PERFORMANCE EVALUATION OF GROUND WATER PUMPING SYSTEM

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

WATER RESOURCES DEVELOPMENT

By

KAKARLA NARENDRA VARMA

DEPARTMENT OF WATER RESOURCES DEVELOPMENT & MANAGEMENT
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)

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CANDIDATE'S DECLARATION

I here by declare that the work that is being presented in this dissertation report entitled **"PERFORMANCE EVALUATION OF GROUND WATER PUMPING SYSTEM"** submitted in partial fulfillment of the requirements for the award of the degree of **Master Of Technology** with specialization in **WATER RESOURCES DEVELOPMENT,** in the **Department Of WATER RESOURCES DEVELOPMENT AND MANANGEMENT, Indian Institute Of Technology, Roorkee**, is an authentic record of my own work carried out, under the guidance of Prof. GOPAL CHAUHAN, Department of WRD&M, Dr. DEEPAK KHARE, Assoc. Professor, Department of WRD&M, and Prof. B.K.GANDHI, Department of Mechanical & Industrial Engineering.

The matter embodied in this dissertation report has not been submitted by me for the award of any other degree or diploma.

Date: 29/6/07
Place: Roorkee

K. Narendra Varma.
(KAKARLA NARENDRA VARMA)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Prof. GOPAL CHAUHAN
Professor,
WRD&M,
I.I.T.Roorkee.

Dr. DEEPAK KHARE
Assoc. Professor,
WRD&M,
I.I.T.Roorkee.

Prof. B. K. GANDHI
Professor,
MIED,
I.I.T.Roorkee.

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DATE: June-2007

PLACE: Roorkee

K. Narendra Varma.

(KAKARLA NARENDRA VARMA)

ABSTRACT

The present thesis work is carried out on the tube wells of Roorkee, where the discharge and the pipe lengths and current consumption and the power of the pumps of 48 tube wells are collected for which the department of tube wells, Roorkee was approached which provided the transport facilities for the work carried. Proper selection of a submersible pumps is essential for good life of tube well and its appropriate utilization. If a pump of higher head and discharge is used than required then higher initial cost, operation cost will incurred and tube well life will also be reduced. Similarly if a pump of under head or discharge is used tube well capacity will be utilized. Hence a tube well must be tested as per standard practices for a safe capacity of discharge at safe drawdown of water.

Irrigation is of paramount importance in development of agriculture. India has a unique agro-climatic permitting the cultivation of variety of crops adapted to tropical, subtropical, temperate, semi arid and arid environments. Thus, Indian society is mainly agrarian with about 75% of the people depending on agriculture. In India about 68% of total sown area of the country is drought prone. Irrigation development has a major factor in increasing agricultural production.
So therefore all the pumps data is analyzed to pick the pumps which will not work properly throughout the year that is the pumps which fail in summer season where the drawdown is not considered are found out and these pumps should be replaced so that there is continuous supply of water throughout the year for the farmers

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Chapter 1

INTRODUCTION

1.1 General

Water is vital for mankind and regions with easy availability of water save always been the most prosperous. Surface water is generally easy and economical to harness, but availability varies with the season and place to place. Ground water, on the other hand, is obtainable all the year round and its use(apart from drinking purposes in conjunction with surface water holds the subsoil water level within reasonable limits. Further groundwater yields clear water at almost constant temperature which is preferred for municipal water supply and several industries. Ground water can be exploited by open well and tube wells Depending on the available aquifers.

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The ground water pumping system plays a major role in the irrigation development, for which effective pumping of water is required.

1.2 Pumping System Requirements

The heart of most irrigation systems is a pump. To make an irrigation system as efficient as possible, the pump must be selected to match the requirements of the water source, the water piping system and the irrigation equipment.

Pumps used for irrigation include centrifugal, deep well turbine, submersible and propeller pumps. Actually, turbine, submersible and propeller pumps are special forms of a centrifugal pump. However, their names are common in the industry. In this circular the term centrifugal pump will refer to any pump located above the water surface and using a suction pipe.

Before selecting an irrigation pump, a careful and complete inventory of the conditions under which the pump will operate must take place. The inventory must include:

1. The source of water (well, river, pond, etc.)
2. The required pumping flow rate
3. The total suction head
4. The total dynamic head

There usually is no choice when it comes to the source of the water; it is either surface water or well water and availability will be determined by the local geology and hydrologic conditions. However, the flow rate and head will be determined by the type of irrigation system, the distance from the water source and the size of the piping system.

Out of various types of pumps centrifugal pumps are the most popular for water wells which can be subdivided into two categories

(a) shallow well pump for used to lift the water from depths of less than 7.5m

(b) Deep well pumps used to lift water from depths exceeding 7.5m.

Various types of deep well pumps are used depending upon the requirements such as vertical turbine pumps, submersible pumps, centrifugal jet pumps, air lift pumps.

Here we will discuss about submersible pumps, in some details.

In this pumps entire assembly including the electric motors and the pumps is submerged under the water level in the well.

Therefore there is no suction condition. The motor is usually at the bottom and the pump at the top of such an assembly. Hence the motor is never out of water. The motor is connected to the electric supply at the ground level by means of special submarine type of electrical cable. The pump is usually multistage centrifugal type i.e. its conventional impellers and diffusers are arranged in series such that adequate head is developed.

In such pumps motors used are of two types, dry motors & wet motors. A dry motor is hermetically sealed to completely exclude the water of well. It runs in dielectric oil which completely fills the cavity inside of the motor. Thus submerging the windings, bearings and rotor & the motor and the bearings rotate in this water.

In this type of motor the windings of the stator are canned or completely sealed off from the rotor by means of an inner liner which prevents water from getting into the windings.

This type of motor requires an adequate filter around the shaft to prevent entrance of sand into the water as it's is not suitable where the sand content of water is high.

Submersible pumps can be installed in pipes as small as 10 cm in diameter. Hence a smaller bore is required as compared to that for a vertical turbine pump. Further savings can be affected by building a small pump house or emitting it altogether.

Proper selection of a submersible pumps is essential for good life of tube well and its appropriate utilization. If a pump of higher head and discharge is used than required then higher initial cost, operation cost will incurred and tube well life will also be reduced. Similarly if a pump of under head or discharge is used tube well capacity will be utilized. Hence a tube well must be tested as per standard practices for a safe capacity of discharge at safe drawdown of water.

