

PAPER No. 139.
SOME INTERESTING TUBE WELLS ON THE NORTH
WESTERN RAILWAY.

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Introduction.

In a Paper presented to this Congress last year on "Locomotive and Drinking Water Supply on the North Western Railway," the writer endeavoured to emphasize the urgent need for a Provincial Ground Water Division, to advise and help the public in developing the ground water resources of the Province for agricultural and industrial purposes, and to act as a reference bureau for all the Government Departments dealing with Ground Water Supplies.

2. Such a division would naturally develop into an organization for carrying out experimental and research work in all the phases of this branch of engineering, and would be in a position to establish or refute the correctness of existing theories on the different aspects of Tube Well water supplies, as well as improve the technique of such work.

3. Some progress has been made along these lines by the Irrigation Department of the P. W. D., but outside the Departmental Circles concerned, very little is known of their activities, even to the men dealing with similar work in other Government Departments.

4. During the past few years, large sums of money have been spent by the N. W. Railway, in sinking trial bores to determine the possibilities of obtaining suitable ground water supplies from wells, where such supplies are needed for locomotive and drinking purposes.

5. These trial borings constitute experimental work in one sense only. They establish the possibility of obtaining a supply of water at the particular locality. They do not provide any information that would advance our knowledge of Tube Well engineering. The scope for experimental work of this nature is vast, but such work would require careful planning, a trained organization, and ample funds. The benefit that would be derived from such expenditure may not be available for some considerable time, and in many cases would not be of sufficient direct value to the Railway to justify us in undertaking work of this nature on even a moderate scale.

6. Where conditions warrant investigations and experimental work, for the purpose of improving existing watering arrangements and the prospects of success are reasonable, the Railway authorities have always been willing to provide funds. In some cases the experiments made have not been successful, but in others success has been very marked, and resulted in savings large enough to justify all the experimental work that has been done.

7. It is the intention of the writer briefly to describe a few wells that he considers would be of special interest to those dealing with this branch of engineering, and of general interest to all engineers.

8. It is felt that these descriptions may in some measure help others to solve similar problems when they are encountered, and may lead to improvements on the methods adopted by the Railway, with correspondingly better results, which would benefit engineers working on Tube Wells.

The wells it is proposed to describe are located at—

Laki Marwat.

Rohtak.

Campbellpur.

Lyallpur.

Umballa Cantonment.

Tube Well at Laki Marwat.

1. This well is of special interest, in that it was the first effort I know of in the Punjab, to gravel shroud a well after it had been installed.

2. Those of you who have read the Paper on "Locomotive and Drinking Water Supply on the North Western Railway" will remember the description of Air Made Gravel Wells which were observed in the U.S. A. and the efforts made to install similar wells on the North Western Railway at Rohtak and Umballa Cantonment.

3. The well at Laki Marwat was installed in 1924, a year before the formation of the Special Tube Well Division.

4. The strata drilled through was analysed by Mr. Ashford of Amritsar, and the location of the "Ashford" Screens used, was determined by him. His estimate of the probable yield from the well was 7,000 gallons per hour, with a "Drop" of 7'-0".

5. The well was tested by the Divisional Engineer with a Centrifugal Pump, and the delivery was only 1,000 gallons per hour. On this poor result it was believed that the well was a failure, and the Tube Well Division, which had just then been formed, was ordered to take over the well and withdraw the Strainers and Plain Pipes.

6. Before doing this, it was considered that a further test should be made with a more suitable pump than the Centrifugal used for the first test.

7. An Air Lift Pump was arranged, and on test an yield of 4,000 gallons per hour with a 36'-0" "Drop" was obtained, but as very large quantities of sand were being drawn through the strainers, it was feared that serious cavitation would occur, which might result in damage to the fragile "Ashford" Screen.

8. It was therefore decided to stop further pumping and endeavour to gravel shroud the Screen through two 4" pipes sunk on either side of the well.

9. This was done and pumping restarted. For the first two days the gravel in the 4" tubes did not move, but on the third day the tubes were tapped, and the gravel moved down very rapidly. The tubes were refilled as the gravel moved down and altogether 42 c. ft. were fed down in this way.

10. The yield from this well is now 6,500 gallons per hour with a "Drop" of 44'-0". The water delivered is quite free of sand and the well has been in regular use since 23rd August 1928. A sketch of the well showing the location of the strainers and gravel tubes is appended.

11. The sand from which the water is being drawn is very fine and there is an appreciable proportion of clay in it.

12. I have had reports of two wells that a contractor was compelled to abandon and withdraw because of sanding. The contractor concluded that this was the only course open to him, and attributed the trouble to his error in using a screen with too wide slots.

13. The description of the well at Laki Marwat indicates how troubles from similar sanding wells may be overcome, but it is almost essential to use an air lift pump for this purpose, as sanding causes no trouble to such a pump.

14. A somewhat remarkable feature of this well is the depth at which the shrouding was done, with the relatively small bore of gravel tubes used. This will be better appreciated by those engineers who may be called upon to deal with a similar problem. It will be found, that although large quantities of sand are being drawn through the screens, gravel does not work down the tubes to take its place, due mainly to the arching effect of the gravel in the tube. Obviously it is preferable to use the largest size of tube one can, taking into consideration the extra cost of sinking a large tube.

15. A simple calculation will show that if the gravel fed down the tubes distributed itself evenly around the 56'-0" of screen, (the gravel could not get down to the lower length of 16'-0" of screen) it would only form a shroud 3" to 4" thick, sufficient however to keep the velocity of the water outside the shrouding below the "Critical Velocity" of the sand.

Tube well at Rohtak.

1. The tube well at Rohtak was the first air made gravel well attempted on this Railway and perhaps the first of its kind in India.

2. It was installed by my Sub Divisional Officer during my absence on leave, in accordance with a written description of the procedure to be adopted, sent out by me after studying the methods in the U. S. A. An account of it is to be found in the Paper presented to the Congress last year,

3. At that time the permanent pumping plant for this well had not been provided. Development was completed, and the yield test showed that 5,000 gallons per hour could be obtained from it with a drop of 20'-0".

4. The 6'-0" length of screen used was made up in the Railway Shops from an ordinary 6" pipe, in which were milled 75 longitudinal slots each $4" \times \frac{3}{8}"$. The yield per square foot of screen used, works out at 550 gallons per hour.

5. The air lift *cum* centrifugal plant provided for this well was erected and was due to be tested on 25th April 1929.

6. After a short run the plant was shut down, and when restarted, it was found that sand had blown in and filled the well from the bottom, located at 214'-0" below ground level, to the top of the screen at 74'-0" below ground level, "freezing" the Air and Eduction Pipes in the well.

7. This came as a shock to us, and appeared to be a very serious set back for this type of well. As the permanent pumping plant had been supplied, something had to be done to provide a well from which this plant could pump water.

8. It was immediately decided to resort to the Laki Marwat method, which proved so successful there. The Air and Eduction pipes were jacked out, and the well cleaned with an ordinary "Sludger." Six gravel tubes of 6" bore were sunk around the well to the top of the screen, as shown in the diagram appended. They were filled with gravel to a depth of 8'-0". The cost of doing all this work amounted to about Rs. 300.

9. The Air and Eduction pipes were again lowered into the well, and pumping restarted. No gravel moved down the well although a considerable quantity of sand was pumped out. Arching of the gravel in the tubes was believed to be the cause of this, and it was decided to sludge out the gravel, clean the tubes and refill them to the top.

10. During the process of sludging it was found that sand had worked up into the gravel tubes, and formed, with the gravel, a semi-solid mass, which blocked the end of the tube and prevented the gravel moving down.

11. Before refilling the tubes with gravel, the sand was cleaned out to a depth of 3" to 6" below the bottom of the tubes, to ensure an open clear outlet for the gravel, which was then filled to the top of the tubes, and pumping restarted.

12. As sand was pumped out, gravel moved down the tubes, and this continued till 55 c. ft. had been fed down as a result of about 80 hours' pumping.

13. Sanding has almost completely ceased, except when the well is "Back Blown" when a very small quantity is drawn into the well and pumped out. This sanding lasts for about ten minutes only, after that the water is again quite clear.

14. When the well was installed in 1928, during development 50 c. ft. of gravel was fed around the Screen, which with the 55 c. ft. added in May last, makes a total of 105 c. ft.

15. If this quantity has distributed itself uniformly around the 6'-0" length of 6" screen, there ought to be a 2'-0" ring of shrouding, and I am inclined to believe that this thickness of shrouding does in fact exist around the screen now, as the extremely fine sand in which the screen is located would have to be some distance from it, for the velocity of the water flowing through it to be below the "Critical Velocity."

16. It was not possible for me to verify this by actual boring, as the pucca "Collecting Sump" had been built around the well, and we had nearly exhausted the funds allotted for this work.

17. When an opportunity occurs to verify the calculated thickness of a well shrouding, by boring, this will be done and the results communicated to any of you who may be interested. It may be that similar experiments will be made by other engineers of the Punjab. I am sure several of us here would be obliged if the results obtained could be published or communicated to us individually.

Tube Well at Campbellpur.

1. The first attempt to replace the existing Railway Water Supply from a 20'-0" dia. open well, by a tube well, was made in April 1925.

2. The boring was sunk with a hand outfit, using 13" casing pipes. These could not be sunk below 150'-0" owing to a layer of large boulders struck at this level.

3. A tube well with 10" Ashford Strainers was lowered into the boring, and the well tested for yield with an Air Lift Pump.

4. With the Static Water Level at 75'-0" below Ground Level, a "Starting Submergence" of less than 50% was available, which was just sufficient for test purposes. The "Drop," however, was much greater than was anticipated and the small discharge of 4,000 gallons per hour was the most that could be obtained from the available "Working Submergence." Various means were adopted to try and increase the yield by pumping to a bigger "Drop," but owing to the shallow depth of the well this could not be done.

5. It was therefore decided to abandon the well, withdraw the Strainers, and do a fresh boring deep enough to give the required submergence, for a big "Drop." This could only be done with a Power Drilling Machine.

6. In May 1928 a "Star" Drilling Machine was available, and was sent to do this boring, which was carried down to a depth of 280'-0", through various beds of large boulders known to Drillers as "Nigger Heads." Such formations are perhaps the most difficult to get through with a straight hole. We were fortunate, however in having an expert oil driller who managed to get down with a straight hole to the depth required, in remarkably quick time.

7. The diagram appended shows the strata drilled through, location of screen and the probable distribution of the gravel shrouding. The

strata in which the screen is placed was considered the most promising, as it was composed of large boulders and coarse sand. The screen was the same type as that used at Rohtak.

8. It was considered that gravel development from the surface would not be necessary, as, when pumping, the sand would be drawn through the $4" \times \frac{3}{8}"$ slots, and the smaller boulders would gradually pack around the screen, eventually keeping the sand out. Apparently the boulders and gravel in their natural setting, were so packed as to allow of the sand being drawn out and up, when the well was pumped, but the smaller gravel did not move and shroud the screen, with the result that the cylindrical gap, left around the screen when the casing was drawn, allowed the sand in the strata above the screen, as far up as the red clay at 115'-0" to move down and through the screen.

9. After several hours pumping it was decided to plumb down along the outside of the well. The plumbob stopped at 100'-0", showing that a clear opening existed around the well down to this depth, and perhaps deeper. The discharge from the well had by this time increased from 5,000 to 12,300 gallons per hour, but the sanding continued, and the water contained very distinct traces of clay.

10. As the casing pipes had been completely drawn, it was not possible to feed down gravel between the casing and the screen. The methods used at Laki Marwat and Rohtak suggested themselves, but were not adopted, as previous experience had proved that it was going to be a long and expensive job to sink tubes through the boulders down to the depth required *viz.*, 150'-0". In fact it was most unlikely that gravel tubes of 4", 6" or even 8" could be got down to this level, even if the boring was done with a drilling machine.

11. It was therefore decided to try the effect of feeding gravel down the gap around the tube well. This was done and in five hours the 300 c. ft., of gravel, which was available at the site, had all been used, and in plumbing down again the plumbob stopped at 80'-0".

