′—0″ to 328″—0″ | 16′ ″ | Boulders, shingle and sand. |

In withdrawing the casing the pipes once again parted at 278′—0″ below ground level, leaving only 21′—0″ of strainer uncovered.

Another failure appeared inevitable, as only 60% of the screen, estimated as required to produce the supply needed, was effective, the remaining 40% being covered by the casing left behind in the borehole. The position was worse still as only 16′—0″ of the 21′—0″ was located in a stratum free from clay, the remaining 5′—0″ being in the layer of boulders, shingle, and sand with traces of clay from 267′—0″ to 283′—0″

In spite of these mishaps it was felt that there was still a possibility of obtaining our requirements from this well, and pumping was started on the 14th. January 1929. The discharge rose steadily from 870 gallons per hour with a drop of 53′—0″ to 2,180 with a drop of 70′—0″, but the water contained a very large quantity of clay in suspension. In a week, as a result of pumping the well daily for 8 hours, the water gradually cleared and the discharge steadily increased to 3,500 gallons per hour with a drop of about 60′—0″.

From July 1929 the well was brought into regular service for supply of locomotive water, and was pumped with a portable compressor, as it was not deemed advisable to provide a permanent plant till, as a result of continuous use for a prolonged period, there was sufficient proof that conditions had stabilized around the screen, and the yield was being maintained.

By November 1929 the well had been in regular use for 5 months. During this period not only had conditions stabilized and the yield been maintained, but the drop had decreased from 60′—0″ to 22′—0″. We thus felt we were now justified in providing the permanent plant.

The well has been in regular service since, and the last test carried out on 19th. June 1931 gave the discharge as 3,260 gallons per hour and the drop 22′—0″ which is almost exactly what it was in November 1929.

The total cost of the well was Rs. 9,000.

The cost of the pumping plant including a pucca pump house and the rising main is Rs. 8,000.

The approximate cost per 1000 gallons of water delivered into the H. S. tank exclusive of interest and depreciation charges is 3 annas.

**Alozai. Elevation 4950.**

The work at Alozai, mile 102, was done by a hand drilling outfit with 13″ casing, in 4 months from the date work started to the day plant was loaded up and booked to the next job, including the time taken to test the well with a portable air lift pump.

Nowhere was rock struck, though in places the boulders were large enough to hold up the casing and considerably retarded progress in boring.

It will be seen from the diagram that shallow beds of gravel, shingle and boulders were encountered, and that advantage was taken of all these to locate a short length of 4′—0″ Tej strainer in each of them, to tap what water they could supply. In the lower two beds a certain amount of clay was present in the gravel, but it was considered that this quantity could be washed out by repeated "back blowing," during the yield test.

The yield from the well during the test with the permanent air lift cum centrifugal pumping plant was 2,909 gallons per hour with a drop of 6′—6″ only or 80 gallons per square foot of strainer area, a result which is considered extremely satisfactory having regard to the locality and the small drop.

The cost of the Tube Well was Rs. 4,250.

The cost of the pumping plant including a pucca pump house, erection and the rising main was Rs. 8,710.

The approximate cost per 1000 gallons of water delivered into the H. S. Tank, exclusive of interest and depreciation charges, is 2·5 annas.

**Shinkai. Elevation 4933.**

Work was started at Shinkai station, Mile 120, with a hand drilling outfit and 13″ casing pipes on 6th. November 1930.

As the formation of soft stone, boulders bedded in clay, and stiff clay, stood up in the 6′—0″ dia. guide pit, it was decided to continue digging this pit with *Pharwas* till it showed signs of caving.

At 87′—0″ water was struck in a bed of sandstone, and digging stopped. The casing pipes were lowered into the pit and boring started.

In a fortnight the casing was only sunk 5′—0″ into the sandstone to 92′—0″ and work stopped on 28th. February 1931 as it was evident that a hand boring could not be done here.

The reason for trying this method for a fortnight was the belief that the bed of stone, as in several other cases in this locality, might be only a few feet in thickness, under which the strata would be the usual alluvial deposits of sand and clay.

The pit was left unfilled, and on 20th. May 1931 the 'Armstrong' drilling machine from Fort Sandeman started operating on this boring and carried down the hole uncased by 21st. July to 222′—0″, the minimum depth required to obtain the submergence for an air lift pump.

As the formation to the depth drilled showed no signs of caving, and as no porous alluvium existed, from the level at which water was struck to the bottom of the boring, it was decided to test the yield from the uncased hole, by pumping with a portable air lift plant.

The discharge obtained was 5,000 gallons per hour with a drop of 15′—0″ only. The yield tests were carried out for 3 days of 12 hours per day. On the 3rd. day the water was slightly coloured for the first two hours but for the remaining 10 hours was crystal clear.

After the test the well was sounded and showed that no caving had occurred. The 13″ casing was then replaced by a 7″ plain pipe bedded on the stone layer 89′—0″ below ground level, and the 6′—0″ guide pit filled in to ground level.

The total cost of the well was Rs. 8,800.

The cost of the pumping plant including a pucca pump house and the rising main was Rs. 9,500.

The approximate cost per 1000 gallons of water delivered into the high service tank exclusive of interest and depreciation charges is 3 annas.

**Simzai. Elevation 4766.**

The tube well at Simzai, mile 138, gave us more trouble than at any other station on the Zhob Valley Railway, with the result that no less than four borings were sunk, in each of which a tube well was installed, but none of these, on test, yielded sufficient water for loco requirements.

These failures are mainly attributable to the peculiar strata condition of the country, which misled the subordinates in charge of the boring gangs, who had gained all their experience in the Punjab, where the strata are more or less well defined, and come under 3 main categories as far as tube well work is concerned, viz., pure sand, pure clay, mixture of sand and clay, and are therefore easily identified and correctly sampled.

It was only when a special type of well was installed, in the fifth boring to meet the unusual conditions, that success was achieved.

The first well was sunk at the end of 1928, in which 16′—0″ of 7″ Tej strainer was installed in a bed of what was believed to be "coarse sand and bujree", from the sample submitted by the mistri in charge of the work.

On test a yield of 114 gallons per hour was obtained, only a very small fraction of our requirements at this station.

At the request of the Divisional Superintendent the well was retained and provided with a hand pump for a drinking water supply for the station staff.

The test showed that the mistri had been completely misled in his sampling as this stratum was a mixture of "clay, coarse sand, and bujree."

During sludging operations the clay was displaced, remaining in suspension in the water, and the sludger brought up a mixture of washed "coarse sand and bujree".

In July 1929, the Armstrong machine was sent to Simzai to do the next boring, as the previous hand boring could not be sunk below 126′-0″ where it was held up on a bed of large boulders bedded in clay. Up to this depth, as the first boring showed, there were no porous beds, from which a sufficiently large supply of water could be drawn, so that it was necessary to investigate the lower strata for which a drilling machine was essential.

The boring was carried down to a depth of 289′—0″, and although up to this depth, there were no good water yielding strata, it was decided to instal an experimental tube well using 36′—0″ of 7″ Tej strainers in the beds of boulders, bujree, and clay lying between 226′—0″ to 275′—00″, and 279″—0″ to 289′—0″, in the belief that air lift pumping and "back blowing" would wash the clay out, leaving a porous bed of boulders and bujree from which a fair quantity of water could be drawn.

On test the yield gradually increased to 2,620 gallons per hour with a drop of 83′—0″, but later fell to 647 gallons per hour with a drop of 81′—0″.

A feasible explanation of this failure is, that the proportion of clay in the strata was considerably larger than estimated, and although a certain amount of gravel shrouding was done, it was not sufficient to keep the surrounding clay from moving to the screen at the same rate as it was being pumped out. The nett clearance between the 7″ bore screen and the 10″ bore casing was just one inch, and it is doubtful if the gravel was able to distribute itself uniformly in this small annular space. The result was that pumping gradually washed out some of the clay, and increased the yield till it reached 2,620 gallons per hour, when the increased velocity of flow moved larger quantities than could pass through the fine slots of the screen into the well, resulting in the screen slots, which were only 10/1000″ wide, becoming choked. The extreme fineness of the slots would not allow of the clay being displaced even though repeated "back blowing" was tried.

As all efforts to clear the slots and thereby increase the yield were unsuccessful, it was decided to withdraw the screens, and to drill a large well with 13″ casing to increase the clearance between the tube well and the casing, for a greater thickness of shrouding.

In the process of withdrawing, the screens parted and could not be recovered, as the hole caved in on them. The well had therefore to be abandoned and a fresh one started.

The third and fourth wells were drilled with 13″ casing into which 7″ Tej strainers were lowered and gravel shrouded. On test both these wells yielded an insignificant quantity of water and had to be abandoned after the screens were withdrawn.

The third well was drilled with the Armstrong machine, and the fourth by hand.

These failures conclusively proved that enough water was available in the strata to meet our requirements, and that fine slot screens, like the Tej, were not suitable for the conditions encountered, as the clay present in the beds of sand and bujree invariably choked the fine slots.

A large sum of money had been spent in these failures, but as a locomotive water supply was essential at this station, it was decided to make one more effort, taking advantage of the lessons these failures had taught us.

The fifth and last boring was sunk to a depth of 220′—0″ with 13″ casing at a site 100′—0″ from the nearest of the previous 4 borings, and a hand drilling outfit was used.