Despite all the care in operation and maintenance, engineers often face the statement "the pump has failed i.e. it can no longer be kept in service". Inability to deliver the desired flow and head is just one of the most common conditions for taking a pump out of service. There are many other conditions in which a pump, despite suffering no loss in flow or head, is considered to have failed and has to be pulled out of service as soon as possible. These include seal related problems (leakages, loss of flushing, cooling, quenching systems, etc), pump and motor bearings related problems (loss of lubrication, cooling, contamination of oil, abnormal noise, etc), leakages from pump casing, very high noise and vibration levels, or driver (motor or turbine) related problems

Effective troubleshooting requires an ability to observe changes in performance over time, and in the event of a failure, the capacity to thoroughly investigate the cause of the failure and take measures to prevent the problem from re-occurring.

1.3 Submersible pumps

Submersible pumps are mostly being used for pumping water from deep wells. As the ground water level is going down day by day and hence shallow wells are becoming costly and obsolete, the submersible pumps are now widely popular due to their simplicity of design and low cost. The other advantages of using submersible pumps are easy installation procedure and also they neither require a pump house nor special skill for operation.

The major classification of these pumps are based on the outer diameter of the pump which ranges from 100mm to 300 mm. these pumps find applications in the following areas

1. domestic and municipal water supplies
2. industrial water applications
3. fire fighting applications
4. dewatering of pumps in thermal power stations and other large pumping installations
5. agricultural field to supply water to the crops
6. Land drainage applications.

ADVANTAGES OF SUBMERSIBLE PUMPS

Submersible pumps were introduced in India nearly three decades. Major benefits of submersible pump sets are

a. Energy conservation higher overall efficiency
b. Reduction in civil works with no foundation, pump house etc.
c. Self priming since submerged
d. Noise free operation
e. Risk of pilferage reduced due to submergence
f. Elimination of 2 stage pumping
g. Can be operated by gensets in remote areas
h. Lighter in weight hence easier to install.
i. No need of periodic lubrication.

1.4 OBJECTIVES AND SCOPE OF WORK

In view of the importance of ground water pumping system, the present study is undertaken with the following objectives;

1. To identify various tube wells in the study area and understand their pumping systems.
2. To collect the relevant data related to ground water pumping system.
3. To analyze the existing pumping systems, and study the performance of the pumps.

The work is carried on the submersible pumps of the Roorkee area to find out and remove the pumps that will not work properly throughout the season with some problems. Some pumps will fail in the summer season due to which there will be no water for the crops, so the pumps that will fail in summer season needs replacement.

1.5 ORGANISATION OF THE DISSERTATION

The present thesis work is concerned with the study of various ground water pumping system of Roorkee and Bhagawanpur command area (Uttarakhand state)

The chapters have been organised in such a manner that the required information has been stepwise drawn to meet the objectives of the study.

Chapter 2 : Discussion about the literature review.

Chapter 3 : Description about the study area.

Chapter 4 : Deals with the data collection and methodology adopted.

Chapter 5 : Analysis and results followed by discussions.

Chapter 6 : Conclusions.

Chapter 2

LITERATURE REVIEW

2.1 Earlier work on Submersible Pumps

The literature reviewed is about the basics of submersible pumps their applications where they are used concentrating on the importance of their usage in the agricultural field.

M.D.Agarwal [1]discusses about the testing procedures of the centrifugal and submersible pumps the classification of different testing procedures are mentioned for the flow rate, head, gauge pressure, total head , static water depth, drawdown, submergence.

Anonymous [2] KSB pumps manual gives the operating instructions of the submersible motor pumps.

Baweja I.S., Dube R.K., [3] gives the constructional features of the submersible pumps and discusses about the pump sets which are available in the market and their quality. The errors noticed in some pumping sets in water supply schemes during the last years.

1) Stages coupled by threaded connection
2) Improper fixing of stamping with stator body of the motors
3) Improper threading in discharge outlet
4) Inaccuracies of dimensional tolerance
5) The problems experienced about the use of submersible pumps

Gandhi B.K., Agarwal M.D., Sharma B.M., [4] have mentioned about the testing of the submersible pump sets. Its not possible to test all the pumps manufactured but a sample testing agreed by manufacturer and purchaser to keep the process of manufacturing within control should be adopted.

Gandhi B.K., Sharma B.M., [5] discuss about the submersible pumps their importance and their applications. The constructional features are discussed about submersible pumps and submersible motors (dry type and wet winding type).And the raw material required for manufacturing a submersible pumps are discussed. The change in raw material requirement for each stage in the pump and each hp of the motor and estimation of the raw material required by the manufacturer for making different pump sets.

Gupta J.K.[6] mentions about the corrosion and the faulty construction and maintenance of the operating equipment.

Jain V.K. [7] mentioned about the submersible pumps selection and their operation. The common causes of break down of submersible pumps and the common troubles in submersible pump operation are discussed.

Mody J.D., [8] discusses about the submersible pumps, criteria for selection of submersible pump sets by the customers. Factors improving the performance of the submersible pumps, selection of pumps, installation of pump sets and the efficiency of the pumps and their maintenance.

Tiwari N.C. and Bhootra K.C. [9] discuss about the international standard to the Indian standards of the submersible pumps and about the technological status of the submersible pump sets in India

Comparative data of Indian and international submersible pump sets are given. The gap between Indian and international levels of technological advancement can be narrowed down only by sincere and dedicated R&D efforts.

Submersible pump testing to measure the rate of flow ,head measurement , power measurement, speed measurement, testing procedures for submersible motor testing , routing tests are discussed.

2.2 Constructional Features

Submersible pumps have basically bowl assembly construction similar to one observed in vertical turbine type pumps but they are closely coupled to a submersible motor by means of suitable coupling arrangement instead of long shaft assembly provided in the vertical turbine pumps.

In most of the applications either radial or mixed flow impellers are used depending on the capacity, head and maximum limit on outside diameter of the pump. As all these types of submersible pumps are used to lift liquids from a greater depth, they generally have multi stage construction. Each stage increases one bowl assembly which normally comprises of an impeller, a diffuser and a sleeve.

All submersible pumps have side entry at the suction case. In most of the cases, the submersible pumps are used to lift the water or liquid with some amount of foreign material, hence a strainer is provided at the pump suction to prevent the entry of bigger foreign material which may choke the impeller passages.

In certain cases some manufacturers provide a discharge case, the basic function of which is to diffuse the flow and streamline it after the last stage bowl. In addition a non return valve is also provided at the top of the discharge case.