12. It is impossible to suggest how this quantity of gravel has distributed itself around the tube well. The fact remains that the sanding had ceased, although small quantities could still be drawn up when the well was "Back Blown." If it is assumed that a clear gap existed from the bottom of the well to the top, and that this 300 c. ft., of gravel distributed itself evenly around the well from 280'-0" to 80'-0", the depth of the shrouding would be about $4\frac{1}{2}"$. It is unlikely that the gap left when the casing was drawn, remained open below the screen from 170'-0" to 280'-0" during the time the pumping was done, and at the time the gravel was fed down. It is probable that the 300 c. ft. of gravel distributed itself from about 170'-0" to 80'-0" which would mean a 8" ring around the well, between these levels.

13. Before completing this work some more gravel was obtained and fed around the well up to ground level, as it is possible when the well has been put into service, that as a result of continuous pumping, this gravel will work down towards the screen.

Tube Well at Lyallpur.

1. This well has an entirely different feature of interest, from that of the other wells described. It appears to have established the fact that the quality of water supplied from a tube well, located in heavily irrigated country, tends to improve in quality, when pumped regularly for some months. This improvement would only be likely to occur if the yield of the well was relatively large, and the well was pumped for several hours a day.

2. Prior to the installation of the Tube Well at Lyallpur, the Railway obtained its supply of water for Locomotive and drinking purposes from irrigation canals. The drinking water was passed through a "Jewell" filter.

3. In October 1926 a boring was put down in the Station Yard with a view to substituting a Tube Well supply for the Canal supply.

4. As work progressed samples of water were taken at 110'-0", 159'-0", 210'-0" and 258'-0" below Ground Level, and sent for analysis to the Chemical Examiner to the Punjab Government, as to their suitability for Locomotive and drinking purposes.

5. The analysis showed that the quality of the water down to the 210'-0" level is more or less uniform, whereas below this level the quality rapidly deteriorates.

6. It was therefore concluded that it would be possible to obtain suitable and ample water, from the water yielding strata, by keeping the bottom of the Screen above the 210'-0" level and this was done by installing 120'-0" of "Ashford" Screen, between 86'-0" and 206'-0". The yield test of the completed well was carried out on 11th to 13th March 1927.

7. During the test another sample of water was taken and the following report was received from the Chemical Examiner:—

Results of Analysis Expressed in Parts per 100,000.

Water sample test.		Sample taken on 13th March 1927, during the test. "A".
Reaction	..	Alkaline.
Free Carbonic Acid	..	Slight.
Chlorides (as NaCl)	..	5.85 parts per 100,000.
Nitrates	..	Nil.
Nitrites	..	Nil.
Sulphuretted Hydrogen	..	Nil.
Lime	..	Slight.
Iron	..	Traces.
Sulphates	..	Moderate.
Total solids	..	100 parts per 100,000.
Hardness Clark's Scale	{ Total Hardness	3.5 Clark's
	{ Temporary	3 "
	{ Permanent	.5 "
Oxidisable matter	..	..
Free Ammonia	..	.006 parts per 100,000.
Albuminoid ammonia	..	.004 parts per 100,000.
Opinion:—	..	Fit for drinking and Loco. use.

This analysis agreed fairly closely with the average of the analyses of samples taken during the boring. For purposes of ready comparison I have selected the more important heads.

	Na Cl.	Total Solids.	Total Hardness.	Temporary Hardness.	Permanent Hardness.
Sample at 110'	11.7	90	6	3.5	2.5
Sample at 159'	6.7	50	4.5	3	1.5
Sample at 210'	7.5	110	7	5	2
Total ..	25.7	250	17.5	11.5	6
Average ..	8.5	83	5.8	3.8	2
Sample during Test "A" ..	5.85	100	3.5	3	.5

8. As this report was satisfactory an Air Lift Cum Centrifugal Pumping Plant capable of delivering 25,000 gallons per hour was ordered for the well.

9. For various reasons the plant was not erected till July 1928, and tested on the 7th August 1928. During the test another sample of water was taken and sent for analysis. It will be noted that this sample was taken 17 months after the last, when the yield test of the well was carried out. All this time the well had been idle and the top covered and sealed.

10. The sample taken was sent to the Metallurgist, who had recently been appointed to this Railway, and one of whose duties is to analyse samples of water as to their chemical suitability for Locomotive and drinking purposes.

The following is the report of his analysis :—

**" B " REPORT ON THE SAMPLE OF WATER TAKEN
ON 7TH AUGUST 1928.**

	Parts per 100,000.
Chlorides (Cl)	4.4
Sulphates (SO ₃)	6.4
Carbonates (CO ₂)	21.5
Nitrates (N ₂ O ₅)	Traces.
Lime (CaO)	2.9
Magnesia (MgO)	.5
Soda (Na ₂ O) plus other minor constituents, not determined ..	31.9
Total Soluble Minerals ..	67.6

Report :—

This works out approximately :—

Magnesium Carbonate	..	..	1.0
Calcium Carbonate	..	..	5.2
Calcium Sulphate	..	..	Nil
Sodium Carbonate	..	..	45.0
Sodium Sulphate	..	..	11.3
Sodium Chloride	..	..	7.3

Remarks :—

"Is a very alkaline water, and will be found to be highly corrosive to boilers. There is also some tendency to prime. I do not recommend this water if other is available."

11. This adverse report caused considerable disappointment as every precaution has been taken to ensure that the supply from the well would be suitable, by having a sufficient number of samples of the water taken during the progress of the boring, and during the yield test, before ordering the permanent plant.

12. On a careful comparison of the analysis of samples "A" and "B" the former by the Chemical Examiner to the Punjab Government, and the latter by the North Western Railway Metallurgist, which are tabulated rather differently, it will be observed, that the Total Solids in sample "B" was lower than in sample "A", but the injurious constituent as reported in sample "B" was the high Sodium Carbonate content. This was not brought out in the Chemical Examiner's Report on sample "A."

13. What appeared to be a confirmation of the unsuitability of this water was brought to notice by the Divisional Superintendent in a report that drivers maintained that the Lyallpur Tube Well water was bad for their boilers.

14. Drivers are not in a position to state why any particular water is bad, but are able to appreciate the difference in the steaming results, after they have watered at a certain station, so that when persistent reports are received from them by Operating Officers that the water at a station is bad, investigations are started to establish the cause for these complaints.

15. It was found that the steaming troubles complained of were due to priming, caused by the mixture of Tube Well water from Lyallpur and canal water supplied from Gojra and Sangla Hill the next watering stations on either side of Lyallpur.

16. By actual test it was proved to the satisfaction of the Operating Officers, that the quality of the Lyallpur water was in no way responsible for the steaming troubles complained of by drivers, but there remained the question of corrosion, of which the drivers could know nothing, and which would only be noticed by the Boiler Inspectors, on careful examination. The question to be decided was—should the Tube Well water be used for the period that would be required to develop corrosive action?

17. Reports received by the Divisional Officers, none of which appeared to be definitely established, led them to believe that the water from tube wells that had been installed in the past in and around Lyallpur, steadily deteriorated, and in course of time the wells had to be abandoned for this reason.

18. From a common sense point of view these reports seemed to be directly contrary to what one might expect. For over 30 years Lyallpur has been heavily irrigated with sweet water from the rivers, which undoubtedly are the main source of supply of the subsoil water.

19. From the section of the boring a copy of which is appended it will be seen that the strata below the Static Water Level, at 59'-0", to the depth bored, are all sands and gravels, which permit of a free flow of subsoil water. I see no reason for believing that there are appreciable variations in the strata for some miles around our Railway Tube Well. If this is so, one would conclude that if we pumped our well to 25,000 gallons per hour 12 hours a day, for some months, the tendency must be to wash out the Chemical Constituents of the subsoil by the induced flow of sweet water from the canals.

20. The points at which this sweet water is actually fed into the subsoil, to take the place of the chemically laden water, obviously cannot be defined, but it can be assumed that they are in the vicinity of the well. Although the quantity of water pumped out in a day is very small as compared to the storage capacity of the subsoil reservoir of water, a flow does in fact take place, which can only tend to sweeten the water, as replenishment is only taking place with sweet water.

21. It was therefore decided to keep this well in use, and every quarter, take a sample of water for analysis by our Metallurgist, to observe the changes in quality, if any, that were taking place.

22. Unfortunately, early in October 28, only two months after the plant had been in operation, trouble was experienced with the foundations of the engine, and the installation was shut down. It was not brought into use again till the middle of April 29, and 3 months later, on 22nd July 1929, another sample was sent for analysis. A further sample "C" was taken 3 months later, on 14th October 1929. The sample taken on 22nd July 1929 differed slightly from that taken on 7th August 1928.

23. The table below gives the details of the analysis of the sample "C" taken on 14th October 1929 as compared with "B," the analysis of the sample taken on 7th August 1928, the differences being shown as plus or minus in the adjoining columns :—

Lyallpur Water Test.	Samples taken on 7-8-28.	Samples taken on 14-10-29.	Changes as compared with "B."
	"B".	"C".	
Chlorides ..	4.4	2.8	- 1.6
Carbonates ..	21.5	7.9	-13.6
Sulphates ..	6.4	4.6	-1.8
Nitrates ..	traces.	traces.	
Lime ..	2.9	3.4	+ .5
Magnesia ..	.5	2.0	+1.5
Soda ..	31.9	10.9	-21.0
Silica ..	..	.4	+ .4
Iron Oxide & Alumina ..	..	.1	+ .1
Total Soluble Minerals ..	67.6	32.1	-35.5
This works out (approximately) ..	..	..	..
Calcium Carbonate ..	5.2	6.1	+ .9
Calcium Sulphate ..	Nil.	..	..
Magnesium Carbonate ..	1.0	4.2	+3.2
Magnesium Sulphate ..	..	..	..
Sodium Nitrate ..	..	..	..
Sodium Carbonate ..	45.0	7.2	-37.8
Sodium Sulphate ..	11.3	8.2	-3.1
Sodium Chloride ..	7.3	4.7	-2.6
Silica etc. ..	..	.5	+ .5
Remarks :— .. It is very alkaline water and will be found to be highly corrosive to boilers. There is also some tendency to prime. I do not recommend this water if other is available.			
		Quite good. Probably safe to drink.	

24. From the comparative statement of the analysis of the samples taken from this well, there is sufficient evidence to believe that the quality of the water has improved, during the 6 months the well had been in regular use when sample "C" was taken.

25. The average pumping hours per day is only $6\frac{1}{2}$, which gives a total of 18,000,000 gallons, roughly 1,000 cusecs pumped from the well.

26. We shall continue to take further samples for analysis, every quarter, for the next year or two, and will be glad to forward the results to anyone interested in the subject.

27. I would like to point out that these analyses are done with the greatest care by the North Western Railway Metallurgist who is an authority on Boiler Feed Waters and is keenly interested in the quality of water supplied for our Locomotive Boilers. These analyses therefore can be taken as correct, but we have yet to establish that this improvement is not merely seasonal.

28. The last sample "C" was taken just after the rainy season, which was exceptionally heavy this year, and it is just possible that this may have influenced the quality of the water at the time.

29. The next two samples which will be taken in January and April should prove this.

Tube Well at Umballa Cantonment.

1. By far the most interesting and successful of the Gravel Developed Wells that have been installed on the N. W. Railway are two that have recently been completed at Umballa Cantonment.

2. Troubles, due to the inadequate supply of water at this station, have been experienced, I should think, for over 30 years.

3. I am informed that the N. W. Railway have since 1913 tried to increase the water-supply at Umballa by the use of Tube Wells. Prior to this date, whenever the shortage became acute, one more large open well was sunk, with the result that to-day we have a battery of five open wells near the Tangri River. In one of these, two tube wells have been installed, but there are no records to show when this was done.

4. Apparently the D. U. K. Railway experienced similar troubles with their water-supply at Umballa, and resorted to the same methods to tide them over their difficulties, for they have a battery of three open wells, also near the Tangri River. In one of these wells a tube well has been sunk.

Since the D. U. K. now belongs to the N. W. Railway, we have taken over their watering arrangements, so that we now possess at Umballa :—

1—25'-0" dia. open well.

1—25'-0" dia. open well.

2—16'-0" dia. open well.

4—12'-0" dia. open well.