Up to this depth two moderately good water-bearing strata were encountered. The first was a layer of fine sand and bujree between 34′-0″ and 40′—0″, and the second, a fine sand, bujree, and shingle bed between

118′—0″ and 124′—0″. In each of these a 4′—0″ length of Tej strainer was installed, as a close examination of the samples showed that they were almost entirely free of clay.

It was estimated that the yield from this 8′—0″ length of fine slot screen would not be more than a few hundred gallons per hour, as the static water level was 24′—0″ there was a possibility of the working water level falling below the upper section of Tej screen lying between 35′—0″ and 39′—0″ and so rendering it ineffective.

The only other strata that could be developed, to provide the balance of our requirements, were from 181′—0″ to 199′—0″ sand bujree and clay, and 199′—0″ to 215′—0″ sand, bujree, boulders and clay. It was decided to attempt this, 34′—0″ of 6″ bore large slot screen (slots 4″ × ½″) was located from 118′—0″ to 215′—0″. Air lift pumping was depended on to draw out the fine sand, clay, and finer bujree, leaving the screen shrouded with the larger bujree and boulders present in the strata, supplemented by gravel shrouding placed between the 13″ casing and the 6″ iron screen, during the process of withdrawing the casing.

The results fully justified the procedure adopted, as will be seen from the following statement of the yield test :—

| Date. | Period of test hours. | Discharge gallons per hour. | Drop. | remarks. |
|---|---|---|---|---|
| 6-10-31 | 8 | 2,630 | 21′—0″ | Water very dirty, large quantities of sand being discharged. |
| 7-10-31 | 10 | 2,630 | 14′—0″ | Improving slightly in colour. Sand decreasing. |
| 8-10-31 | 10 | 3,120 | 14′—0″ | Ditto. |
| 12-10-31 | 5 | 4,920 | 25′—0″ | Ditto. |
| 13-10-31 | 12 | 6,410 | 19′—0″ | Water nearly clear but sand still coming up. |
| 14-10-31 | 15 | 6,410 | 23′—0″ | Water dirty for first 8 hours then cleared. Sand decreasing. |
| 15-10-31 | 15 | 6,410 | 21′—0″ | Water slightly coloured throughout. |
| 16-10-31 | 10 | 6,410 | 21′—0″ | Water dirty for first 5 hours. Afterwards quite clear. |
| 17-10-31 | 3 | 6,410 | 21′—0″ | Water was quite clear throughout test. |
| | 88 | | | |

It required nearly half a million gallons of water to be pumped out of the well before it was possible to get a perfectly clear discharge, from the time pumping was started on the last day of the test. As a rule, gravel developed wells pumped by air, deliver a certain amount of sand or clay each time pumping is started. From observations of such wells on the North Western Railway (we now have 8 gravel developed wells) this occurs for 2 to 5 minutes from the time the well commences delivering water.

The reason for this is that the initial discharge from the well, and consequently the initial inflow velocity, when the air valve is first fully opened, is from 50% to 100% more than the regular, steady flow. Each time pumping is started, this initial high velocity displaces a certain amount of clay and sand around the screen, which are drawn into the well, and pumped out with the water.

The total cost of the tube well was Rs. 14,000.

The cost of pumping plant including a pucca pump house and rising main was Rs. 8,800.

The approximate cost per 1000 gallons delivered into the high service tank exclusive of interest and depreciation charges is 3 annas.

**Badinzai. Elevation 4667.**

The tube well at Badinzai station, mile 157, was the last to be installed on the Zhob Valley Railway, and curiously enough it gave the least trouble to sink and produced more water than any of the other five.

The drilling was done with an Armstrong machine, and was carried down to a depth of 279′—0″, in just under two months without encountering hard rock.

Another month was spent in lowering strainers and plain pipes, gravel shrouding, withdrawing casing, and testing the yield of the well.

Water was first struck at 63′—0″ and rose to 60′—0″. It stood, with only slight variations, at this level throughout the boring operations.

To be on the safe side 40′—0″ of 7″ Tej strainer was provided for the well, which on test yielded 6,400 gallons per hour with a drop only 1′—5″, a result far beyond our expectations.

This yield calculated on the basis of a 12′—0″ drop (assuming that yield is proportional to drop.) would amount to over 50,000 gallons per hour, and 700 gallons per hour per square foot of strainer area.

The well is being provided with an air lift cum centrifugal pumping plant.

The total cost of the well was Rs. 7,250.

The cost of the pumping plant with pump house and rising main was Rs. 8,000.

The approximate cost per 1000 gallons, delivered into the high service tank, exclusive of interest and depreciation charges, is 3 annas.

**Fort Sandeman. Elevation 4543.**

From a general survey of the country around Fort Sandeman railway station, mile 174, it was decided that a hand drilling plant would not be suitable for sinking a borehole at this station.

The petrol driven Armstrong drilling machine was therefore sent to carry out this job, and boring operations with 13" casing were started on 27th. June 1930.

The section of the strata drilled through shows that our conclusions as to the unsuitability of a hand outfit were correct.

Although hard rock was not struck till a depth of 183'—0" was reached, most of the clay beds were extremely hard and could not be drilled without a power plant.

Water was first struck in the layer of brown clay, bujree, and boulders at 135'—0", and immediately rose to 122'—0", at which level it stood throughout the rest of the boring.

At 154'—0" difficulty was being experienced with sinking the casing further, so it was decided to continue the hole uncased, to 412'—0" the depth required for submergence for an air lift cum centrifugal pumping plant.

Including a serious breakdown of the drilling machine due to overloading it, causing a delay of 1 month, the total time taken in drilling down to 412'—0" was 4 months, at a cost of Rs. 4,200.

As no porous water bearing alluvial deposits were encountered, and the open 13" hole from 154'—0" to 412'—0" was standing up well, it was felt that the possibility of obtaining a small supply of water from the unlined hole should be tried out, and an yield test was accordingly made, with the following result :—

| | |
|---|---|
| Static water level .. .. .. | 121'—0". |
| Working water level .. .. .. | 181'—0". |
| Discharge .. .. .. .. | 1,440 gallons per hour. |

When pumping started each day the initial discharge was 3,670 gallons per hour, but in 20 minutes it fell to 1,440 gallons per hour, and remained steady at this level for the remaining period of the test.

This result was unsatisfactory as the yield was only 50% of the normal requirements of the station. It was therefore decided to consult the Director of the Geological Survey of India as to the possibilities of obtaining a better supply by either continuing the boring to a greater depth or starting a fresh boring at some other site in the vicinity of the railway station.

The Director's reply was as follows :—

"I cannot recommend the sinking of the present boring to a greater depth, as it is unlikely that water in any quantity would be met except at a much greater depth and then would be likely to be brackish. It is also impossible to recommend any other site on the plan sent with your letter, but I would suggest that a boring might be made in the dry *nallah* south of and between the Civil Hospital and the Police Lines. Here also the water level is likely to be deep."

In accordance with this advice a fresh boring was started at a site, as near as possible to that indicated by the Director, and carried down to a depth of 312′—0″ through strata similar to that met with in No. 1. The well was cased up a 110′—0″, the level at which water was struck, and a yield test of the 202′—0″ of open hole below 110′—0″ was made with the following result :—

| | |
|---|---|
| Static water level .. .. .. | 87′—0″ |
| Working water level .. .. .. | 161′—0″. |
| Discharge .. .. .. .. | 200 gallons per hour. |

A result considerably worse than well No. 1, which fortunately had not been abandoned and filled in when No. 2 boring was started.

It was then decided to abandon and fill in well No. 2 and make further tests of No. 1. to see if any development and improvement could be effected. The well was retested on 24th. March 1931, five months after the first tests were made, and the results were identical with those obtained previously, although the well had caved in during this period and filled 102′—0″ of the hole.

This was rather a serious set-back, as it was felt that we could use the open hole as a last resort to provide our requirements here, by pumping for 24 hours a day, instead of the regulation 8 hours. This now seemed extremely doubtful, as once caving started, it was likely to continue in an aggravated form the longer the well was pumped.

To instal air and suction pipes in such a well was out of the question. Some arrangement had to be made to clean out the cavings and to prevent any possibility of further caving, without shutting off the very small flow of water all along the 300′—0″ of open hole.

The only solution possible was adopted. This was to instal 262′—0″ of 6″ large slot iron screen (size of slots 4″ × $\frac{1}{2}$″) from 412′—0″ to 150′—0″ below ground level, and to gravel shroud the well so thoroughly as to prevent the surrounding strata from moving and yet not block the fine interstices in the formations.

The result was gratifying as will be seen from a comparison of the yield test on 7th. September 1931 after the screens were lowered and shrouded, with the test made on 30th. October 1930.

Details of yield test :—

| | 7-9-31. | 30-10-30. |
|---|---|---|
| Static water level .. .. .. | 122′—0″ | 121′—0″ |
| Working water level .. .. .. | 184′—0″ | 181′—0″ |
| Discharge .. .. .. .. | 1800 G.P.H. | 1440 G.P.H. |

The tests were carried on for 55 hours in periods of 8 to 12 hours each, with no variation in the figures. It was therefore concluded that conditions had stabilized, and the permanent air lift cum centrifugal plant for the well is now under supply.