2.2.1 Selection of the pump

Correct selection and correct material specification are the basic aspects ensuring the reliability of the pump and motor set. A pump with minimum number of stages and maximum pump efficiency can be the most economical pump.

The selection of the pump requires the following:-

I. Type of tube well (open well or open well with boring).
II. Chemical analysis of water and turbidity.
III. Minimum inside diameter of well.
IV. Depth of open well or deep well.
V. Amount of water to be pumped.
VI. Static water level.
VII. Delivery pipe diameter and length.
VIII. Draw down.
IX. Lift above ground.
X. Yield capacity of well.
XI. Total length of the cable required.
XII. Line voltage.
XIII. The pump should be such that the pump should not get over loaded in its entire working range.
XIV. The total head requirement can be found our by the following factors to the head requirement i.e. static height from the draw down level to the overhead tank outlet.
XV. Friction losses for bends.

2.2.2 Selection of the cable

The cables must be suitable for underwater application if the pump is a submersible pump

And adequate in size to operate within the temperature limits and maintain proper voltage at the motor. For this we have to consider 2 points

(A) The rated current of the motor shall be as per the product information sheet. From its rated current , one can actually select the basic size of the cable

(B) The length of the cable is well head plus the distance of power supply via pump controls or the pump house.

2.2.3 Starter for 3 phase

The submersible motors when directly switched on consume more current. The initial current is objectionable due to large line voltage drop. Therefore to avoid the initial short circuit of the motor the voltage applied to the motor terminals is reduced using star delta. Most of the starters are also fitted with the under voltage protection relay, which does not allow motor to start than the specified rated voltage. The starter should be dust proof.

Factors for selection of Pump set:

1. Yield of the bore well
2. Depth to low water level of bore
3. Height and length to which water is to be pumped
4. Water requirements

A well drilled in summer normally shows a low yield which is likely to improve in the monsoon. Similarly a well drilled in October may even become dry in summer.

It is a good practice to select a pump such that it does not exceed the maximum yield of the well. Thus ensures that

- The pump does not run dry in the bore thereby enhancing the pump's life.
- Water of the bore does not become saline.

Normally the driller of the well is supposed to provide the accurate information regarding,

- No. of veins and distance from ground level at which these veins have been trapped
- The maximum yield of the well

Depth to low water level

If the pumped capacity of the well is matched to the yield of the well then obviously the maximum depth to low water level has to adjust to the height at which the last vein is tapped in the bore.

Height and length of delivery point

The height to which the water is to be pumped has to be precisely estimated. This is most important especially on long upward inclined terrains. The length of the pipeline and the height to which the water is to be pumped together with the depth of low water level decides the total head f the pump set. Friction in long pipeline is to be calculated. The higher diameter pipe gives lower frictional heads. This helps to reduce load on pump and thus increase it life.

2.3 Operation of Submersible Pumps

Before operation of the pump, the direction of the rotation of the pump is checked. To ascertain the correct direction of the rotation the motor is run in both directions with stop valve closed. The direction is changed by interchanging two of the phases. The direction which gives higher pressure at pressure gauge reducing to the correct one and quantity of water should then be judged.

Sluice valve of pump should be initially such regulated that a clear water start coming out of tube well. Generally pump should not allowed to remain stationary for a period more than 14 days at a stretch as otherwise, line, iron and other substances tend to settle in the bearings, impeller gaps and block of pump rotor.

Common cause of breakdown of submersible pumps:

(A) The most common cause of breakdown of submersible pump is the burning of motors. The following are the common causes of burning of motors

- Uniform burning of motor winding due to formation of the insulating layers.
- Burning of motor due to overloading.
- Burning of the motor due to excessive number of starts.
- Burning of motor due to electrical discharge.
- Burning of motor due to wrong repairs and replacement.

(B) Damage of motor and pump parts due to manufacturing of repaired defects.
(C) Damage to pump or motor due to heavy fine sand pumping.
(D) Fallen pump and motors.
(E) Seizure of pump and motor bearings.

Remedies of above causes must be taken immediately for proper function of the tube well.

2.4 Common Troubles in Submersible Pump Operation

1. Pump fails to start.
2. Pump starts but the discharge is lower or there is no discharge at all.
3. Pump runs and discharges steadily, but the discharge is below normal.
4. Pump runs and discharges intermittently and air bubbles are present in discharge.

Due remedies should be taken after diagnosing the trouble and remedial measures for proper function of tube well.

Typical submersible pumps and their cross sections are given in Figs. 2.1 and 2.2 respectively. The general layout of the submersible pump is given in Fig. 2.3.