These wells can only provide 12,250 gallons of water an hour, which is insufficient for our present requirements.

5. A brief account of the efforts made by other authorities to deal with the problem of a ground water-supply at Umballa, will not be out of place, as it is due to the geological conditions in this area that led to the experiments being made with Gravel Developed Wells, which, so far as can be gauged at present, promise to be entirely successful.

6. The peculiar difficulties of obtaining a ground water-supply at Umballa Cantonment are dealt with in a Report on "The Water-supply of Umballa City and Umballa Cantonment" by Mr. D. A. Howell, A. M. I. C. E., Executive Sanitary Engineer, Public Works Department, Punjab. Extracts from this report are quoted to indicate the reasons ascribed for the difficulties experienced, and the methods adopted to cope with them.

"The present Umballa City Water-supply Scheme from wells at Handesra was carried out about 1895, and was designed to yield a supply of 240,000 gallons per diem. The yield has now dropped to about 80,000 to 90,000 gallons of water per diem, probably due to clogging of the sandy strata round the well bottoms by clay particles carried and deposited by the infiltration of water into the wells. It should be noted that the decrease of yield of water above described has taken place in spite of the fact that a considerable expenditure on remedial works, such as lowering pumping plant, increasing the number of wells, putting down tube wells and strainers in the beds of the wells, cleaning out wells, etc., has been carried out from time to time during the last 30 years.

"In 1921 about Rs. 66,000 was spent by Government in putting down a tube well fitted with a vertical and horizontal strainer, and a subsidiary pumping station, at Sarangpur, in Patiala State, on the banks of the Tangri Nallah, in order to pump additional water to Handesra. This has proved more or less a failure, as the yield which was about 4,000 gallons per hour in the first instance dwindled within 12 months of starting pumping operations to less than 1,000 gallons per hour at a depression head of 10 feet. In 1923 an experimental well 40 feet internal diameter was completed at Sarangpur at a cost of about Rs. 35,000. The bed of the well is in good sandy strata and on being tested gave a yield of nearly 5,000 gallons per hour at a depression head of four feet. This well is now being pumped under careful observation, but already there are indications of a fall in yield. Sufficient time has not yet elapsed to enable a final decision to be reached as to whether by carefully controlling the rate of pumping from this well the rate of infiltration of water into the well can be so reduced as to prevent clay particles from being carried and deposited around the base of the well, causing it to choke."

"**Umballa Cantonments supply.**—This supply has gone through similar vicissitudes. The original supply from wells at Khera, a place on the Tangri Nallah adjacent to Handesra, the headworks of the City supply, is still in operation, but it has had to be supplemented by another independent scheme from wells at Bibyal, also on the Tangri, but about eight miles downstream from Khera.

"The Bibyal wells have been gradually decreasing in yield due to 'choking' effect, and additional wells have been sunk from time to time; the last, sunk in 1923, being two in number, each about 30 feet diameter, and now ready to be pumped. The present systems for Umballa Cantonments are quite inadequate to provide a proper water-supply for the Cantonments."

7. Mr. Howell refers to the deep boring which the Military Works were sinking, and which at the time his report was written had only reached a depth of 250'-0".

8. He also refers to a hand boring sunk in 1869-72 to a depth of 701'-0", which passed through bands of fine sands and clays, and states that up to the depth bored by the Military Works, the strata passed through corresponds generally with those met in the 701'-0" boring. Quoting him again, "the belts of sand, although no doubt containing a good deal of water, are incapable of yielding much water by any known practicable means of extraction."

9. This statement sums up the crucial problem of the ground water-supply at Umballa Cantonment. Water does exist in the belts of water bearing strata. The question is, how is this water to be recovered. To my mind the only way is by the Air Made Gravel Well.

10. This solution only applies to relatively shallow wells, by which I mean, to wells located in the beds of water bearing sands which are encountered to a depth of about 250'-0", for two reasons:—

(a) Gravel development at depths below 250'-0" is expensive and rather uncertain.

(b) At depths below 250'-0" and up to 600'-0", at Umballa Cantonment, there are sufficient beds of coarse sands and gravels to obtain a large yield, (up to 40,000 gallons per hour) with the ordinary fine slot screen as generally used in the Punjab.

11. Looking at the sections of the 701'-0" boring, referred to by Mr. Howell, and the 1,600'-0" boring sunk by the Military Works, it will be seen that the beds of sand and gravel encountered in these borings below 240'-0" are as follows:—

701'-0" BORING.

278-302 = 24'-0"	Sand with clay pebbles boulders.
335-376 = 41'-0"	Sand with some clay and kunkar.
394-424 = 30'-0"	Sand with some gravel, large stones and kunkars.
515-546 = 31'-0"	Coarse sand.
585-601 = 16'-0"	Sand fine with boulders.

142'-0"

M. W. S. BORING 1,600'-0".

240-0—270-0 = 30'-0"	Sand.
280-0—312-0 = 32'-0"	Gravel sand and boulders.
333-0—345-0 = 15'-0"	Sand.
386-0—395-0 = 9'-0"	Sand.
445-0—465-0 = 20'-0"	Gravel and boulders.
480-0—498-0 = 18'-0"	Sand.
528-0—603-0 = 75'-0"	Coarse sand.
199'-0"	

In the former boring it would have been possible to instal 138'-0" of strainers, and in the latter 188'-0".

12. I have not heard definitely why the Military Works did not make use of these beds of water yielding sands, as they could easily have obtained an yield of 40,000 gallons per hour, (1,000,000 gallons per day for 24 hours pumping) with a "Drop" of about 20'-0". This allows for an yield of 85 gallons per l. ft. of strainer, which is by no means the limiting yield of a fine slot strainer.

13. I was informed that the Engineers were expecting an Artesian Supply, and therefore discarded these beds of water bearing sands, and continued the boring down to 1,600'-0" in the hope of striking such a supply, which they did not.

14. Apparently Mr. Howell's conviction that a ground water-supply either from Open Wells for Tube Wells, in the vicinity of Umballa, could not be relied on to provide and maintain the yield required, decided him in carrying out investigations further afield.

15. These investigations led him to discover a plentiful supply of good water, between Ghaggar and Chandigarh stations on the D. U. K. Railway, and he worked out a scheme for a supply from this area, which could be made large enough to provide the requirements of Umballa City, Umballa Cantonments and the Railway.

16. As the Railway were experiencing acute difficulties with their water-supply at Umballa Cantonments, and could not find a solution to them, they suggested participating in this scheme, provided the Punjab Government could guarantee that the other parties, *viz.*, the Umballa City Municipality and the Umballa Cantonment Board, would also agree to join within a specified period. The Military Department declined to consider the proposal, as their deep boring was still in progress, and they hoped to meet their needs from this source.

17. The Railway would have preferred to have their own independent supply, under their direct control, as their past experience of Joint

Water Supply schemes has proved that they have not been entirely satisfactory from the Railway point of view. As they were not able to arrange this, and needed additional water urgently, they had to fall back on this scheme which seemed to offer a solution to this difficult problem.

18. Early in 1926 the Railway started independent investigations in the Ghaggar-Chandigarh area, and the conclusions they arrived at agreed closely with those on which Mr. Howell's scheme were based. An agreement would have been concluded with the Punjab Government at the end of 1928, for the Railway to share in the Joint Scheme, but for the fact that the situation had altered considerably on the Railway.

19. During the period (1926-28) the investigations and negotiations for this Joint Scheme were in progress, improvements had been effected in operating methods on the Railway, with the aid of the powerful locomotives that had been provided. These methods permit of the elimination of a number of engine changing stations, and concentrating on a few large sheds, with the result that Umballa Cantonment will very soon not have the large number of engines based there, that it now has, and consequently will require much less water. However, something had to be done quickly and inexpensively to provide the immediate needs of the station till these changes had been made.

20. The Gravel Developed Well at Rohtak had just been completed successfully and it was decided to try a similar well at Umballa Cantonment. This proved a complete failure, and I have since come to the conclusion that the reason for this failure was due to the very small clearance between the casing pipes and tube well pipes, which was insufficient to allow of the free downward movement of the gravel to take the place of the sand pumped out. Similar troubles were experienced with the first Gravel Developed Well we put down for the Irrigation Department in Gujranwala in March last. In both these cases the gravel fed down between the casing pipes and the tube well pipes, wedged between these pipes, and prevented the casing being drawn without lifting the tube well with it. Trouble from this cause was feared, but as larger pipes than 15" bore were not in stock, nor procurable in the country, we had no option but to try them out.

21. For Air Developed Wells in the U. S. A. 30" and 24" casing is used for 12" and 10" wells, which gives a nett clearance of 8" to 6" for the gravel to move down. In our wells we were using 15" casing for 10" and 6" wells, which left a clearance of from 1½" to 3½".

22. In our second effort at Gujranwala we were more fortunate and succeeded in putting down an Air Developed Gravel Well at a cost of Rs. 1,400 which gave a delivery of one cusec with a "Drop" of only seven feet. The well had 10 feet of large slot screen of 6" bore. The yield works out at 1,500 gallons per hour per square foot of screen, which I believe is a record for a Tube Well in the Punjab, for a "Drop" of 7'-0" only. The amount of gravel shrouding placed around the well was 272 c.ft. and the quantity of sand pumped out was 1,000 c.ft.

23. Encouraged by this success, orders were issued to make another attempt at a Gravel Developed Well, and an estimate for Rs. 11,000 was sanctioned for this work.

24. Before starting the Gravel Well, it was decided to establish the water yielding capacity of the strata, and with this in view, a "Pilot" Tube Well with 16'-0" of 10" "Ashford" Screen was installed between 38'-0" and 54'-0", in the only layer of sand available up to 145'-6", the depth bored. The well was tested for yield for 24 hours and delivered 3,110 gallons per hour with a Drop of 19'-9".

25. This result indicated that water was available in the stratum, and that it was being replenished as fast as it was being drawn out, as the "Drop" remained steady at 19'-9" for more than 23 out of the 24 hours test. It was therefore decided to proceed with a Gravel Developed Well located 36'-0" from the "Pilot" well. The well was sunk to a depth of 130'-0" to provide the required "Submergence" for an Air Lift Pump. The strata drilled through were similar to that in the "Pilot" well. A length of 6'-0" of 10" bore, large slot screen, was lowered and placed between 46'-0" and 52'-0". The casing pipes used were 13" bore, allowing a nett clearance of about 1½" between the well and the casing. This small clearance ruled out the American method of feeding down gravel between the casing and well pipes, and the only other way to attempt gravel development was by means of tubes sunk around the well.

26. The question to be decided was, the number, size and spacing of these tubes, bearing in mind that the further away from the well the gravel development extended, the larger the yield one might expect. After due consideration, it was decided to sink six tubes of 8" bore, spaced equally around the well on a circle with a 7'-0" radius and three tubes of 8" bore with a 1'-6" radius. All the tubes were sunk to the level of the top of the screen and filled with gravel. Development was started and the discharge steadily increased, whilst the screen was being exposed from about 1,500 gallons per hour to 9,070 gallons per hour when the whole length of screen was exposed. Development was however continued for some days after, and the well frequently "Back Blown." The yield steadily increased till it reached 11,170 gallons per hour with a "Drop" of 20'-0", at which level the "Drop" and yield remained stationary. The yield works out at 740 gallons per s. ft. per hour which is much lower than the record at Gujranwala, and the "Drop" is nearly three times that at Gujranwala. This result was considered satisfactory when the difference in the grade of sand at the two places is considered. Besides, at Gujranwala one is dealing with waterlogged country, at Umballa the water though present, has to be coaxed out of the ground.

27. This well showed that outside development was a suitable way of getting over the difficulty with small casing pipes and in sufficient

clearance, and as far as India is concerned, is, I believe, a cheaper and more practicable method, as large casing pipes would require machine drilling, with the consequent heavy outlay in plant and machinery. With small casing, hand boring sets can be used, the cost of sinking the casing is less, and for the shallow wells which will normally be developed in the Punjab, the cost of sinking the additional gravel tubes is small. Those sunk at Umballa Cantonment took two days each and cost Rs. 198 to sink the nine that were used.