The following comparison of the yield from this well, and large slot screen wells in some of the railway stations in the Punjab, gives a good idea of the very poor water yielding capacity of the strata in Fort Sandeman :—

| Station. | Bore of slotted screen. | Length slotted screen. | Yield gallons per hour. | Drop. | Yield gallons per square foot of screen area. | Yield gallons per square foot of screen area for a 10′-0″ drop. |
|---|---|---|---|---|---|---|
| Fort Sandeman | 6″ | 262′-0″ | 1,800 | 62′-0″ | 4·6 | ·08 |
| Quetta Cantt. (H. S. Tank). | 10″ | 13′-6″ | 13,500 | 35′-0″ | 400 | 114 |
| Rohtak .. | 6″ | 6′-0″ | 5,000 | 20′-0″ | 550 | 275 |
| Delhi .. | 10″ | 5′-5″ | 19,100 | 10′-0″ | 1400 | 1400 |
| Campbellpur .. | 10″ | 20′-0″ | 12,300 | 22′-0″ | 246 | 110 |

The total cost of the tube well was Rs. 19,000.

The cost of the pumping plant including a pucca pump house and the rising main was Rs. 10,750.

The approximate cost per 1000 gallons of water delivered into the high service tank exclusive of interest and depreciation charges is 3 annas 6 pies.

A table is given below summarising the tube well installations already described and the water yields from each :—

| Station. | Size of casing pipe. | Depth of bore-hole. | Yield in gallons per hour. | Drop. | Cost of installation. |
|---|---|---|---|---|---|
| Kila Saifulla .. | 13″ | 328′-0″ | 3,500 | 60′-0″ | 17,000 |
| Alozai .. .. | 13″ | 222′-0″ | 2,909 | 6′-6″ | 12,960 |
| Shinkai .. .. | 13″ | 222′-0″ | 5,000 | 15′-0″ | 18,300 |
| Simzai .. .. | 13″ | 220′-0″ | 6,410 | 21′-0″ | 22,800 |
| Badinzai .. .. | 13″ | 279′-0″ | 6,400 | 1′- 6″ | 15,250 |
| Fort Sandeman .. | 13″ | 412′-0″ | 1,800 | 62′-0″ | 29,750 |

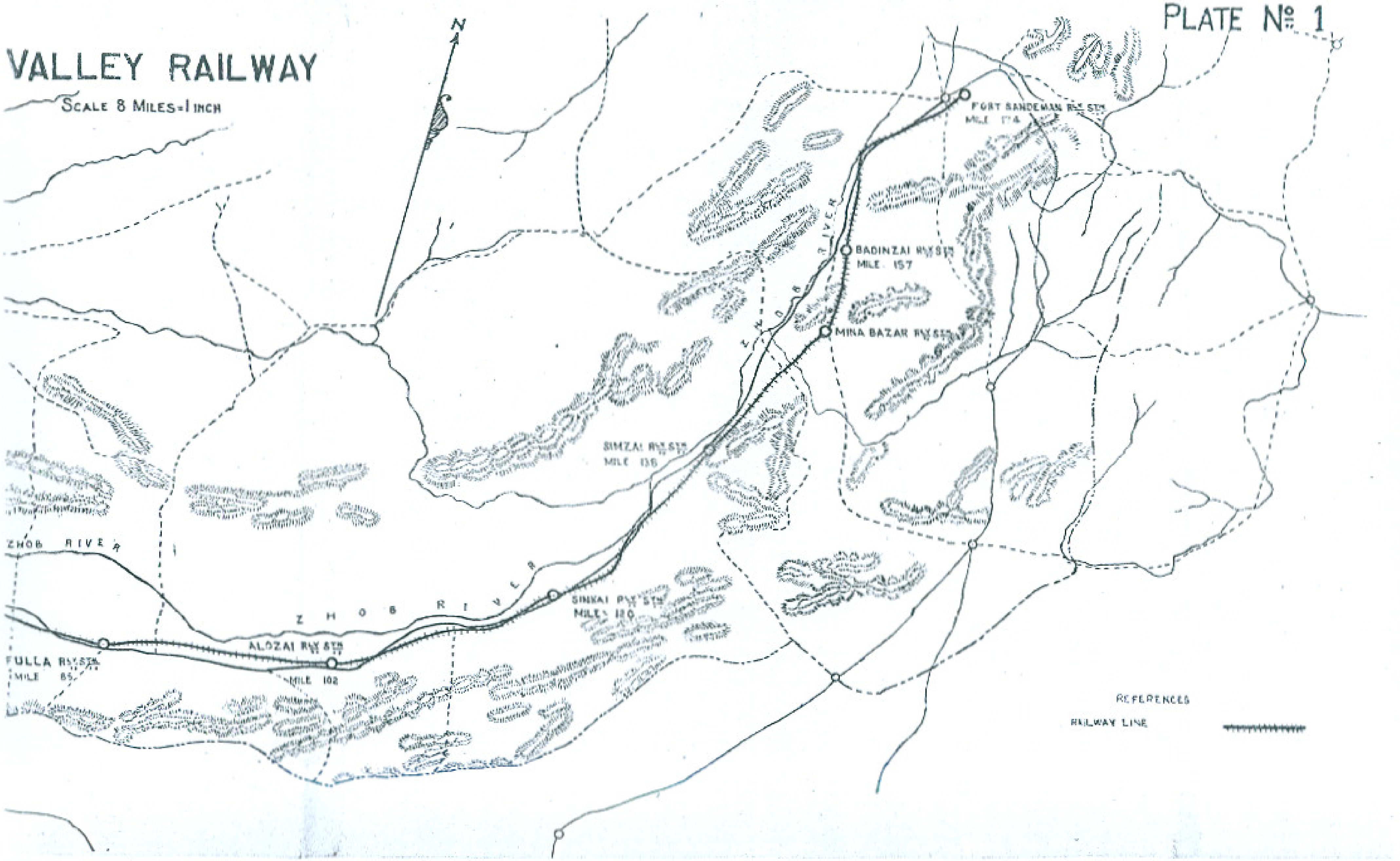
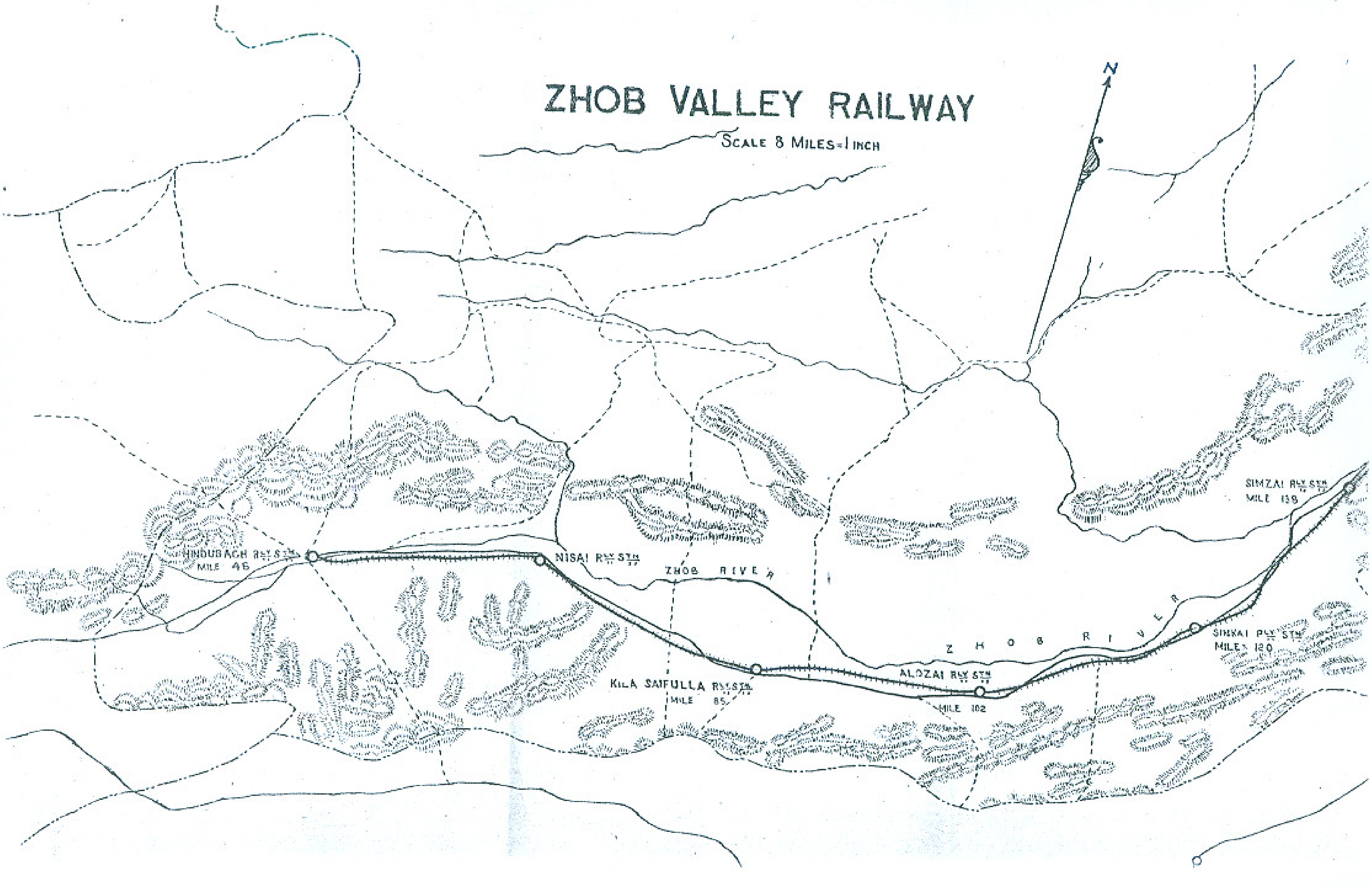