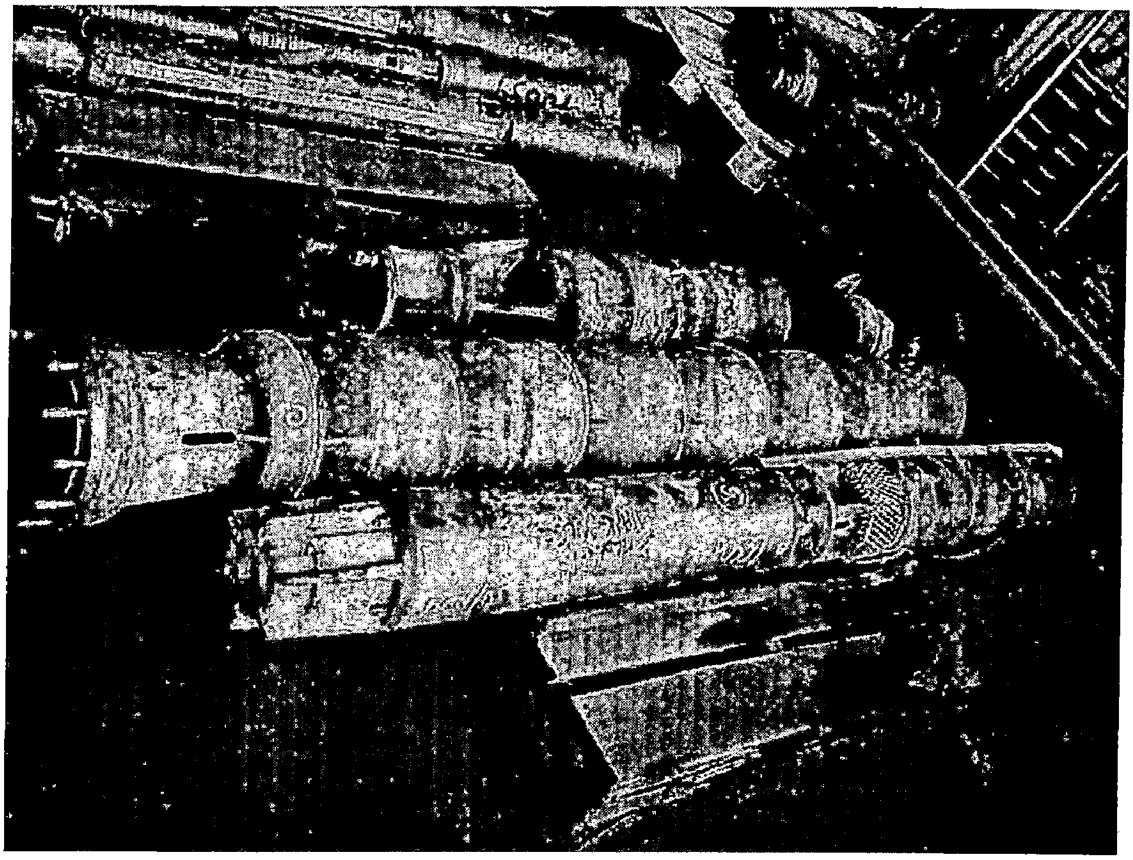

Fig: 2.1 showing Submersible Pumps

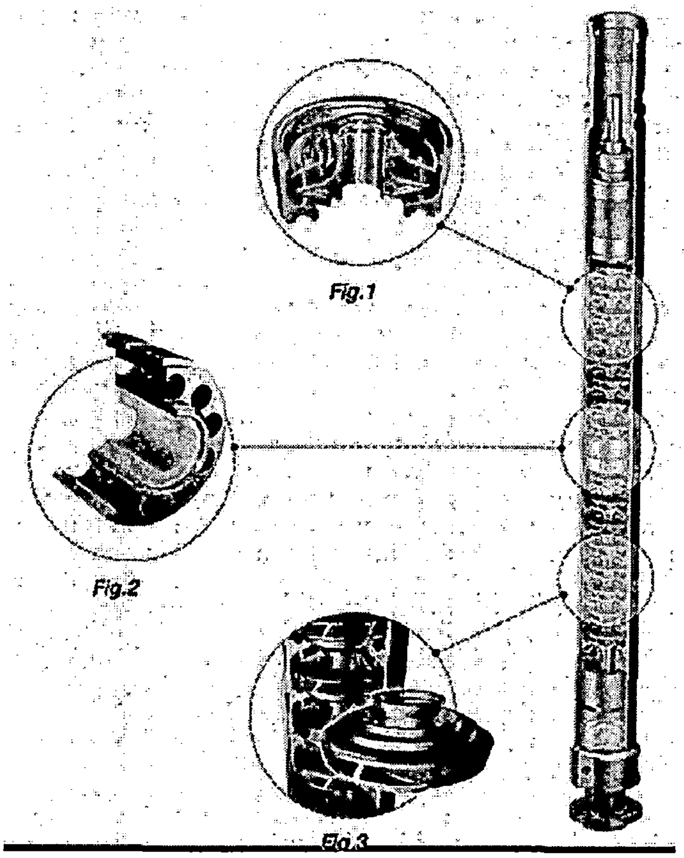

Fig. 2.2: Cross section of a Submersible Pump

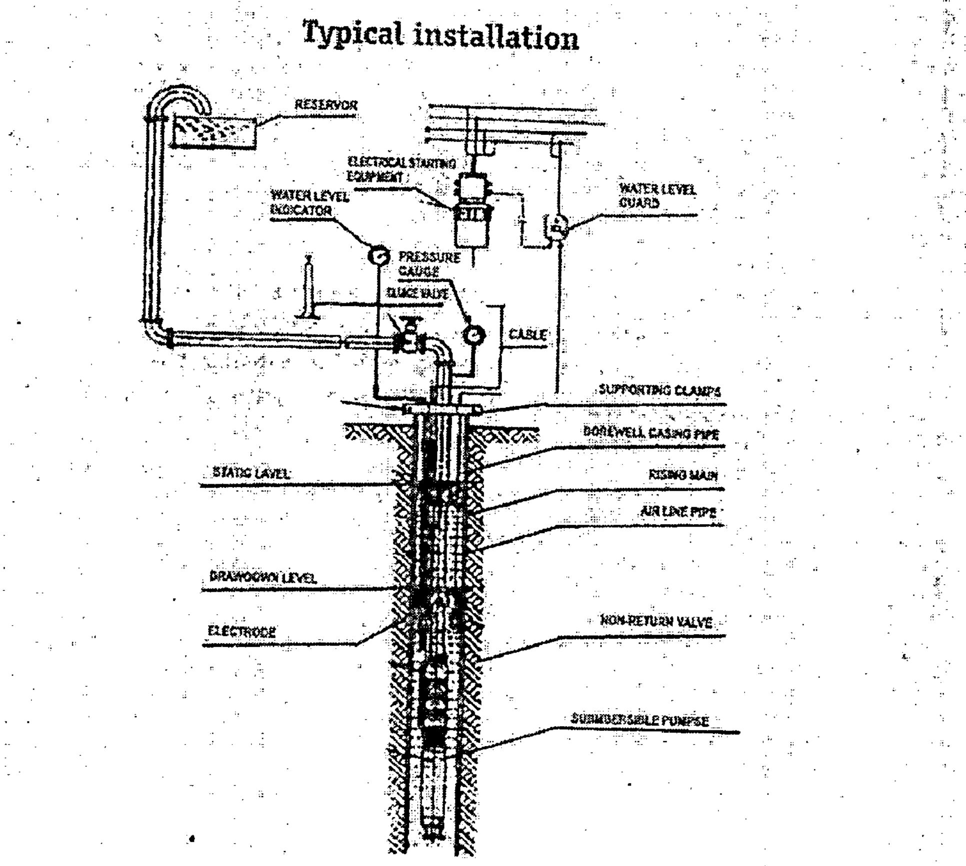

Fig. 2.3: General layout of the Submersible Pump

2.5 Latest Trends in Submersible Pumps

At international level, submersible pumps find 30% share of total pump sets demand against 15% in our country. The size wise share of 100 mm and 200 mm submersible pumps is 5%, 70% and 25% respectively in our country against 55%, 35% and 10% at the international level. This is mainly because in our country submersible pumps mostly find application in agriculture and water supply schemes and it has yet to establish in domestic application. In spite of low efficiency of jet pumps, today people prefer to go for these pumps in domestic application for low initial investment, more reliability and reduction in cost of 100 mm submersible pumps can change this scene.