28. As there was sufficient money saved from the sanctioned estimate of Rs. 11,000 a second Gravel Developed well was sunk 158'-0" from the "Pilot" well and 168'-0" from No. 2.

29. The same length and size of screen was used, and the strata drilled through differed only slightly from the other two wells. The only change made was in the location of the gravel tubes. In No. 2 well it was found that the majority of the gravel that moved down to the screen was from the tubes placed at a 1'-6" radius from the well. It was therefore considered that if all the nine tubes were placed at a radius of 3'-6" from the centre of the well, a more uniform development and a greater width of shrouding would be obtained, which should result in a better yield.

30. In this we were entirely mistaken, as was found when the screen was exposed for a few inches, and pumping for the development started. Enormous quantities of sand were pumped out but no gravel worked down the tubes, with the result that in half an hour serious cavitation occurred, almost completely blocking the screen with the clay and ashes which had fallen in from above. Pumping was stopped and we appeared to be faced with a complete failure. The cause of the trouble was quite apparent, and was due to the gravel tubes being located too far from the well for the initial stages of development. Instead of the sand moving towards the slots in the screen at an angle, as we believed it would, and so allow of the gravel in the tubes, 3'-6" away, being drawn down and around the screen, the sand pumped out apparently left a 2'-6" cylindrical gap all around the screen into which the upper strata of clay and ashes fell.

31. The only way that suggested itself to save this well was to sink four large gravel tubes as near as possible to the well and down to the bottom of the screen, fill them with gravel and withdraw them to the top of the screen. This would clear some of the clay and ashes blocking the screen, and provide four porous cylinders through which water could flow into the well. Once this flow was again established, we were confident of being able to wash the clay and ashes out and replacing them with gravel. To do this four tubes of 13" bore were sunk around the well and 6" from it, and after filling them with gravel and withdrawing them to the level of the top of the screen pumping was restarted. The results obtained were as anticipated. The clay and ashes were washed out and gravel moved down

the tubes to replace them. By frequent "Back Blowing" and pumping for about 240 hours the well now delivers 9,070 gallons per hour of clear water practically free of all traces of sand, with a "Drop" of 24'-3". This is not as good as well No. 2 but when one considers that as a result of the serious cavitation, the screen was completely choked at one time, the result must be considered as satisfactory, particularly as the "Drop" is steadily getting less for the same discharge, which indicates that fresh channels for the flow of water are being gradually cleared. In a month the "Drop" has decreased from 30'-0" to 24'-3". A statement is appended which gives all the details connected with the "Pilot" Well and Gravel Developed Wells Nos. 2 and 3.

32. The points which it is desired to emphasize are:—

- (a) The low cost of a Gravel Developed Well as compared with the fine slot tube well of equal yield and "Drop." The cost of the well at Kurkhetra installed in October 28 with fine slot "Tej" Screen was Rs. 5,800 against Rs. 3,500 for Well No. 2.
- (b) The scope of the Gravel Well. These can be used in shallow beds of sand where the fine slot screen would be of little or no use. In the case of Umballa Cantonment 16'-0" of Ashford Screen yielded 3,110 gallons per hour with a "Drop" of 19'-9" against 11,170 gallons per hour with a "Drop" of 20'-0" from Gravel No. 2 located 36'-0" from the Ashford Well.
- (c) The troubles encountered with clotting of screen opening is not likely to be experienced with the wide slot screen, as the width of these openings are about $\frac{400}{1,000}$ against $\frac{12}{1,000}$ for the "Ashford" and "Tej" Screens.
- (d) The "Drop" in a Gravel Developed Well is far less likely to increase than in a fine slot one, as the finer sands are continually being drawn into the well and pumped out, opening up fresh supply channels to the well.

33. With the experience we have had so far with the installation of Gravel Developed wells, I would recommend the use of separate gravel tubes which should be of the largest possible bore. The number of tubes used should not be less than six and they should be arranged as in the sketches appended. Obviously better results may be expected if the number of gravel tubes could be increased to 9 or 12, but this would of course increase the cost of the well.

Tube Well.	No. 1 "Pilot".	No. 2 Developed.	No. 3 Developed.
Depth of Tube ..	91'-3"	130'-0"	146'-6"
Dia. of plain pipe ..	10"	10"	10"
Dia. and type of Screen	10" Ashford.	10" Large Slotted.	10" Large slotted.
Length of Screen ..	16'-0"	6'-0"	6'-0"
Location of Screen ..	38'-0" to 54'-0"	46'-0" to 52'-0"	47'-2" to 53'-4"
Size number of gravel tubes ..	..	Nos. 9 8" Tubes.	Nos. 9 8" Tubes.
Distance from Tube Well ..	..	Nos. 3 at 1'-6" Nos. 6 at 7'-0"	Nos. 4 13" Tubes. Nos. 9 at 3'-6" Nos. 4 at 6"
Static Water Level ..	25'-3"	25'-0"	25'-3"
Discharge when Screen was totally exposed ..	3,110 gallons per hour.	9,070 gallons per hour.	4,910 gallons per hour.
Drop when Screen was totally exposed ..	19'-9"	20'-0"	30'-0"
Discharge when developed ..	..	11,170 gallons per hour.	9,070 gallons per hour.
Drop when developed ..	..	20'-0"	24'-3"
Discharge per sq. ft. area of Screen ..	74	740	600
Sand pumped out ..	..	417 c.ft.	1,807 c.ft.
Gravel poured in ..	..	62 c.ft.	118 c.ft.
Number of pumping hours to develop ..	..	132 hours.	240 hours.
Number of pumping hours after development ..	..	246 hours.	66 hours (This well is still being pumped).
Effect on Tube Well when others are being pumped ..	None.	None.	Not observed.
Cavitation ..	..	A little	A vast amount.
Cost of material ..	Rs. 910	Rs. 1,900	Rs. 1,800
Cost of labour ..	Rs. 630	Rs. 1,600	Rs. 2,700
Total cost ..	Rs. 1,540	Rs. 3,500	Rs. 4,500

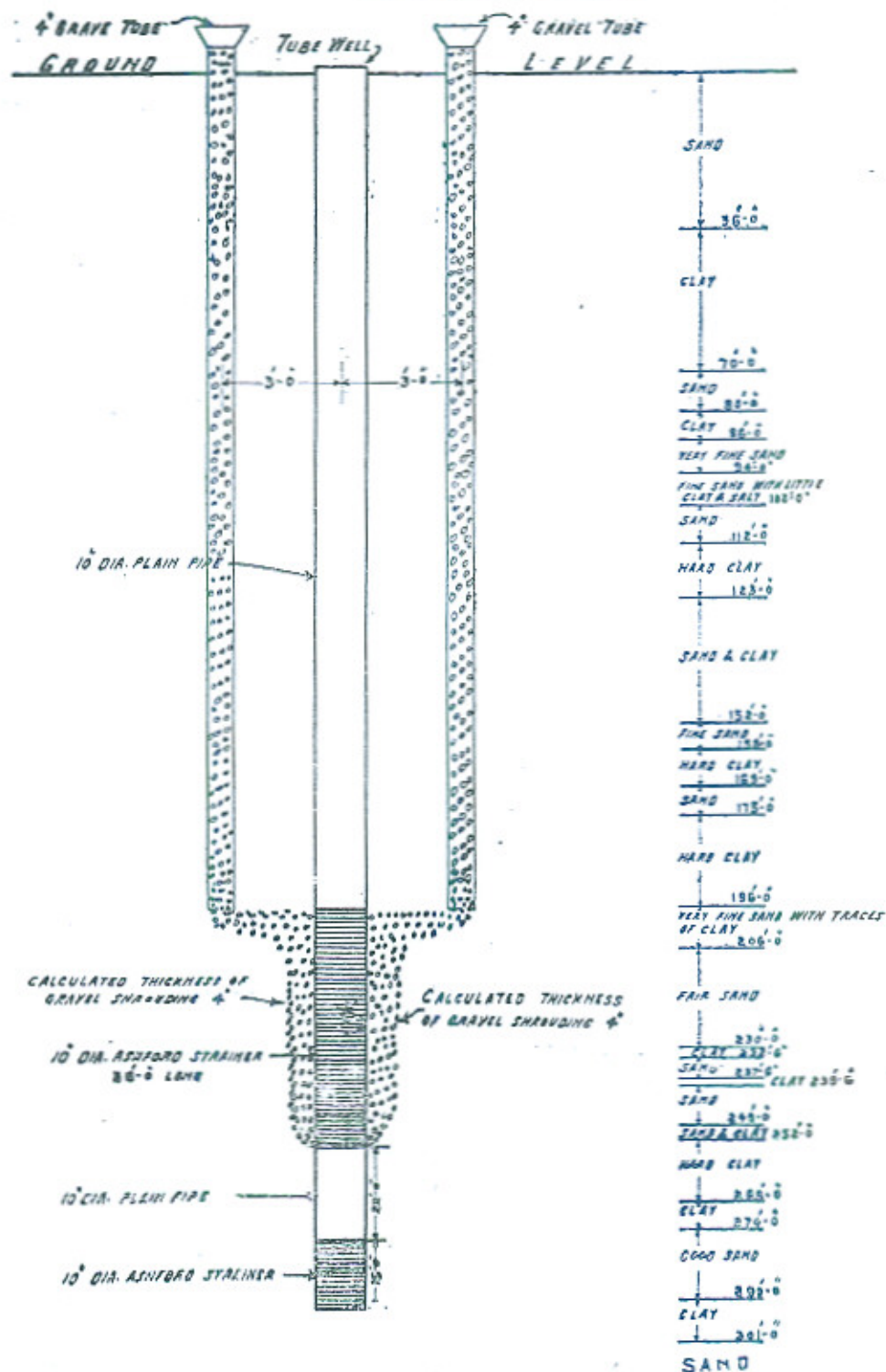
N. W. R.

TUBE WELL AT LAKI MARWAT

SHOWING

METHOD OF GRAVEL SHROUDING SCREENS

SCALE VERT 25 FEET 1"



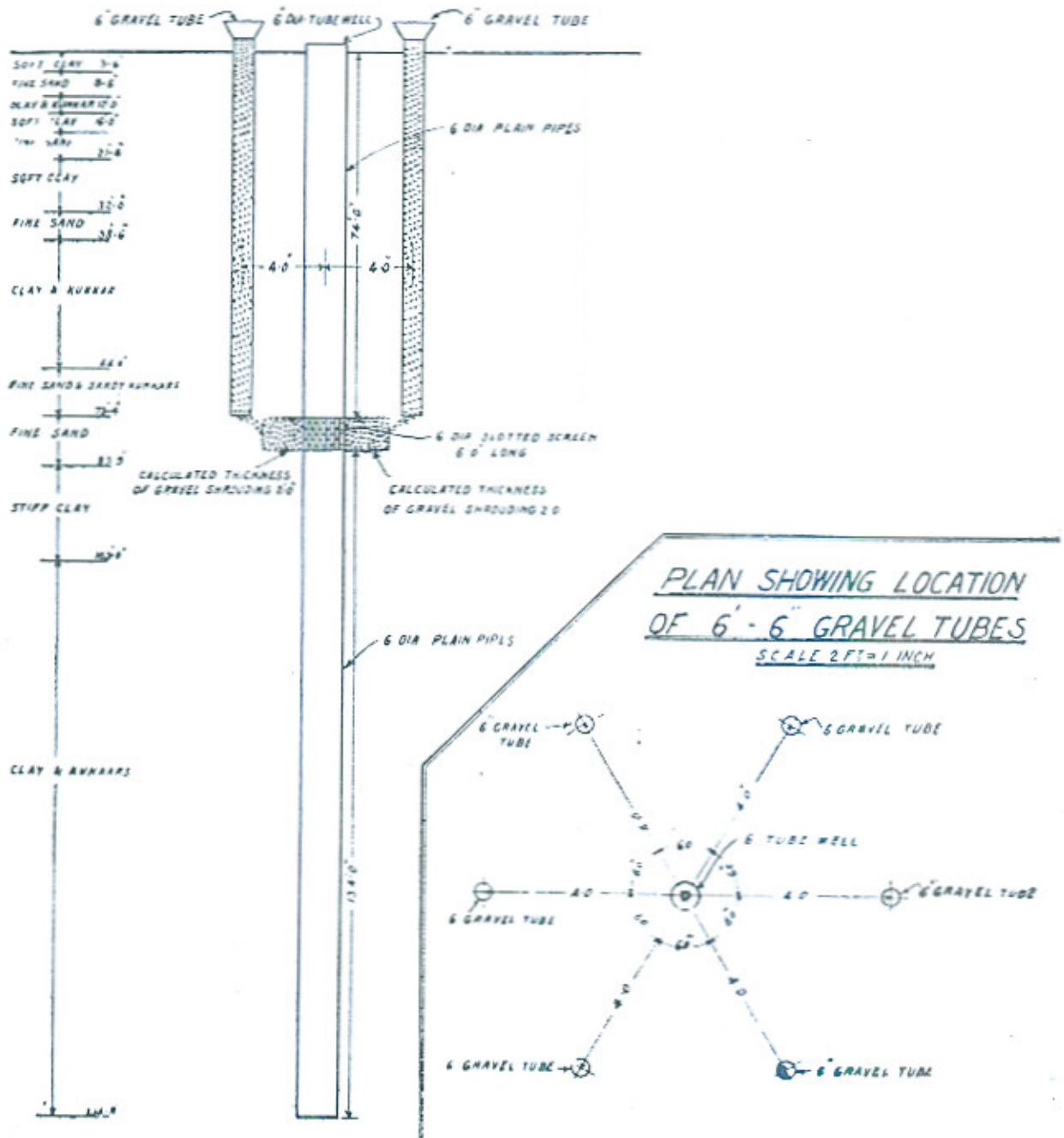
N. W. R.