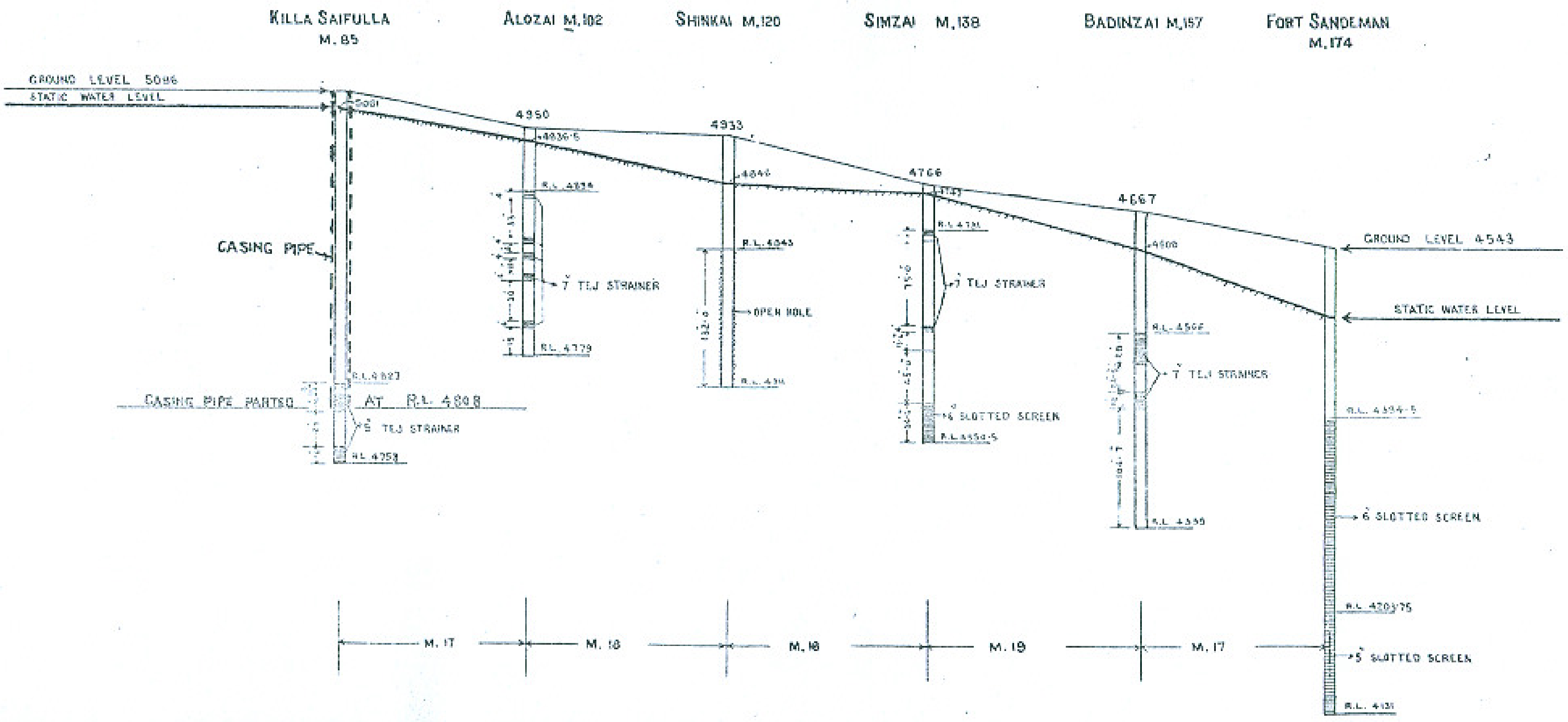
PLATE No. 1
VALLEY RAILWAY
SCALE 8 MILES=1 INCH
N
FORT SANDEMAN RLY. STN.
MILE 174
BADINZAI RLY. STN.
MILE 157
MINA BAZAR RLY. STN.
SIMZAI RLY. STN.
MILE 136
SINKAI RLY. STN.
MILE 120
ALOZAI RLY. STN.
MILE 102
FULLA RLY. STN.
MILE 85
ZHOB RIVER
ZHOB RIVER
REFERENCES
RAILWAY LINE



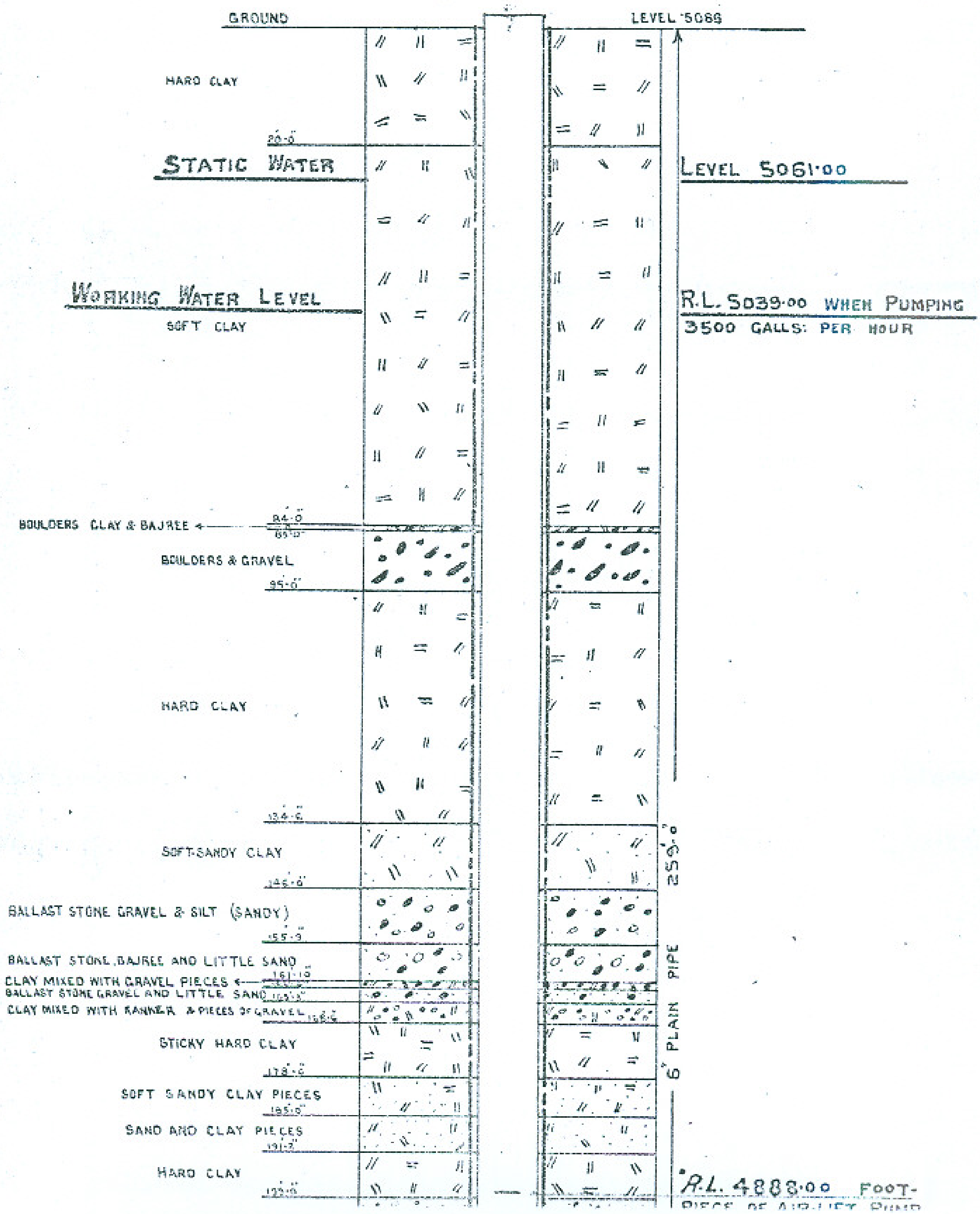
ZHOB VALLEY RAILWAY
SCALE 8 MILES=1 INCH
N
HINDUBAGH RLY STN
MILE 46
NISAI RLY STN
ZHOB RIVER
KILA SAIFULLA RLY STN
MILE 85
ALOZAI RLY STN
MILE 102
ZHOB RIVER
SINKAI RLY STN
MILES 120
SIMZAI RLY STN
MILE 139