Increased electrification on rural areas would also increase the demand for agricultural and water supply application.

We can see that there is substantial growth potential for submersible pumps as these pumps are economical and energy efficient as compared to other alternatives available.

As compared to the international level, the technological status of submersible pump sets in our country is very dismal. Majority of the pump sets available in the country are using design of fifties due to lack of R&D efforts. Most of the manufacturers are resorting to the reverse engineering on available pump sets in the country. Many of the manufacturers are simply assembling the parts purchased from the market. We are far behind in efficiencies, material content and manufacturing technology from international level.

The gap between Indian and international levels of technological advancement can be narrowed down only by sincere and dedicated R&D efforts. But the transition from Indian technology cannot be overnight. Concentrated efforts are required to absorb foreign technology to suit operating conditions prevailing in India.

Chapter 3

STUDY AREA

3.1 Climate

The climate of the area is tropical monsoon with four distinct seasons: summer-March to May, monsoon- June to September, post-monsoon- October to November and winter- December to February marked. Climate is composite, hot during summer, cold during winter and humid during Monsoon season. Average maximum and minimum temperatures in January are 20.2 ^{0}C and 6.5 ^{0}C and corresponding temperatures in July are 37.6 ^{0}C and 23 ^{0}C. The average annual sunshine duration is 2800 hrs.

3.2 Rainfall

The area forms part of semi-arid tract and receive rainfall by south-west monsoon season. The annual rainfall is about 1050 mm. out of which major amount occurs during south west monsoon in months of june to September. There exists a wide varying of rainfall both partially and temporarily in the area.

3.3 Soil type

In the roorkee block and bhagawanpur block, the soil type is alluvium, sandy loam to clay loam. The topography has played a more dominant role than climate and vegetation in the formation of the soils

3.4 Agriculture

There are two cropping season namely Kharif from June to December and Rabi from December to May in practice.The major Kharif crops are paddy, maize and the main Rabi crop is wheat. Sugarcane is also extensively cultivated. The largest area is covered by wheat followed by sugarcane, paddy, maize, pulses, groundnut and cotton. Production of sugarcane provides good commercial prospects. Irrigation plays an important role and in bringing more area under agriculture. Tubewells and canals are the important source of irrigation in the area.

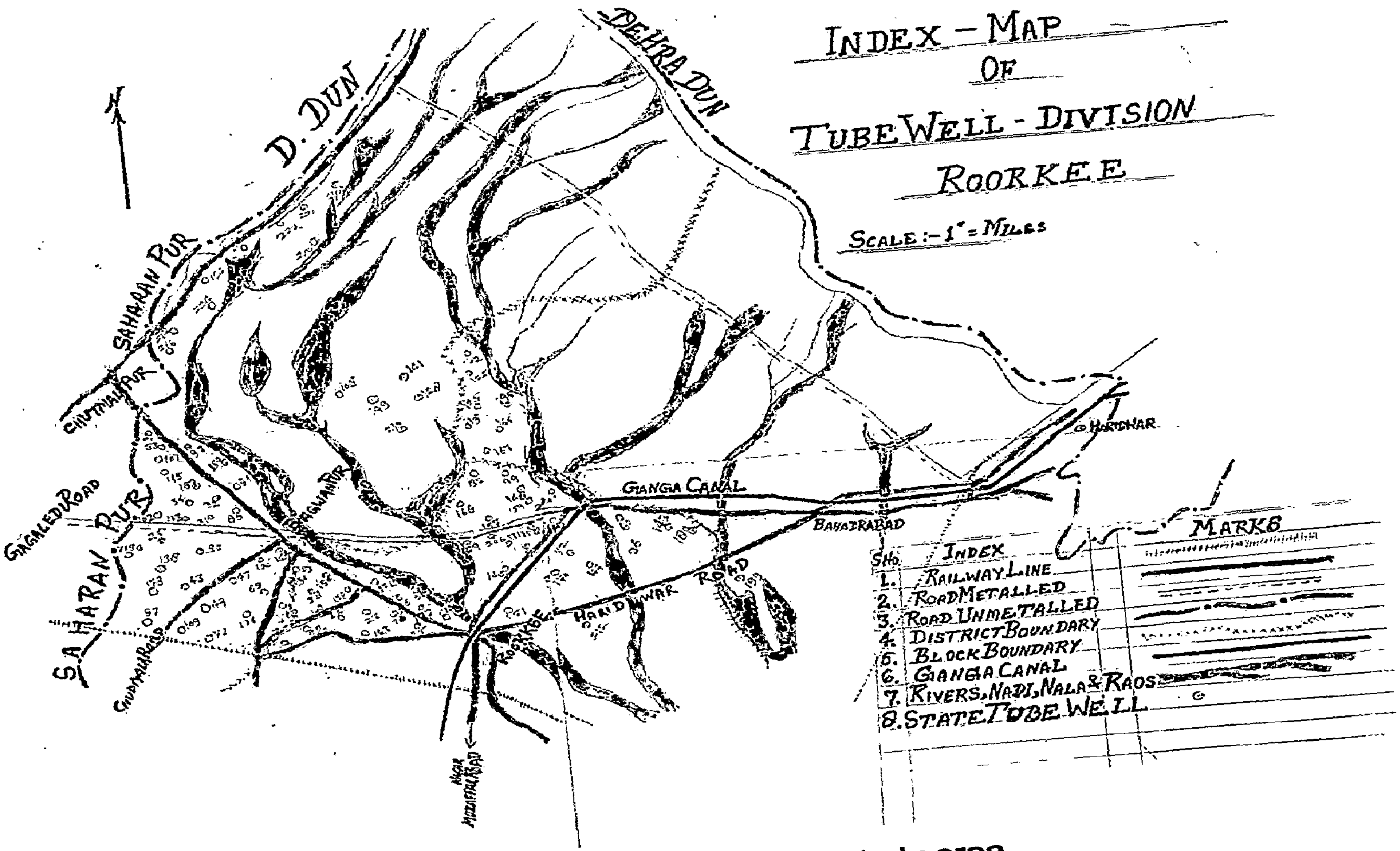

Fig.3.1: Map of study area

Chapter 4

DATA COLLECTION

4.1 General

The data of 48 tube wells are collected in the Roorkee block and the Bhagawanpur block for which the department of tube wells was contacted which provided all the transportation arrangements. Data is collected for the discharge, the pipe lengths, the current consumption of the pumps, power rating of the pumps. The depth of the normal level and the drawdown levels were collected from the tube wells office.