APPENDIX 2

TUBE WELL AT ROHTAK

SHOWING METHOD OF GRAVEL SHROUDING SCREENS

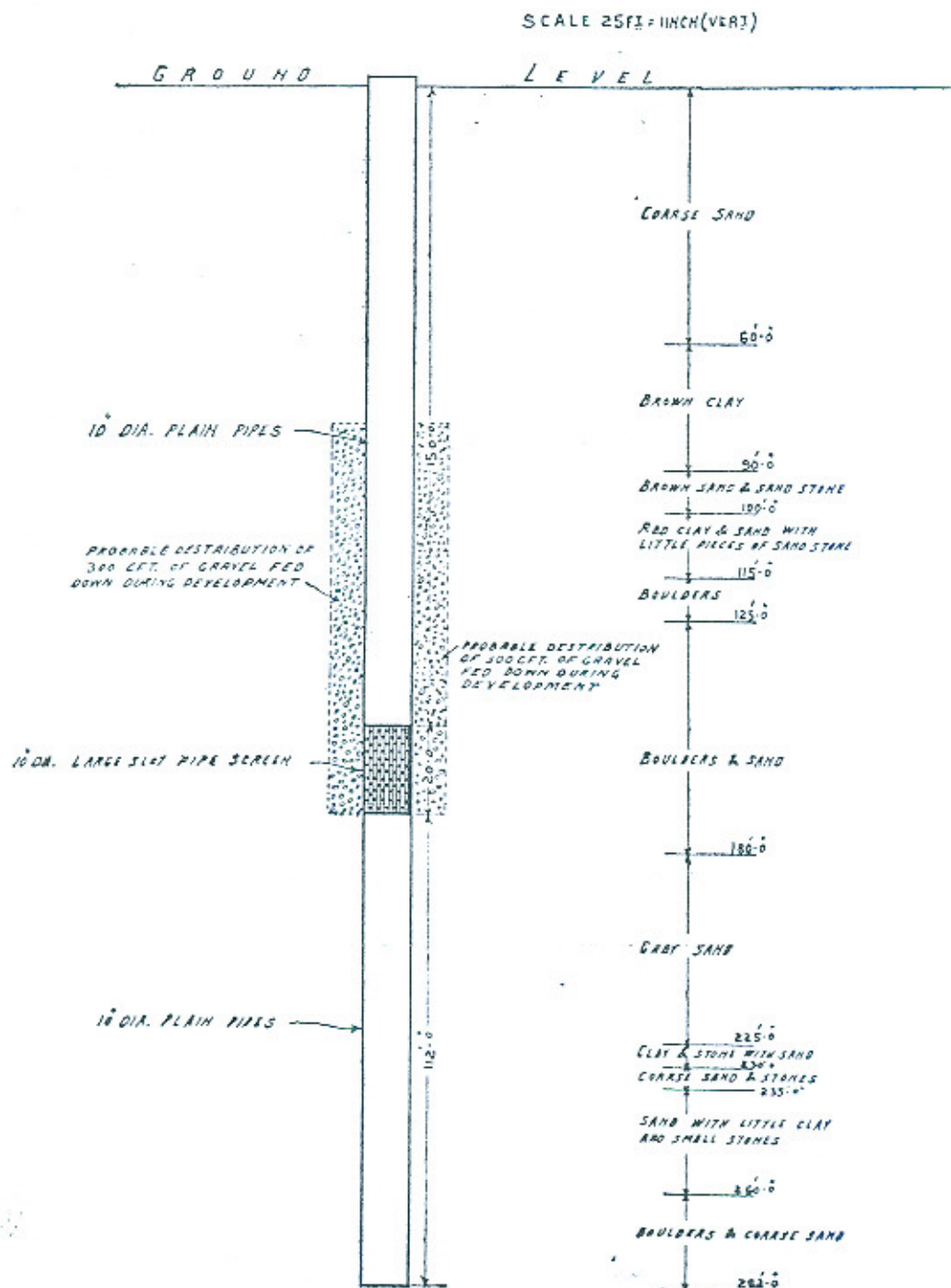
SCALE VERT. 20 15 10 5 0 20 40 FEET



N. W. R.

TUBE WELL AT CAMPBELLPUR

DRILLED WITH STAR DRILLING MACHINE

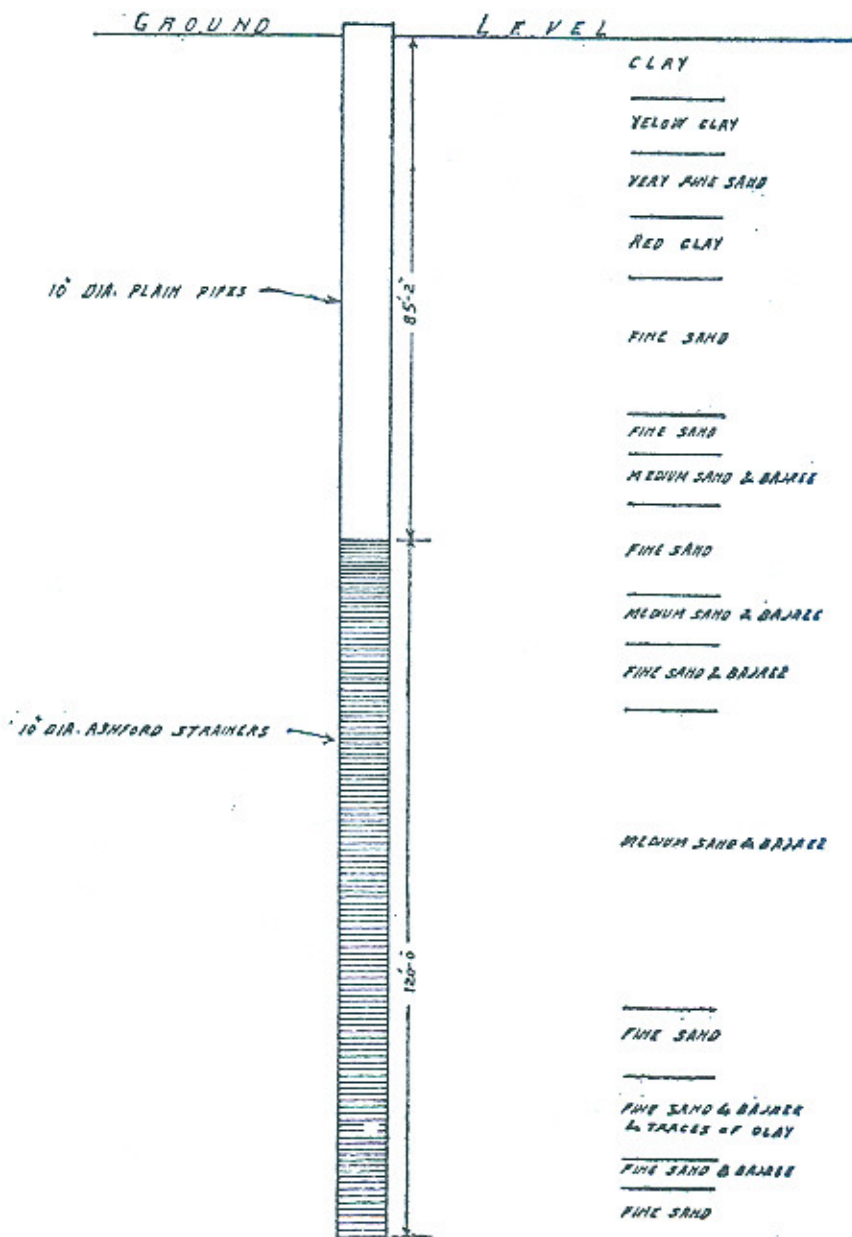


N. W. R.

TUBE WELL AT LYALLPUR

SHOWING
LOCATION OF STRAINERS AND STRATA DRILLED

SCALE VERTICAL 25 FEET TO AN INCH



N. W. R. APPENDIX 5

SECTION OF PILOT WELL & GRAVEL DEVELOPED WELL AT UMBALA CANT:

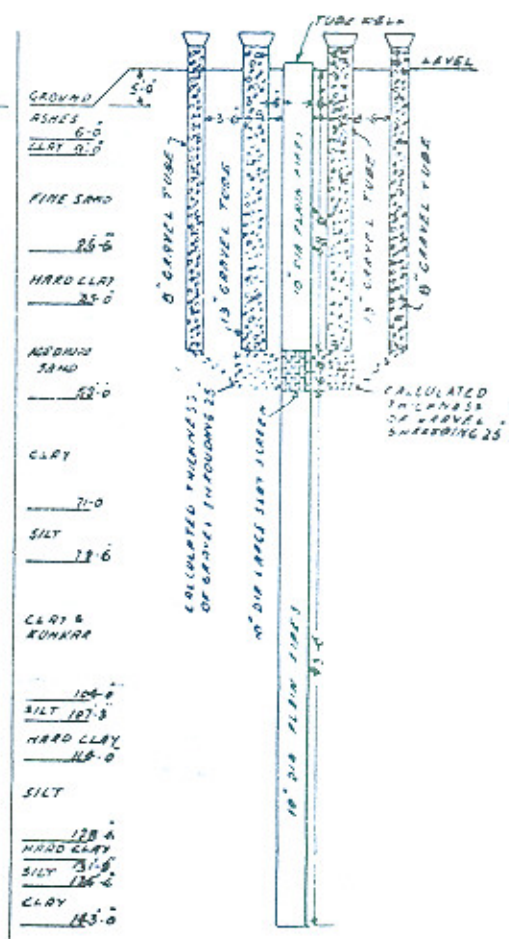
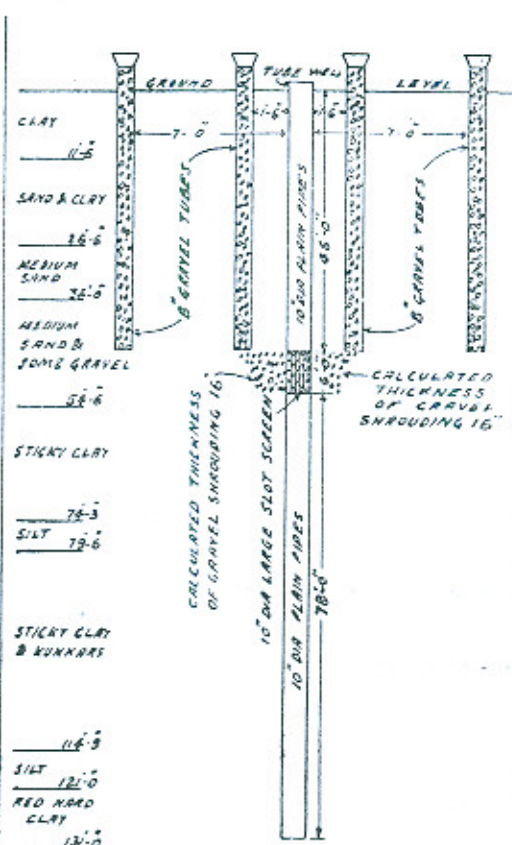
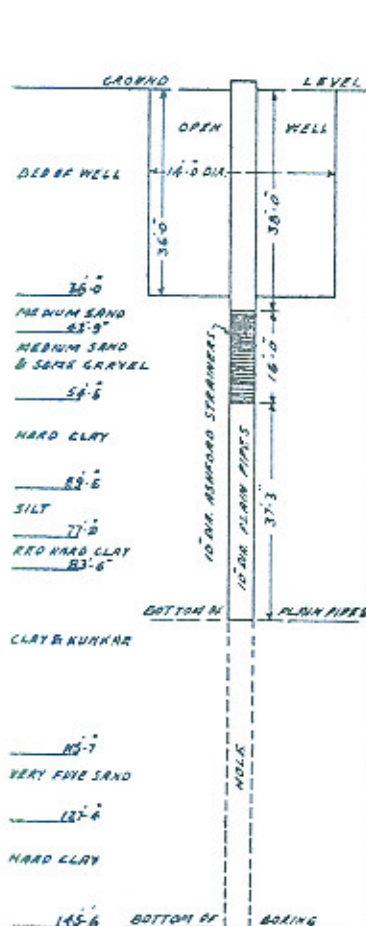
SHOWING LOCATION OF SCREEN & GRAVEL TUBES