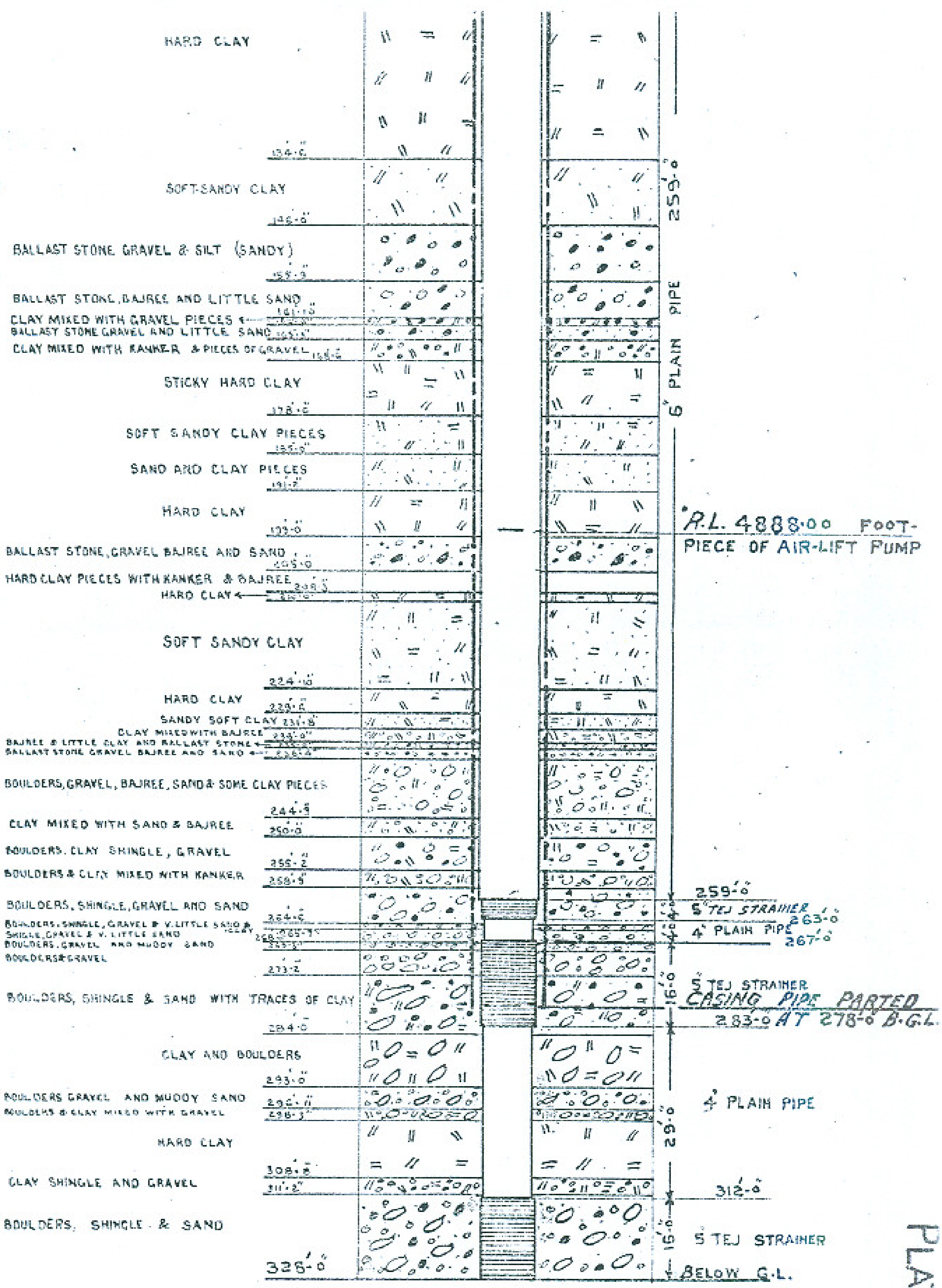
PLATE No. 2

# SECTION OF TUBE WELLS ON Z. V. RLY.



# SECTION OF TUBE WELL
# AT KILLA SAIFULLA
# MILE 85





HARD CLAY
134'-6"
SOFT SANDY CLAY
146'-0"
BALLAST STONE GRAVEL & SILT (SANDY)
BALLAST STONE, BAJREE AND LITTLE SAND
CLAY MIXED WITH GRAVEL PIECES
BALLAST STONE GRAVEL AND LITTLE SAND
CLAY MIXED WITH KANKER & PIECES OF GRAVEL
STICKY HARD CLAY
SOFT SANDY CLAY PIECES
SAND AND CLAY PIECES
HARD CLAY
BALLAST STONE, GRAVEL BAJREE AND SAND
HARD CLAY PIECES WITH KANKER & BAJREE
HARD CLAY
SOFT SANDY CLAY
224'-0"
HARD CLAY
SANDY SOFT CLAY
CLAY MIXED WITH BAJREE
BAJREE & LITTLE CLAY AND BALLAST STONE
BALLAST STONE GRAVEL BAJREE AND SAND
BOULDERS, GRAVEL, BAJREE, SAND & SOME CLAY PIECES
244'-9"
CLAY MIXED WITH SAND & BAJREE
250'-0"
BOULDERS, CLAY SHINGLE, GRAVEL
255'-2"
BOULDERS & CLAY MIXED WITH KANKER
BOULDERS, SHINGLE, GRAVEL AND SAND
BOULDERS, SHINGLE, GRAVEL & V. LITTLE SAND & CLAY
SHINGLE, GRAVEL & V. LITTLE SAND
BOULDERS, GRAVEL AND MUDDY SAND
BOULDERS & GRAVEL
273'-2"
BOULDERS, SHINGLE & SAND WITH TRACES OF CLAY
284'-0"
CLAY AND BOULDERS
293'-0"
BOULDERS GRAVEL AND MUDDY SAND
BOULDERS & CLAY MIXED WITH GRAVEL
HARD CLAY
308'-8"
CLAY SHINGLE AND GRAVEL
311'-2"
BOULDERS, SHINGLE & SAND
325'-0"
259'-0"
6" PLAIN PIPE
R.L. 4888.00 FOOT-PIECE OF AIR-LIFT PUMP
259'-0"
4'-0"
5" TEJ STRAINER
263'-0"
4" PLAIN PIPE
267'-0"
16'-0"
5" TEJ STRAINER
CASING PIPE PARTED AT 278'-0" B.G.L.
283'-0"
29'-0"
4" PLAIN PIPE
312'-0"
15'-0"
5" TEJ STRAINER
BELOW G.L.