The head for all the tube wells is calculated from the data collected which is discussed in the results and discussion chapter. The power of the pumps is also collected from the different tube wells.

The discharge is measured from the v notch at the site where it is a 90 degrees v notch. For measuring the discharge the distance over the v notch is measured in height in inches according to that the discharge is known which is calibrated on the v notch. The calibration table available with the tube well division in Roorkee is given in Table 4.1.

Table 4.1 Discharge over V Notch

Head in Inches	Discharge in gph
7	15300
$7^{1/4}$	16675
$7^{3/4}$	18112
8	21152
$8^{1/2}$	24080
$8^{3/4}$	26438
9	28371
$9^{1/4}$	30367
$9^{1/2}$	32429
$9^{3/4}$	34587
10	36813

The discharge in GPH is converted into LPS

For conversion of GPH to GPM.

1 GPM = GPH/60.

For conversion of GPM to LPS

111 GPM = $\frac{111*4.54}{60}$ =8.40 LPS

4.2 Data Collected

The data for twelve wells namely W1 t0 W12 as shown in Table 4.2 (i.e.) from well numbers 6RG to 192RG (RG-Roorkee Group) has been collected for the present study. The data for various parameters has been collected such as power rating of the pumps, the depth of normal water level, the rated current of the motors and the discharge of the pumps. The discharge of pumps has been measured with V notch where the calibration of the v notch has been mentioned in Table 4.1.

4.2.1 Data for Discharge of $0.03577 m^3/sec$

The data is arranged in such a manner that all the pumps having same discharge of $0.03577 m^3/sec$ are placed in Table 4.2 with a diameter of 0.15 m. There are 2 wells of same discharge from well 1 to well 12, various parameters are calculated and given in Table 4.2. It can be seen that the depth of the normal water level varies from 24.99 to 28.95 m. The length of the pipe from the top of the well to the discharge point the length varies from 3 m to 3.2 m. The power rating of the pump varies from 13.04 KW to 20.50 KW. The rated current of the pumps varies from 25 A to 41 A. The drawdown of the wells varies from 4.87 to 6.7 m. Also the total maximum head varies from 32.07m to 36.39 m

From the available data the total Minimum head is calculated as:

Static head h_s = depth of the normal water level = 26.82m

Friction head $h_f = \frac{flQ^2}{12d^5}$

Where,

f = friction factor

l = from top of well to discharge point

Q = discharge

d = diameter of the pipe

$$h_f = \frac{0.02*30.02*(0.03577)^2}{12*(0.15)^5} = 0.8430 m$$

$$v_d = \frac{4Q}{\pi d^2}$$

Where, v_d = discharge velocity(m/s)

Kinetic energy head $\frac{v^2}{2g}$ = 0.2087

Minimum operation head = static head + friction head + kinetic energy head

= 26.82+0.8430+0.2087 = 27.87m

Total maximum operating head =total min operating head + drawdown

= 27.87 + 6.09 = 32.74 m

4.2.2 Data for Discharge of 0.013103m³/sec

For discharge of 0.03103m³/sec 8 wells are grouped together from 25RG to 209RG in Table 4.3. Where the depth of the normal water level ranges from 24.99 to 28.95m. The length of the pipe from the top of the well to the discharge point is varying from 3 to 6.1m. The power rating of the pump is varying from 13.04 to 20.50 K.W. The rated current of all the pumps 8 pumps at a rated voltage of 415V is varying from 25A to 40A.

The drawdown level is varying from 4.57m to 7.31 m. The total minimum head is varying between 26.37 m to 29.84 m. The details of all the parameters are are given in Table 4.3 are already explained.

4.2.3 Data for discharge of 0.02726m³/sec

For discharge of 0.02726m³/sec 8 wells are grouped together from 33RG to 177RG in Table 4.4. Where the depth of the normal water level ranges from 25.9 to 28.04m. The length of the pipe from the top of the well to the discharge point is varying from 3 to 3.2m. The power rating of the pump is varying from 14.91 to 18.64 K.W. The rated current of all the pumps 8 pumps at a rated voltage of 415V is varying from 29A to 36.5A.

The drawdown level is varying from 3.04 m to 15.24 m. The total minimum head is varying between 26.46 m to 28.64 m. The details of all the parameters given in Table 4.4 are already explained.

4.2.4 Data for discharge of 0.03829m^3/sec

For discharge of 0.03829m^3/sec 3 wells are grouped together from 76RG to 168RG in Table 4.5. Where the depth of the normal water level ranges from 27.42to 28.04m. The length of the pipe from the top of the well to the discharge point is varying from 3 to 3.2m. The power rating of the pump is varying from 16.77 to 18.64 K.W. The rated current of all the 3 pumps at a rated voltage of 415V is varying from 33A to 35A. The drawdown level is varying from 5.48 m to 8.53 m. The total minimum head is varying between 28.64 m to 29.64 m. The details of all the parameters given in Table 4.4 are already explained.

4.2.5 Data for discharge of 0.04089m^3/sec

For discharge of 0.04089m^3/sec 3 wells are grouped together from 147RG to 201RG in Table 4.6. Where the depth of the normal water level ranges from 24.99 to 26.82 m. The length of the pipe from the top of the well to the discharge point is varying from 3 to 3.1m. The power rating of the pump is varying from 13.04 to 16.77 K.W. The rated current of all the 3 pumps at a rated voltage of 415V is varying from 25A to 33A. The drawdown level is varying from 3.04 m to 7.62 m. The total minimum head is varying between 26.29 m to 28.18 m. The details of all the parameters given in Table 4.6 are already explained.

4.2.6 Data for Discharge of 0.02284m^3/sec

For discharge of 0.04089m^3/sec 2 wells are grouped together from 83RG and 141RG in Table 4.7. Where the depth of the normal water level ranges from 27.42 to 28.95 m. The length of the pipe from the top of the well to the discharge point is 3.2 m. The power rating of the pumps is 18.64. The rated current of all the 2 pumps at a rated voltage of 415V is 36A. The drawdown level is varying from 10.97 m to 14.63 m. The total minimum head is varying between 28.02 m to 29.53 m. The details of all the parameters given in Table 4.7 are already explained.