SCALE { VERTICAL 20 15 10 5 0 5 10 15 20 FEET
HORIZONTAL 5 10 15 20 FEET

№ 1 PILOT WELL

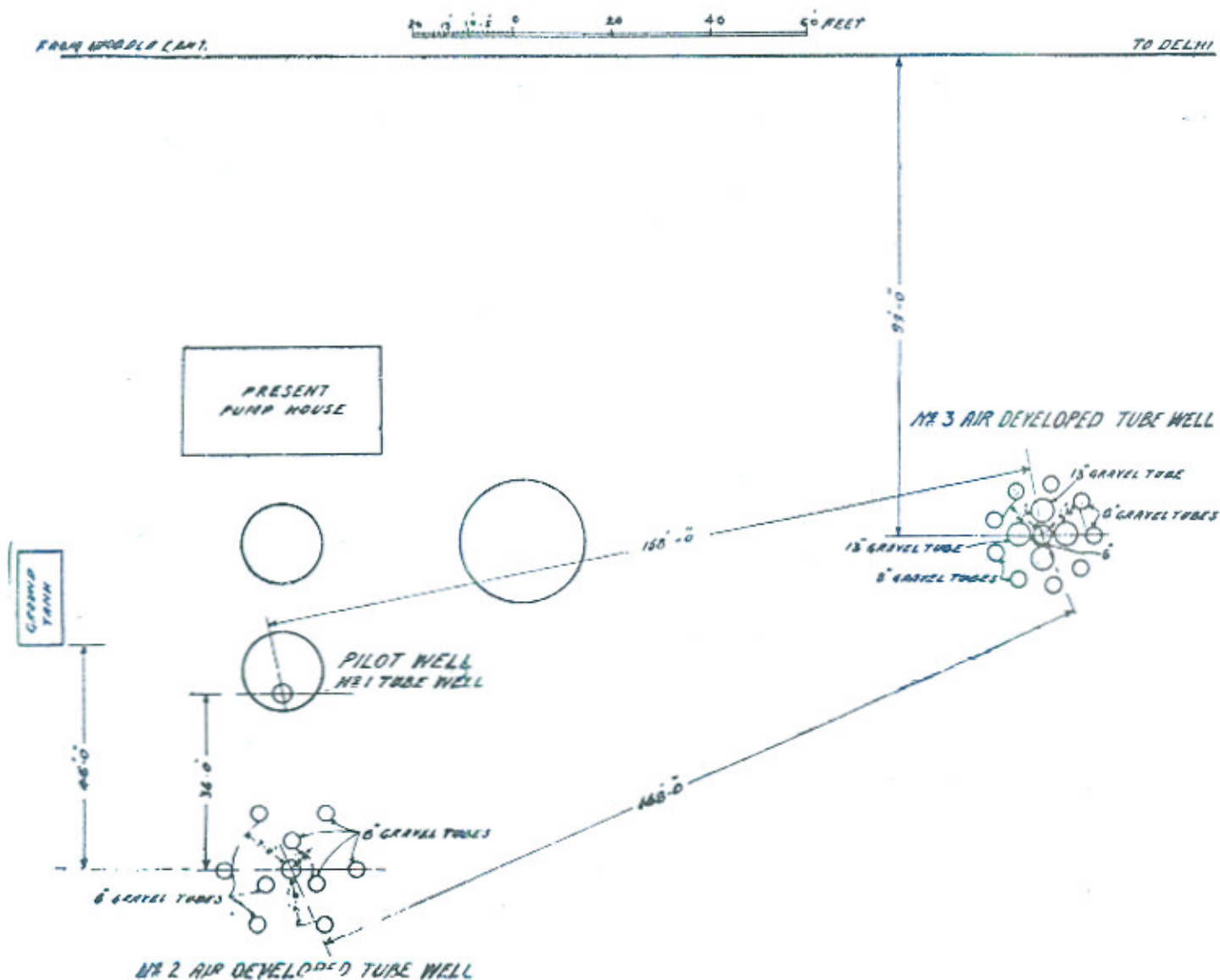
№ 2 GRAVEL DEVELOPED WELL

№ 3 GRAVEL DEVELOPED WELL



N. W. R. *APPENDIX 6*
PLAN SHOWING SITES OF PILOT WELL
&
GRAVEL DEVELOPED WELL
AT
UMBALA CANT:

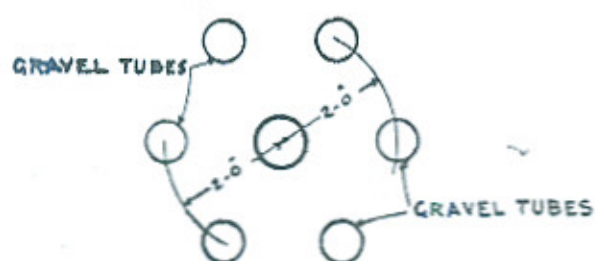
SCALE 20 FEET TO AN INCH



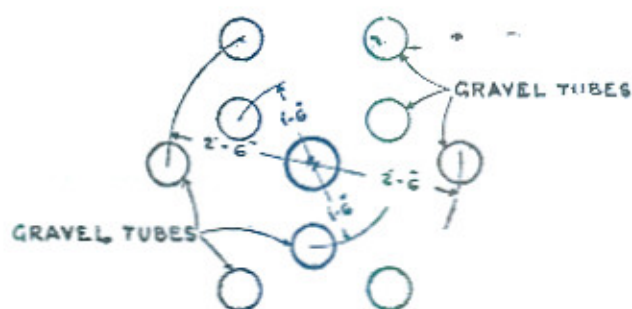
SUGGESTED SPACINGS OF GRAVEL TUBES FOR AIR MADE GRAVEL WELLS

APPENDIX 7

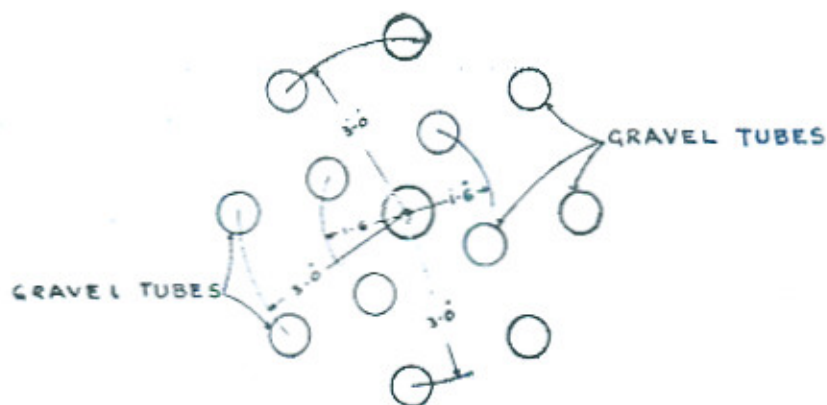
ARRANGEMENT OF GRAVEL TUBES
WHEN SIX ARE USED



ARRANGEMENT OF GRAVEL TUBES
WHEN NINE ARE USED



ARRANGEMENT OF GRAVEL TUBES
WHEN TWELVE ARE USED



DISCUSSION.

The Author introduced his paper and said his intention in submitting the paper was to indicate the progress that had been made on the N. W. Railway in obtaining a suitable and adequate supply of water from Tube Wells in places where it had been previously decided that a Tube Well supply could not be obtained.

This had been rendered possible by the introduction of modifications in the type of Tube Wells hitherto used in the Punjab, as the result of the study of methods adopted in other countries where conditions were similar to those here.

Most of the wells described in the paper were of the Gravel Developed Type with large Slot Screens, and further experience with them strengthened his conviction that this type would solve many of the cases where troubles were experienced in the past with Tube Wells due to choking.

On the N. W. Railway they invariably had to provide a combined locomotive and drinking water supply and therefore could not make use of the first bed of water-yielding-sand encountered due to the surface water being liable to bacteriological contamination. They were therefore compelled to draw their supplies from the deeper beds of sand, thus increasing the cost of every item connected with the well *viz.*, plant, drilling, plain pipes and development.

Where the tube well was not required to provide drinking water, and was only used for irrigation or for dewatering the soil, the first bed of water bearing sand could be used.

Such a well would seldom need to be deeper than 50'-0" and from the yield per S. ft. of screen given in the paper it was easy to estimate that for the same discharge a Large Slot Screen Well would cost only a small fraction of what a fine slot screen well cost. He ventured to suggest this type of well for irrigation and dewatering purposes to the authorities in the Punjab who deal with these works. The screens required were not a Patent and could be made up easily and cheaply at any workshop.

With the advent of cheap electric power and the adoption of a cheap and nonclogging type of the Well such as the Large Slot gravel developed type promised to be, there was reason to believe that tube well irrigation would usefully supplement canal irrigation.

He pointed out an error that had been made in Paras 15 and 16 Pages 161 and 162. The tests that were carried out and described in the paper were made in connection with the Tube Well at Tandlianwala not at Lyallpur as mentioned.

Mr D. A. Howell said he was particularly interested in Mr. Vardon's paper as the author had quoted at considerable length from the speaker's "Report on the water supply of Ambala City and Contonments." The state in the neighbourhood of Ambala had been proved in many wells, on comparatively shallow borings and also by two deep borings, one put down a depth of about 700 feet, many years ago and another to a depth of about 1,500 feet subsequent to 1925.

The strata in both of these deep bores consisted of bands of clays and sands. The sands generally were rather fine and contained an admixture of fine clay.

The Ambala waterworks Headworks which were built about 34 years ago near Handesra, about 8 miles north of Ambala consisted of shallow percolation wells. The yield of these wells had diminished enormously and today the wells yielded only about 33 per cent. or less as compared with their original yield. The same phenomenon had been observed in the case of the Ambala contonment well Headworks at Bibyal near Ambala and also in the case of a 40 feet dia. percolation well sunk as an experiment near Sarngpur on the banks of the Tangre nallah in 1923, although in the later case great care had been taken to ensure that overpumping did not occur. Similar experience at the old Delhi water works had caused the abandonment of the percolation well System there and at Delhi drawn now the supply was from the River Jumna.

The cause of the reduction of yield, he considered to be due to clogging of the pores of the sand strata round the wells due to the draw on the wells, by clay particles carried by the flow of water towards the wells.

Mr. Vardon had shown that he had achieved a certain measure of success with the gravel developed tube well but this did not prove that the final solution of the problem was in sight and the speaker considered that it was a grave risk to rely on gravel developed tube wells as a source of supply for a permanent watersupply scheme to deal with Ambala Contonments and Ambala City, with a population of about 70,000.