PLATE No. 3

# SECTION OF TUBE-WELL
# AT ALOZAI
# MILE 102

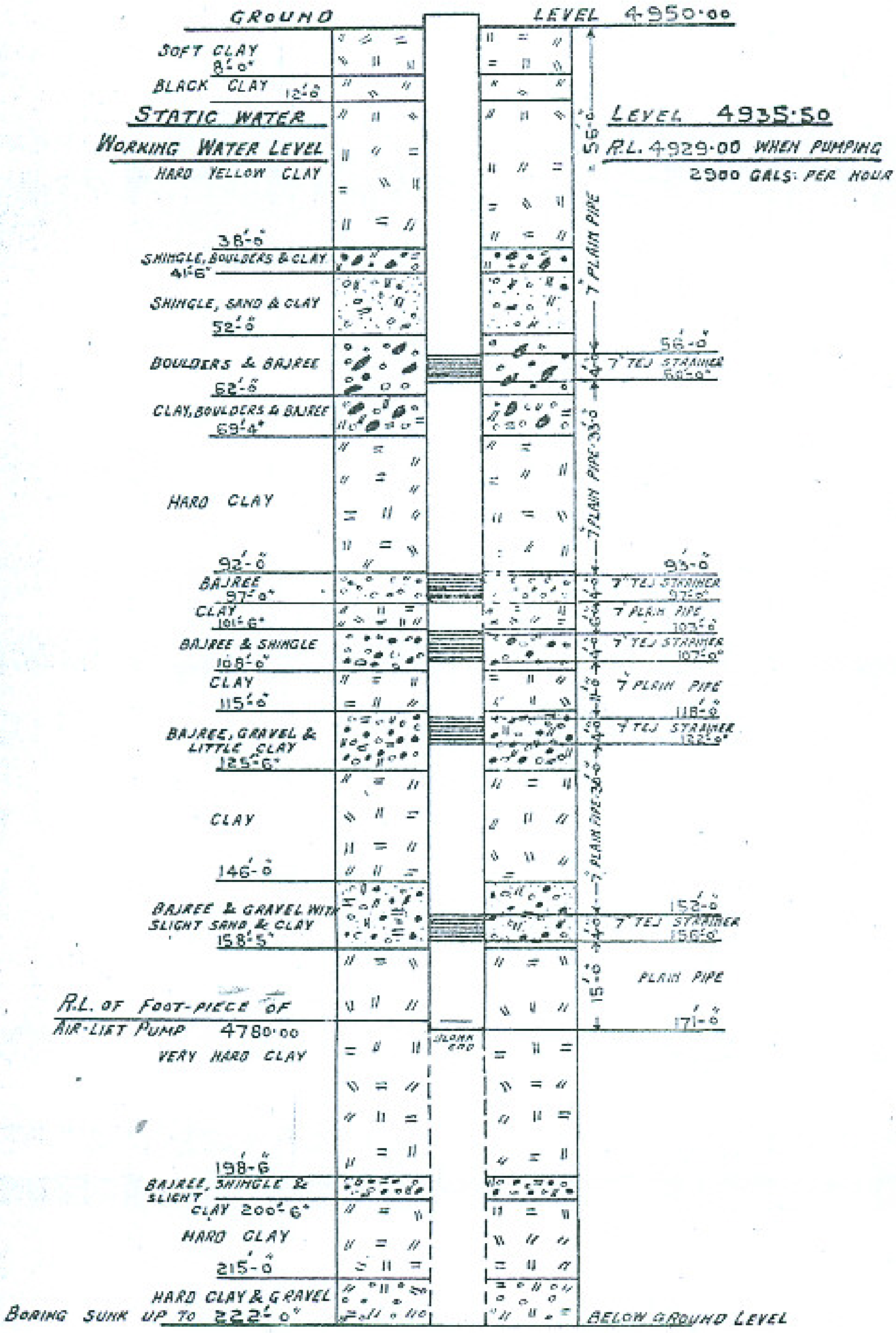



PLATE № 4

# SECTION OF TUBE-WELL
# AT SHINKAI
## MILE 120

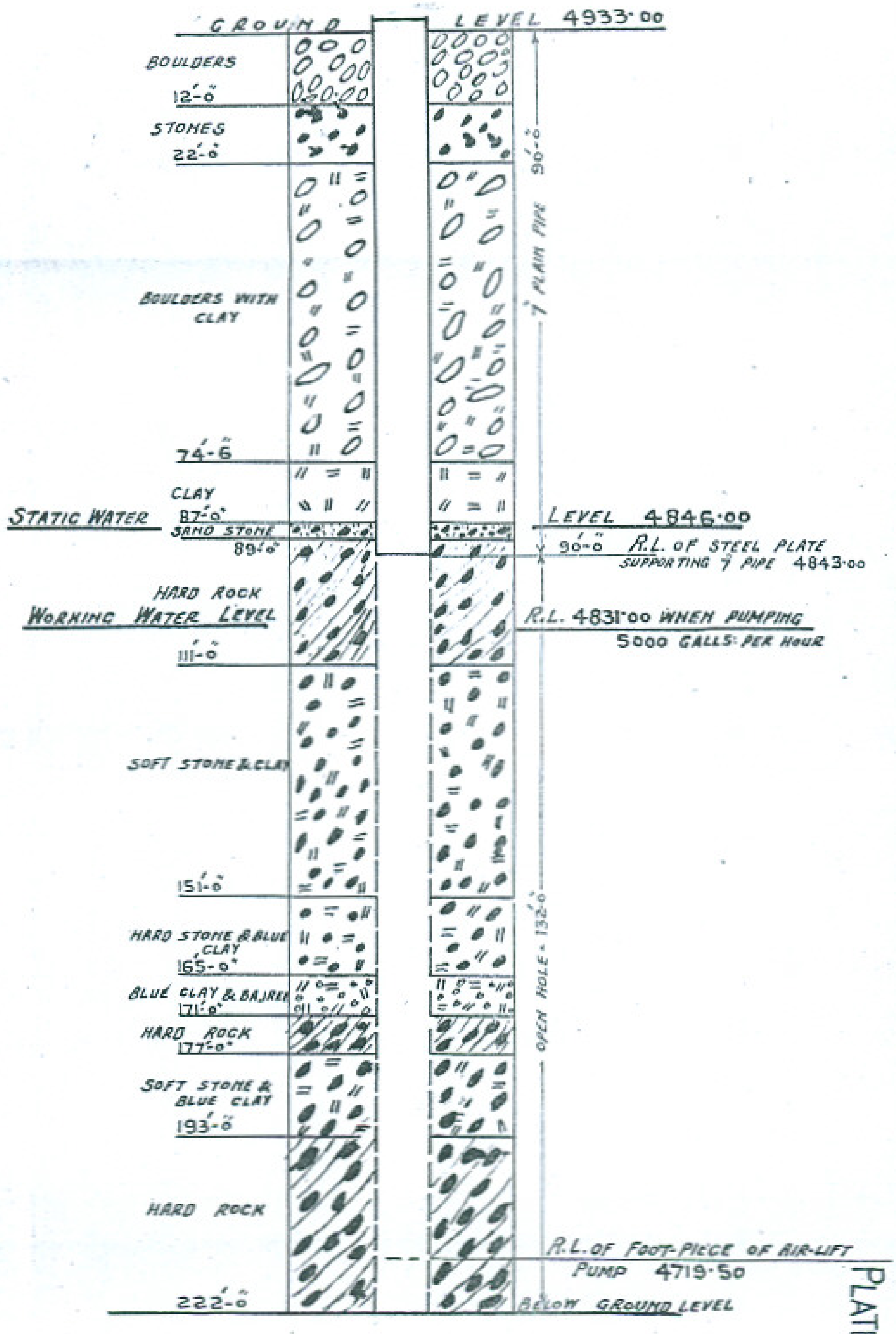