4.2.7 Data for Discharge of 0.00840m^3/sec

For discharge of 0.00840m^3/sec 2 wells are grouped together from 33RG and 1021RG in Table 4.8. Where the depth of the normal water level ranges from 25.29 to 27.73 m. The length of the pipe from the top of the well to the discharge point is varying from 2.82 to 3.2. The power rating of the pumps is varying from 13.04 to 18.64. The rated current of all the 2 pumps at a rated voltage of 415V is varying from 26A to 36.5A.The drawdown level is varying from 10.97 m to 14.63 m. The total minimum head is varying between 8.53 m to 12.19 m. The total maximum head is varying from 33.89 to 39.99 m. The details of all the parameters given in Table 4.8 are already explained.

4.2.8 Data for Discharge of 0.04625m^3/sec

For discharge of 0.04625m^3/sec. In this discharge there is only one pump 212RG in Table 4.9, where the depth of the normal water level is 24.38 m. The length of the pipe from the top of the well to the discharge point is 6.1m. The power rating of the pump is 13.04. The rated current of pump at a rated voltage of 415V is 24A.The drawdown level is varying from 3.04 m to 7.62 m. The total minimum head is 26.86m. The drawdown of the well is 3.96m. The details of all the parameters given in Table 4.9 are already explained.

4.2.9 Data for Discharge of 0.01929m^3/sec

For discharge of 0.01929m^3/sec. In this discharge there is only one pump 212RG in Table 4.10, where the depth of the normal water level is 27.43 m. The length of the pipe from the top of the well to the discharge point is 3.2m. The power rating of the pump is 13.04. The rated current of pump at a rated voltage of 415V is 36A.The drawdown level is 6.70 m. The total minimum head is 27.83m. The drawdown of the well is 6.70 m. The details of all the parameters given in Table 4.10 are already explained.

4.2.10 Data for Discharge of 0.02569m^3/sec

For discharge of 0.02569 m^3/sec. In this discharge there is only one pump 32RG in Table 4.11, where the depth of the normal water level is 26.51 m. The length of the pipe from the top of the well to the discharge point is 3.1m. The power rating of the pump is 16.77. The rated current of pump at a rated voltage of 415V is 33A.The drawdown level is 6.70 m. The total minimum head is 27.20m. The drawdown of the well is 10.66 m. The details of all the parameters given in Table 4.11 are already explained.

Table 4.2: Details of pumping system used for ground water pumping from different tube wells of pipe diameter 150mm for flow rate of 0.03577 m^3/sec.

Parameters	W1 6RG	W2 26RG	W3 29RG	W4 60RG	W5 87RG	W6 120RG	W7 143RG	W8 157RG	W9 158RG	W10 159RG	W11 171RG	W12 192RG
Depth of normal water level(m)	24.99	26.82	26.82	24.99	25.9	26.82	24.38	26.82	28.04	24.38	28.95	27.43
From top of well to the discharge point (m)	3	3	3.2	3	3.2	3	3.1	3	3.2	3.2	3.2	3.2
Power rating of the motor (m)	13.04	16.77	16.77	13.04	14.91	14.914	13.04	16.77	20.50	13.04	20.50	18.64
Rated Current (A) rated at voltage of 415V	25	30	33.25	25.75	21	29	25.5	33	36	25.5	41	36
Total Min Head (m)	25.98	27.86	27.87	25.98	26.92	27.86	25.36	29.12	27.86	25.36	30.06	28.50
Draw/down (m)	6.09	4.87	4.87	7.01	8.53	8.53	6.4	6.7	8.53	6.7	6.07	4.87
Total max head (m)	32.07	32.73	32.74	32.99	35.43	36.39	31.76	35.82	36.39	32.09	36.13	33.37

Table 4.3: Details of pumping system used for ground water pumping from different tube wells of 150mm for flow rate of 0.03103m3/sec

Parameters	W1 25RG	W3 94RG	W4 99RG	W5 123RG	W5 149RG	W6 179RG	W7 180RG	W8 209RG
Depth of the normal water level in the well (m)	26.82	25.90	28.04	24.99	25.90	26.82	26.82	28.95
From top of well to the discharge point (m)	3.2	3	3.2	2.9	3.2	3	3	6.1
Power rating of the motor (m)	16.77	14.91	18.64	13.04	14.91	16.77	16.77	20.50
Rated Current rated at voltage of 415V	33A	29A	37A	25A	29A	33A	29A	40A
Total min Head (m)	26.37	26.66	28.85	25.73	27.60	27.60	29.84	26.67
Draw/down (m)	4.57	6.4	6.09	6.09	7.31	6.09	6.09	6.07
Total max head(m)	30.94	33.04	34.91	31.82	34.91	33.69	35.93	32.74

Table 4.4: Details of pumping system used for ground water pumping from different tube wells of 150mm for flow rate of 0.02726m^3/sec

Parameters	W1 33RG	W2 89RG	W3 97RG	W4 107RG	W5 108RG	W5 113RG	W5 115RG	W6 128RG	W7 144RG	W8 177RG
Depth of the normal water level in the well (m)	25.9	26.82	27.43	27.43	25.9	26.21	25.90	28.04	26.82	26.51
From top of the well to the discharge point (m)	2.9	2.9	2.9	3	3	3	3.2	3.2	3	3.2
Power rating of the motor (K.W)	14.91	16.77	16.77	18.64	14.91	14.91	14.91	16.77	16.77	16.77
Rated Current rated at voltage of 415V	29A	36.5A	36.5A	36.5A	30A	44A	29A	33A	33A	33A
Total max Head (m)	26.46	27.40	28.02	28.02	26.46	26.78	26.47	28.64	27.40	27.10
Draw/down (m)	8.53	13.41	15.24	16.45	3.04	4.8	6.70	10.97	5.18	6.70
Total max head(m)	34.99	40.81	43.26	44.47	29.5	31.58	33.17	39.61	32.58	33.80

Table 4.5 : Details of pumping system used for ground water pumping from different tube wells of 150mm for flow rate of 0.03829m3/sec.

Parameters	W1 76RG	W2 92RG	W3 168RG
Depth of the normal water level in the well (m)	27.43	27.42	28.04
From top of the well to the discharge point (m)	3	3.2	3.2
Power rating of the motor (K.W)	16.77	16.77	18.64
Rated Current rated at voltage of 415V	33A	33A	35A
Total min Head (m)	28.64	28.65	29.64
Draw/down (m)	5.48	7.31	8.53
Total max head(m)	34.12	35.96	38.17

Table 4.6: Details of pumping system used for ground water pumping from different tube wells of 150mm for flow rate of 0.04089m3/sec.