Possible there were cases where no other supply might be available and under such circumstances admittedly there would be no alternative except to experiment with different forms of tubewells, if that were possible.

About 17 or 18 miles north of Ambala there appeared to be an extensive boulder formation at the base of the Siwalik (Tertiary) Foot hills. Due to the flattening out of the slope of the alluvial formation as it left the foot hills, the subsoil water surface reached the surface of the ground near the southern edge of this formation just north of Ghugger Station on the Ambala Kalka Railway.

The formation contained large quantities of water and the level at the point where the water line coincided with the surface was about 100 feet above that of Ambala, which was of great advantage.

A water supply drawn from this formation seemed to be the best and most reliable supply for Ambala, with all due respect to the results obtained with gravel developed wells at Ambala.

The author in dealing with a tubewell at Lyallpur (page 159, para 1) had said "It appears to have established the fact that the quality of water supplied from tubewells located in heavily irrigated country tend to improve in quality when pumped regularly for some months." This argument, however was based on the results of a single tubewell and it seemed dangerous to make a general case out, simply on the result of one particular example.

The author again on page 16 paragraph 192, had stated that he saw no reasons for believing that there were appreciable Variations on the strata for some miles round the Railway tubewell at Lyallpur.

This conclusion was entirely at variance with the speaker's own experience of large numbers of tubewells sunk in the Punjab. He had found that generally the stratification of the sands and clays of the alluvium were definitely centricular in shape and almost everywhere there were considerable differences between the cross sections of boring placed at comparatively short intervals apart.

The speaker referred to paragraph 20 page 162 on which the Author had said that the point at which sweet water was actually fed into the sub-soil could be assumed to be in the vicinity of the tubewell. In this he emphatically disagreed with the Author as in spite of the centricular formations of the alluvium, it was certain that these layers were interconnected longitudinally or horizontally in many directions and there seemed to be no reason why replenishment of any particular sand strata could not take place from considerable distances horizontally.

R. B. Amar Nath Nanda said that he wished to speak on a few points raised in Mr. Vardon's paper, because they in the Public Health Circle had been working in the direction of tube well supplies for large urban areas in the Punjab for 15, on 20 years.

Mr. Vardon had in his paper dealt with a few tube wells which had been sunk by him for the N. W. Railway say at Laki Marwat, Rohtak, Jambellpur, Lyallpur and Ambala Cantonment. Rohtak and Ambala were important centres of urban population of the Punjab and they were deeply interested in the water supply problem for these places and any solution that might be offered by engineers in this behalf.

He further said that the question of Ambala water supply had been engaging their serious attention since 1895. Briefly recapitulating the efforts made here from time to time he stated that the Ambala water

supply was derived from a distance of 8 miles from Ambala city and had taken the shape of 27 percolation wells of 7 to 10 ft. diameter, which gave a discharge of 2 lakh gallons originally in 16 hours pumping. But only the other day he happened to go down to Ambala to carry out a recoupment test and had found that the discharge was only 1 lakh gallons in 24 hours, so that the whole of the sub-soil water basin in that area had either reached the exhaustion point or the choking effect of fine clay particules had proceeded to such an extent in the water bearing subsoil strata surrounding these wells, that the yield had diminished considerably. Another effort they made here was with a 40 ft. diameter well which had been sunk about 20 ft. below spring level on the bank of the river Tangri in 1923. This well originally gave a discharge of 1 lakh gallons in 16 hours pumping and under 4 ft. head of depression. Extreme care was taken to keep the draw down and the velocity of flow low, but in spite of all precautions the yield had gone down to 60,000 to 65,000 gallons a day, on account of the same clogging effect in the subsoil. That being their experience, it was difficult to believe that an engineer who had been experimenting with these forms of tube wells only for the last few years had solved the problem of Ambala water-supply by drawing upon the same unpropitious subsoil.

The only explanation given in the paper was that the subsoil water at Ambala had been coaxed out of the ground. He said this was tantamount to making a regular raid in to the subsoil. Now this coaxing process could not last long, because although a tube well as a form of withdrawal of water from the subsoil had an advantage over a percolation well in that it had its vertical strainer surface exposed to the inflow of the horizontal stream-lets along their natural lines of flow between layers of sand, still the output effect, or the 'net' performance was limited by the limited quantity of water contained in this finely combed subsoil basin of Ambala. The difference between Mr. Vardon's tube wells and theirs was that they had to supply drinking water for urban areas where no risk could be run whereas he had to provide for the locomotives, and if his supply failed eventually in one place he could shift his watering arrangements to another centre.

He described the case of Pasrur for instance where they had to sink tube wells both for the supply of the town and the Intermediate College that had been recently opened here. In 1916, the P. W. D. had sunk a trial well 220 ft. deep and Mr. Ashford had advised with regard to the type of strainer to be used in the well. The discharge obtained under 12 ft. head was 3,025 gallons, per hour which was $\frac{1}{4}$ th of what Mr. Ashford had foretold. Now Mr. Vardon had constructed a well here for the use of the railway, where he had got a discharge of 4,900 gallons an hour at 50 ft. head. In his opinion this discharge obtained under this tremendous head could not last. The Principal of the College had, however, written to enquire as to why they were not able to solve the problem of water-supply for his College when the railway had solved it for their locomotives

only a 100 yards away. That was how these new ideas were putting them to trouble and it was for this reason that he had taken this attitude in dealing with this paper, otherwise he would welcome this type of gravel fed screen well if it was found to stand the test of time and gave eventually what it promised to give in the beginning.

Colonel Battye wanted to know whether the Springs that Mr. Howell referred to in the Siwaliks were in British territory: if not in British Territory there was some prospect of their remaining permanent: otherwise there was every prospect of their drying up in the course of time as the denudation of the Siwaliks continued. This was rather an interesting sidelight on the importance of Mr. Glover's paper.

He then referred to the question of afforestation and its affect on the subsoil water throughout the submontane district. He said that the Enquiry Committee on the Hydro-electric project had been very impressed with the great possibilities of a market for power from tube wells and had asked them in conjunction with the Agriculture and other Departments to investigate this. The prospect of these tube wells being a success however, depended upon the maintenance of the subsoil water beds the submontane districts, which again depended upon afforestation.

Turning now to the questions raised in Mr. Vardon's paper, he pointed out that this opened up a fresh view of the time-old controversy between the fine and the coarse screen. It seemed to him that Mr. Vardon's proposal constituted the equivalent of a filter with an outside superficial area equal to the circumference of a circle of 12' or even more radius, the interstices in the filter increasing in magnitude from the outside until the tube itself was reached which seemed to point to the fact that the interstices in the tube itself, i.e., the screen should be of the same magnitude as those between the gravel particles immediately adjacent to the tube; approached from this point of view, the use of a gravel filter seemed to point logically to the adoption of a coarse screen in conjunction therewith. Mr. Vardon's use of filter really had the effect of increasing the diameter of the well from 12" to 12' and more and thereby decreased immensely the velocities at the outer edge of the filter which might eventually be small enough to prevent the transportation of sand particles. Judged from this point of view it seemed that he was working on the right lines and that all tube wells in future would be based upon the employment of a gravel filter of this type.

Turning to the diagrams at the end of Mr. Vardon's paper, if this aspect of the question was correct, it would appear to be logical to adopt the concentric system of gravel tubes and to differentiate between the size of gravel to be inserted in each tube. For example, coarse

gravel should be put in to those adjacent to the main water tube and finer gravels inserted in to those nearer the circumference. He asked if any experiments had been carried out definitely on these lines.

Mr. Carl King said that the questions discussed really turned on the merits and disadvantages of the coarse screen tube well as against the fine screen tube well. In America at first fine screen tubewells such as those at present mostly installed in the Punjab were generally used. Later however as the result of experimental work, coarse screen tube wells had been developed and to-day this type had largely displaced the fine screen type. The subsoil conditions in the Punjab varied somewhat from those in some places in America where coarse screened tube wells were installed. Mr. Vardon had done very valuable work in showing that gravel developed tube wells could be successfully used and he hoped that his work would continue.

Mr. Musto said he should like to thank and congratulate Mr. Vardon for his most interesting and useful paper, which was a very valuable contribution to the study of a subject which must become of more importance every year to India. He would suggest that a committee be formed of officers in Lahore of all Departments which were experimenting with tube wells, and that such committee should meet not less than once in 3 months to pool and record the information obtained, and for mutual discussion of methods.

In paragraph 13 page 153 Mr. Vardon said that air lift pumps were almost essential for pumping a sanding well. He did not explain why. If the total suction lift with depressed head was within the limit of a centrifugal pump, the latter was a much more efficient machine than an air lift pump, and much cheaper to instal. Occasional and would do no harm to such a pump, as the clearance or wear allowable in a centrifugal was considerable before efficiency is seriously affected.

If heavy sanding was anticipated during the first few days or weeks it should be possible to keep a special old pump for this work, to be replaced by a new one when the well had reached stable conditions.

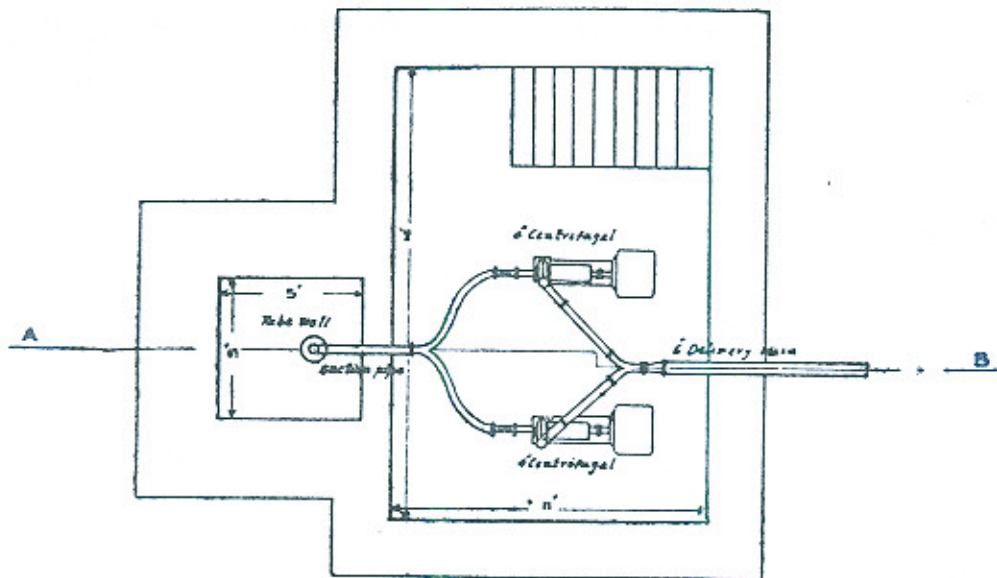
Where there was a **seasonal** variation of water level in the tube well, it would often be cheaper and more efficient to fix the pump **below** the highest water level in the well, providing a stuffing box and gland on the top of the tube well and through which the suction pipe would pass. The cost of excavation and building to low levels was comparatively small (the outside of the pump house should be water-proofed with good cement rendering) and by this means the pump would be self priming at high levels in the tube well, while it was possible thus to deal with a much greater depression of head (as much as 20 feet below the centre of the pump). A good plan was to electric weld the joints in the suction pipe to avoid all possibility of air leaks.