PLATE No 5

# SECTION OF TUBE WELL
## AT SIMZAI
## MILE 138

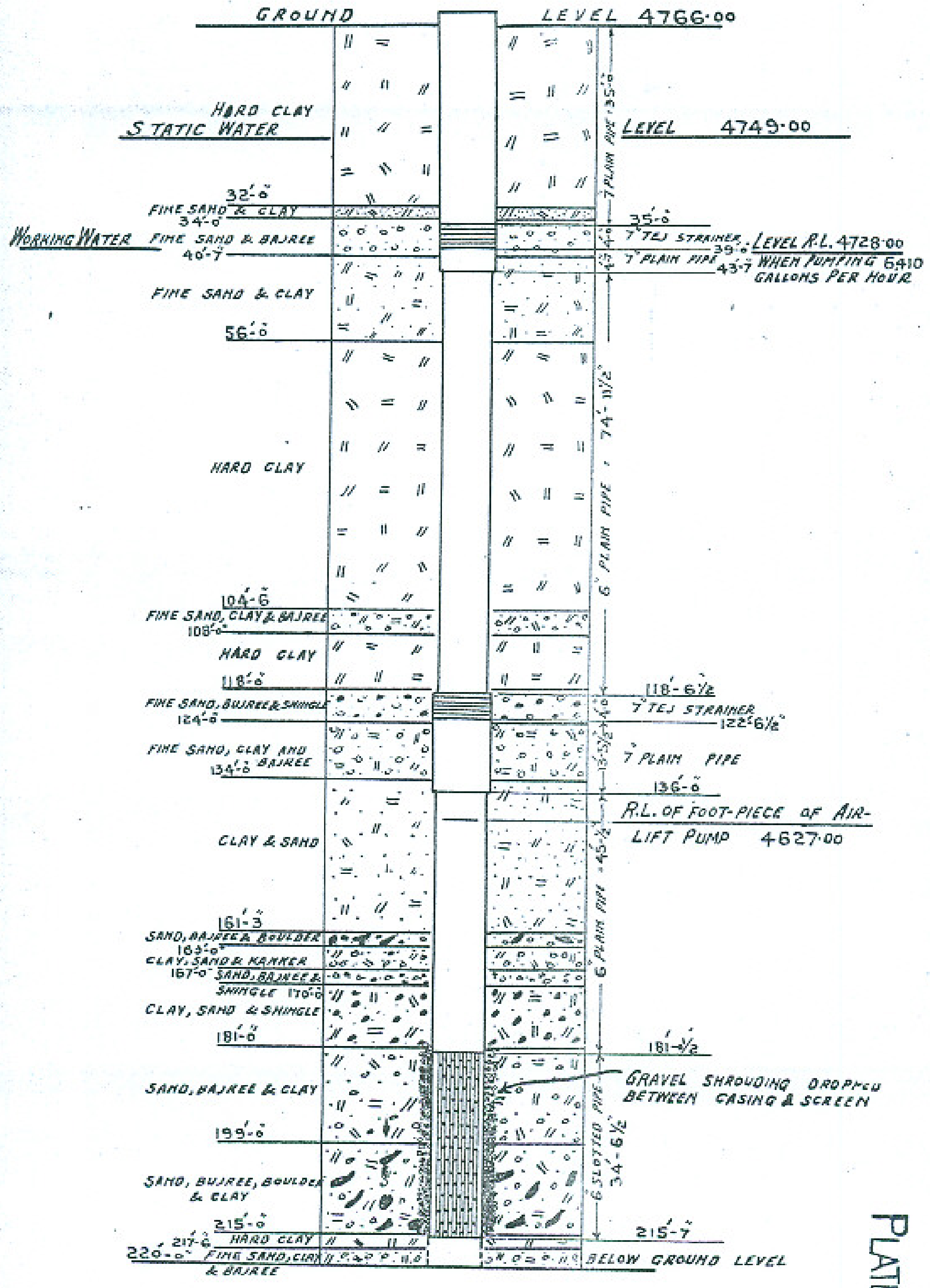
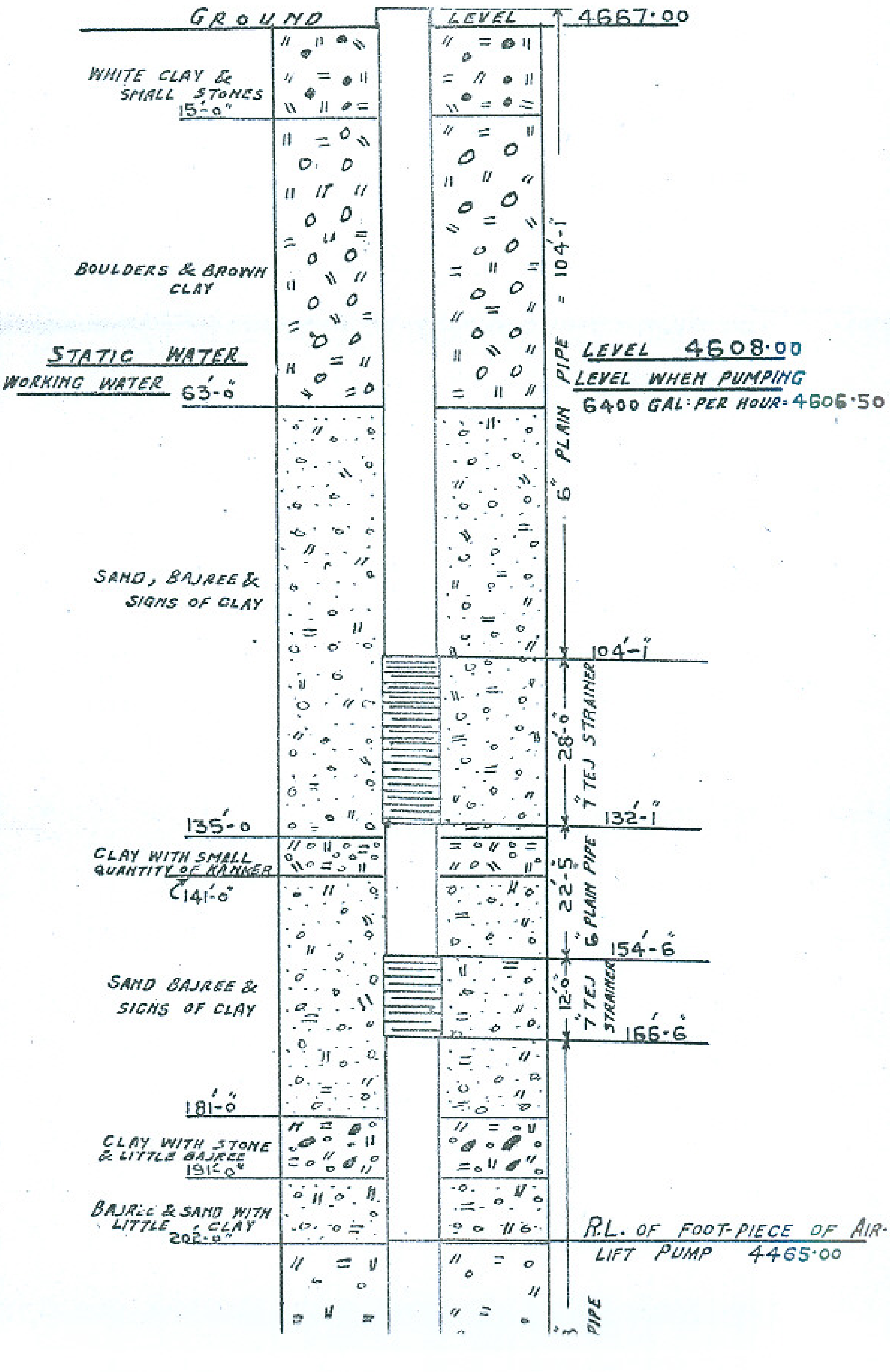
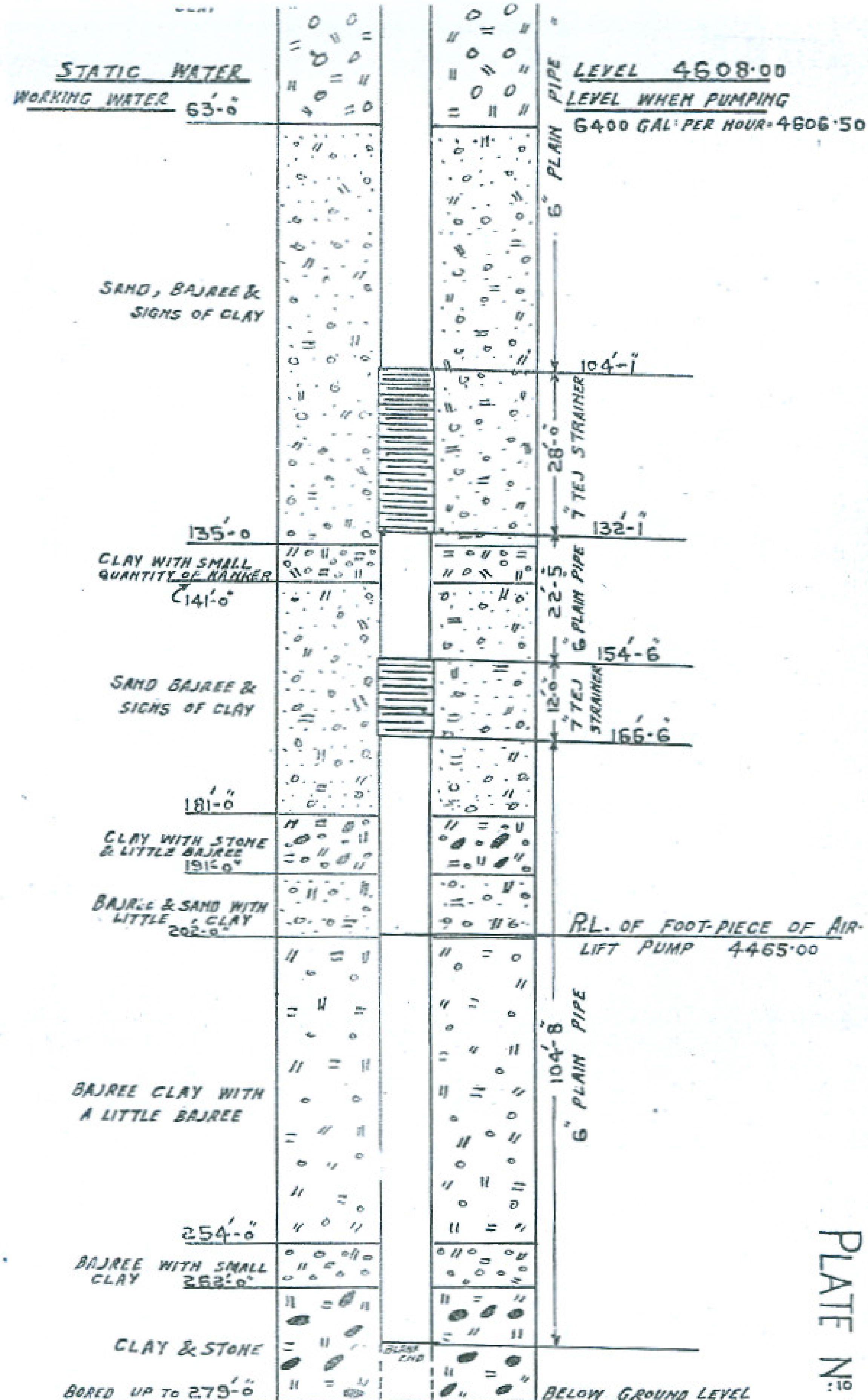