L. B. C.

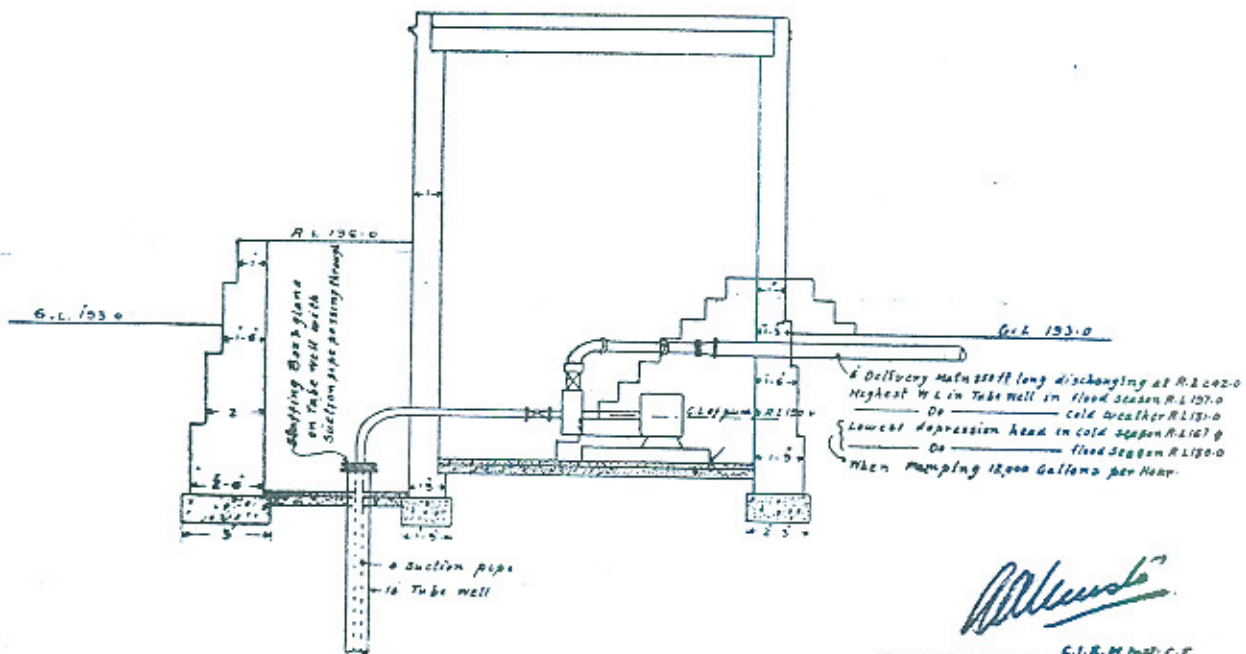
S.E.L.B.C. ORG. No. 227
1530
Accompaniment to No.

DUPLICATE PUMPING PLANT ON TUBE WELL AT SUKKUR

PLAN
SCALE 4" = 1

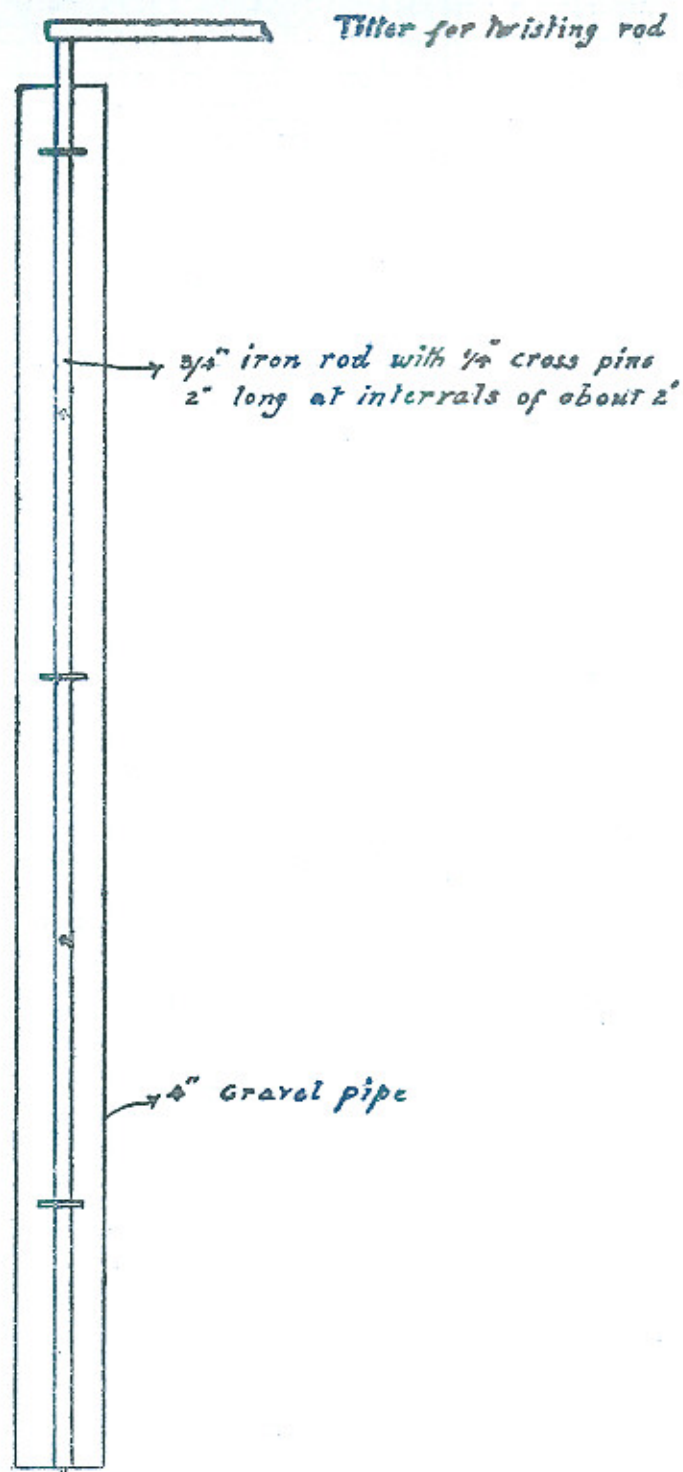
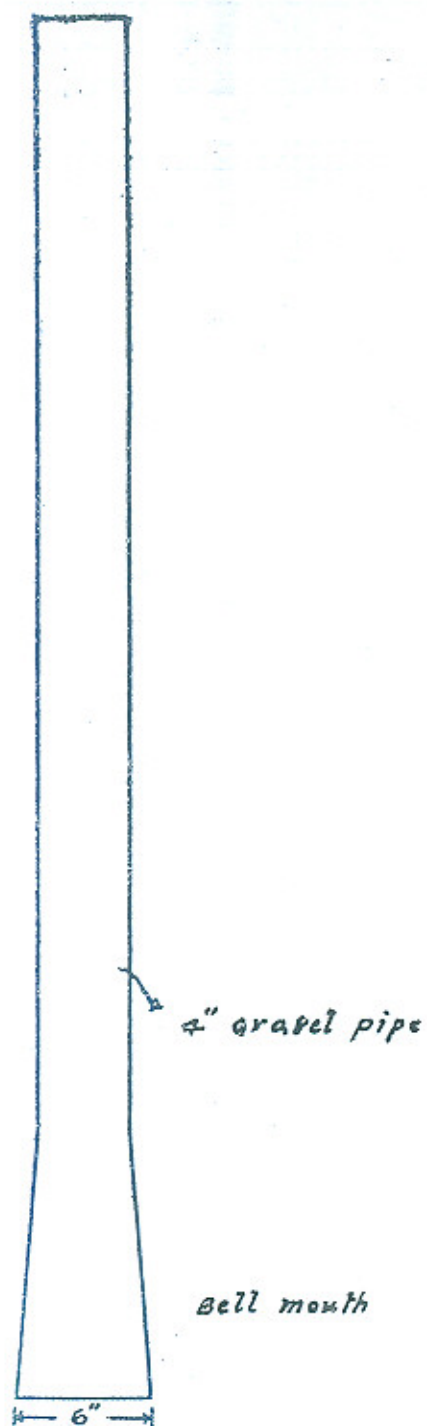


SECTION ON A-B



W. H. M. J.

C. I. E. M. J. C. E.
SUPERINTENDING ENGINEER
LLOYD BARRAGE CIRCLE



Althaus

A double advantage of such a system was that with one tube well, duplicate pumping plant could be kept permanently installed on one well. The tube well itself was never likely to give trouble (once it was established) but it was necessary to have duplicate pumping plant to avoid stoppage of supply in the event of a breakdown or repairs to pump or power unit.

The accompanying sketch shewed such a plant as installed for the potable water supply of the Barrage Township at Sukkur. It had never given a moments trouble in the past three years.

A disadvantage of deep well pumps was that in the event of a breakdown in the plant, the water supply must be stopped during repairs, or at the best, during the removal of the defective pump and its replacement by a duplicate plant kept ready.

If it was desired to avoid such stoppages it was necessary to have a duplicate tube well, in addition to duplicate plant and this was not only expensive, but unless the wells were worked in rotation, the spare well was liable to be found choked or full or sour water when suddenly needed **Paragraphs 10 and 14 Page 156.** The gravel pipes might be jarred from above in order to shake down the gravel, but a better plan would be to put down a central agitating rod about $\frac{3}{4}$ " diameter with some cross pins, before the gravel was filled in. This rod could be turned from the surface as the gravel was filled in and would shake the gravel down. It would also probably help if the bottom of the gravel pipe was made slightly bell-mouthed for a foot or so as the jamming probably occurred at the bottom of the pipe, where the soil had worked up into the gravel before movement started.

The attached sketch illustrated the suggestions.

Mr. Vardon replying to the discussion said he was sorry to hear from Mr. Nanda that the introduction of gravel developed wells by the N. W. Railway caused a certain amount of annoyance and trouble to the P. W. D., but he said it was never intended that this should be a source of worry to them. He said most of the comparisons in connection with the Ambala watersupply had been made between the ordinary open well, and gravel developed wells. He contended however that what applied to open wells was not equally applicable to a large slot tubewell.

With regard to choking, he said the whole idea of introducing large slot screens was to get over the trouble of choking. His experience at Ambala during the last eight months was that the discharge had increased and the drop had decreased and that the reason was that the finer sand particles were drawn through the screen and pumped out, and so opened out fresh channels for the flow of water into the well.

He said if anybody was interested in the records of the Ambala wells, he would be glad to show them that there was no tendency to choke. If the open well sunk by the Public Health Department at Ambala had been causing trouble by choking, there was no reason to believe that choking must necessarily occur in gravel developed large slot screen wells, where the infiltrations conditions were entirely different.

The other point was that they had met their present requirements at a total cost of under Rs. 10,000 from gravel developed tube wells, whereas if they were to participate in the joint gravity scheme, they would have to incur an outlay of 10 lacs of rupees, which they could not afford. He was very much impressed with the possibilities of gravel developed wells and said that they had found another site right at Amballa Cant. station where a boring was being sunk for another gravel developed well.

They had been fortunate in being able to obtain 24" pipes from the Military Works at Quetta, and as a result a centrally developed well would be tried.

With regard to Mr. Howell's criticism, regarding the improvement in Lyallpur in the quality of the water, said that it was obviously due to drawing sweet water from the vicinity. He did not mean by this that the immediate source of supply was in the vicinity of the well but from the heavily irrigated territory round about, and also he meant that no big variation in strata took place. He meant that there was a certain amount of continuity in the sand beds, they might not be horizontal or at any well defined angles, but connected to the main source of supply, which were the canals and therefore, were being sweetened with sweet canal water, gradually washing out the impurities of the subsoil through which it flowed into the well.

He noted that the Chairman was very very suspicious about these large slot screen wells. He wanted to point out as Mr. King did that such wells had been tried out for many years in Texas and other States in the U. S. A., where large sums of money had been spent on other types without success. He said that the authorities where such wells had been sunk were so impressed with steady maintenance of discharge that in many cases it had been decided to put in more. It was new to India and they had not been as successful as they might have been due to the lack of technique. There certainly were possibilities in this direction.

He said that if Mr. Nanda would ever like to witness the discharges which they got from the tube wells he would be glad to take him round and show him.

With regard to cavitation, he said that the worst type of cavitation they had was on well No. 2 in Amballa which was due to trying the development in a different way with the hope of getting better results. The cavitation extended to 4 to 5 feet from the centre of the well.

As regards Colonel Battye's point regarding grading the gravel, used for development he said that that would be the ideal condition but that when one was doing this sort of work, one realised the difficulty of getting the gravel to move. Mr. Cox would tell them of his experience with the gravel well at Gujranwala. He had pumped out 1,500 cubic feet of sand and could not get the gravel to move.

As regards Mr. Musto's question, why they had concentrated on the air lift pump, he said that they had used a considerable number of these on the Railway, but they had not restricted themselves only to this type; they had quite a large number of other types of pumps as well.