PLATE No. 6

# SECTION OF TUBE-WELL
# AT BADINZAI
# MILE 157

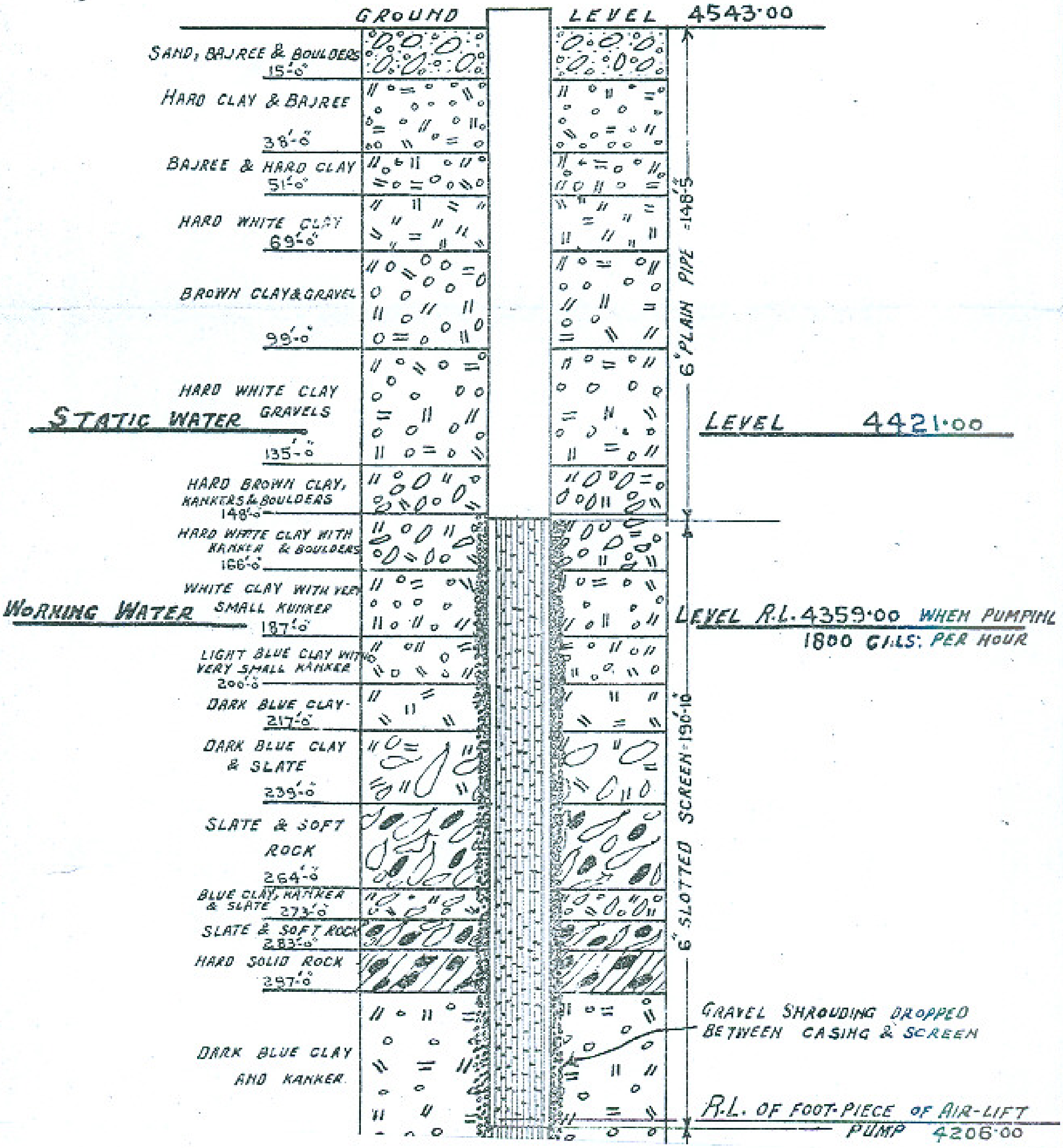


# PLATE No. 7



STATIC WATER
WORKING WATER 63'-0"
LEVEL 4608·00
LEVEL WHEN PUMPING
6400 GAL: PER HOUR-4606·50
6" PLAIN PIPE
SAND, BAJREE & SIGNS OF CLAY
104'-1"
28'-0"
7" TEJ STRAINER
132'-1"
135'-0
CLAY WITH SMALL QUANTITY OF KANKER
141'-0"
22'-5"
6" PLAIN PIPE
154'-6
SAND BAJREE & SIGNS OF CLAY
12'-0"
7" TEJ STRAINER
166'-6
181'-0"
CLAY WITH STONE & LITTLE BAJREE
191'-0"
BAJREE & SAND WITH LITTLE CLAY
202'-0"
R.L. OF FOOT-PIECE OF AIR-LIFT PUMP 4465·00
104'-8"
6" PLAIN PIPE
BAJREE CLAY WITH A LITTLE BAJREE
254'-0"
BAJREE WITH SMALL CLAY
262'-0"
CLAY & STONE
BLANK END
BORED UP TO 279'-0"
BELOW GROUND LEVEL

# SECTION OF TUBE-WELL
# AT FORT-SANDEMAN
# MILE 174



In introducing his paper, MR. VARDON observed that no attempt had been made to deal with any theoretical features of tube well engineering, as most of the Punjab engineers were familiar with them and a considerable amount of literature was available to those who desired to study them.

The author said that the paper described in some detail the conditions encountered in their efforts to obtain tube well supplies on this section of the North Western Railway, the difficulties experienced in executing the works and the methods adopted to meet these conditions and difficulties.

While comparing these installations with ones of similar capacity in the Punjab, the cost of the former was admittedly very high, for example the cost of the Tube Well installed last year at Malakwal, which supplied 28,000 gallons per hour, was 6,500 against Rs. 19,000 for the Tube Well at Fort Sandeman which yielded only 1,890 gallons per hour. This enormous difference was due to the vast difference in the strata conditions of the two stations. At Malakwal the boring was done by a hand operated outfit to a depth of 231′-0″, of which only 47′-0″ was clay, and the remaining 184′-0″ sand in which the progress was as much as 18′-0″ in a day. The complete work at Malakwal only took 8 weeks from the time the plant arrived to the date it was removed, including the time taken for the yield test.

A comparison of this with the detailed account on page 31 of the work entailed at Fort Sandeman with an Armstrong drilling machine operated on petrol, afforded sufficiently convincing reasons for the difference in cost of the wells at the two stations.

The author pointed out that the well at Shinkai was particularly interesting in that it was the only one on the North Western Railway from which a large yield was obtained from an open hole.

Mr. Vardon had planned, if the yield of this well did not come up to our requirements, to "shoot" it as oil drillers say. This method had frequently produced a large supply when the yield from the unshot open hole had been poor.

It would be observed that in the Zhob Valley the large slot screen and gravel development had to be resorted to for two out of the six wells.

The speaker remarked that in the paper presented by him to the Congress in 1930, he had drawn attention to some of these wells that had been installed on the North Western Railway, and particularly to the one at Ambala Cant. In view of the doubts expressed by some of the Members of the Congress as to the success of this well and to the probable troubles they had experienced by cavitation, Mr. Vardon believed that members would be interested to know that the well had been in regular service since 1-9-31 and was being pumped on an average of 23 hours daily.

The well when finally tested for yield on 23-9-30 gave the following results :—

Discharge 13,500 gallons per hour.

Drop 35′-0″.

The latest test made on 11-2-32, *i. e.*, after pumping about 50,000,000 gallons from it was as follows :—

Discharge 12,900 gallons per hour

Drop 33′-0″.

from which it would be seen that the well showed no signs of a diminution in yield nor had they experienced any troubles from cavitation.

The writer would draw attention to an error at the bottom of page 33. It should read Ambala Cant. H. S. Tank instead of Quetta H. S. Tank.

LT.-COL. MACRAE remarked that on the completion of the Tube Well installations on the Zhob Valley Railway he suggested to Mr. Vardon that he should write a paper on this work for the Railway Board Technical Bulletin.

On further consideration he felt that the paper should be presented to this Congress, as his previous papers on Tube Wells dealt with conditions encountered mainly in the Punjab plains, whereas this paper described the conditions encountered, and the methods adopted, in providing tube well water supplies, in country similar to the Salt Range area of this Province and to the Hilly districts of the N.-W. F. Province, where there is no regular water table as in the alluvial plains.

He believed that the paper would be useful to members of this Congress who might be called upon to provide tube wells in these parts of the country, as interesting example being the unlined bore in rock.

The author has pointed out that no definite geological information was available for the Zhob Valley, so that it was necessary to sink one or more trial borings at most of the stations before the actual well boring could be taken in hand.

Though the expenditure on these trial borings was included in the total cost, the capital cost of these tube well installations was not much higher than for similar ones in the plains.

The Armstrong drilling machine purchased for these borings, gave excellent service, and was well adapted for the work it was called upon to perform, and it is still working in Baluchistan, now on a bore to try and replace a spring supply that failed as a result of the 1931 earthquakes.

In the earlier stages of the work, trouble was experienced with parted casings due to the use of pipes that had been in service for some years on boring operations, with consequent weakening of joints. These were later replaced with new pipes and no further trouble of this nature was experienced.

Transport difficulties, and the enormous distance of the works from headquarters and from the Stores Depot were important factors in the cost of these works.

The speaker was of opinion that if tube well supplies were not provided at these stations, they would have been compelled to resort to the unsatisfactory and expensive method of using travelling water tanks on some of the sections of this Railway, as no other means of water supply could be provided at any of the six watering stations at a reasonable cost.

COL. BATTYE said that there were various kinds of strainers, Brownlie, Ashford, Cooks, etc. He would suggest the formation of a committee to tell the members the best type of strainers.

R. B. BABA NATHA SINGH pointed out that in regard to the merits of various forms of strainers, they had sunk about five tubes at Gujranwala in connection with the lowering of water level, two with Tej Strainer, one of porous type and two of the gravel developed type. He found that all of them were of equally good stuff.

MR. HOWELL said that he was speaking without notes on this subject. As a matter of fact he had no intention of speaking, but as Col. Battye raised certain questions as to which type of the strainer was the best type for tube well, he had come here to answer that question. He did not think there was any suitable type of strainer. There were various conditions. One type of strainer might suit one condition, another type of strainer might suit another condition. In one place a gravel developed tube might be suitable, in another case "Tej" type might be suitable ; while in other places the slot type of tube wells might be suitable.

The purpose for which the tube well was required determined the type of strainer. If the tube well was required for dewatering a water-logged area and also in places where there was no fear of contamination of the subsoil water, there the gravel type of strainer would suit the requirements while in the case of town water supplies where an absolute immunity from pullution was required, the slot type of strainer was suitable, and this was the type which the Public Health Department was using.

In reply MR. VARDQN said that Mr. Howell had already replied to the points raised in regard to the types of strainers. Immunity from pollution and the depth of good water bearing strata were the chief factors. At Ambala he had met only 7 ft. of porous sand while at Malakwal 142 ft. of very good coarse sand was met.

As regards the question of using explosives, care should be taken to see that pipes were not shattered.

The PRESIDENT, MR. SMITH, remarked that Col. Macrae had shown how the paper was written. Mr. Vardon had added a valuable contribution and at a time when they needed his paper which was going to be his best paper.

Col. Battye raised the question of a Committee to tell them the best type of strainers. As a matter of fact, the Government initiated a committee two years ago and but for the departure of Mr. Robertson the report would have been presented ere long.