Parameters	W1 147RG	W2 151RG	W3 201RG
Depth of the normal water level in the well (m)	24.99	25.90	26.82
From top of the well to the discharge point (m)	3.1	3	3
Power rating of the motor (K.W)	13.04	14.91	16.77
Rated Current rated at voltage of 415V	25A	29A	33A
Total min Head (m)	26.29	27.23	28.18
Draw/down (m)	7.62	3.04	6.09
Total max head(m)	33.91	30.27	34.27

Table 4.7 : Details of pumping system used for ground water pumping from different tube wells of 150mm for flow rate of 0.02284m3/sec.

Parameters	W1 83RG	W2 141RG
Depth of the normal water level in the well (m)	27.43	28.95
From top of the well to the discharge point (m)	3.2	3.2
Power rating of the motor (m)	18.64	18.64
Rated Current rated at voltage of 415V	36A	36A
Head (m)	28.02	29.53
Draw/down (m)	14.63	10.97
Total max head(m)	42.65	40.5

Table 4.8 : Details of pumping system used for ground water pumping from different tube wells of 150mm for flow rate of 0.00840m^3/sec.

Parameters	W1 33RG	W2 102RG
Depth of the normal water level in the well (m)	25.29	27.73
From top of the well to the discharge point (m)	2.82	3.2
Power rating of the motor (m)	13.04	18.64
Rated Current rated at voltage of 415V	26A	36.5A
Total minimum Head (m)	25.36	27.80
Draw/down (m)	8.53	12.19
Total max head(m)	33.89	39.99

Table 4.9 : Details of pumping system used for ground water pumping from different tube wells of 150mm for flow rate of 0.04625m3/sec.

Parameters	W1 212RG
Depth of the normal water level in the well (m)	24.38
From top of the well to the discharge point (m)	6.1
Power rating of the motor (m)	13.04
Rated Current rated at voltage of 415V	24A
Head (m)	26.86
Draw/down (m)	3.96
Total max head(m)	30.82

Table 4.10 : Details of pumping system used for ground water pumping from different tube wells of 150mm for flow rate of 0.01929m3/sec.

Parameters	W1 218RG
Depth of the normal water level in the well (m)	27.43
From top of the well to the discharge point (m)	3.2
Power rating of the motor (m)	13.04
Rated Current rated at voltage of 415V	36A
Head (m)	27.83
Draw/down (m)	6.70
Total max head(m)	34.53

Table 4.11 : Details of pumping system used for ground water pumping from different tube wells of 150mm for flow rate of $0.02569m^3/sec$.

Parameters	W1 32RG
Depth of the normal water level in the well (m)	26.51
From top of the well to the discharge point (m)	3.1
Power rating of the motor (m)	16.77
Rated Current rated at voltage of 415V	33A
Head (m)	27.20
Draw/down (m)	10.66
Total max head(m)	37.86

Chapter 5

RESULTS AND DISCUSSION

5.1 General

The present study in the Roorkee and Bhagawanpur blocks of Haridwar district, Uttaranchal has been taken to meet out the objectives related to performance evaluation of pumping system. The relevant data and information related to ground water pumping system has been collected from the field and Department of Tubewell division, Roorkee. The data has been utilized to analyse the existing pumping systems for which various parameters namely friction head, total minimum head, and discharge velocity are calculated.

5.2 Analysis and Results

In Table 5.1 for discharge of 0.03577m^3/sec with the discharge velocity of 2.042 m/sec, the data is collected from well 1 to well 6 with well numbers 6RG, 26RG, 29 RG, 60 RG, 87 RG and 120RG. The calculations are made for total minimum head for which friction head is calculated. The calculations made are already explained in previous chapter.

5.2.1 For discharge of 0.03577m^3/sec

For the discharge of 0.03577 m^3/sec the data of 6 wells is collected for 6RG, 29RG, 60RG, 87RG 120RG in Table 5.1. There are 12 wells which are given in 2 tables 5.1 and 5.2; the calculations are made for total minimum head for which friction head is calculated.

For which the calculations are already explained in the previous chapter. The value of h_f is varying in between 0.7860 to 0.8430. The length of the pipe from top of the well to the discharge point varies from 3 to 3.2m.

The depth of the normal water level is varying from 24.99 to 26.82. The total min head found out is in between 25.98 to 27.86 m. the power of the motor is in between 13.04KW to 16.77 KW.

A Graph is plotted for the well number and the total min head in the table 5.1 as shown in FIG 5.1 where the total min head is varying from 25.98 to 27.86. The drawdown of the tube well is indicated above the head.

From Fig 5.1 It can be seen that the pumps 6 RG and 87RG will fail in the summer as the drawdown is not considered with the normal operating head therefore in summer season the pumps will fail.

It seems that drawdown is not considered for the pumps 87 RG and 120 RG so these pumps of higher power will work at the beginning of the summer season and they will fail as the draw/down level will fall in the summer season. It seems that the drawdown is considered for the pumps 25 RG and 29 RG so these pumps will work throughout the year without any problem.

From Fig.5.2 It can be seen that for the pumps 143RG and 159RG the drawdown is not considered with the normal operating head these pumps will fail in summer season the pumps 157RG, 158RG AND 192RG the drawdown is considered these pumps will not fail in summer season. But it seems that 16.77KW rating pump or 18.64KW pump is enough for the area instead of going for 20.50KW in 192RG we can go for a 16.77KW pump thus there will be power saving.

As there are 12 wells in this discharge category, the parameters are presented in two tables. All the parameters for remaining 6 wells are given in table 5.2 and their variables are shown in Fig 5.2

5.2.2 For Discharge of 0.03103 m^3/sec

There are 12 wells in this category given in 2 tables 5.3 and 5.4. For discharge of 0.03103 m^3/sec in table 5.3 the data for 8 tube wells are collected here the friction head h_f varies from 0.5894 to 0.7407

The depth of normal water level varies from 25.61 to 28.95m. The length of the pipe from top of the well to the discharge point is varying from 3 to 6.1 m. The total pipe length which is the depth of the normal water level + the length of the pipe from the top of the well to the discharge point vary from 28.81 to 35.05 m. The motor power for these 8 wells is in between 13.04 to 20.50 K.W. The various parameters in the table are already discussed.

A graph is plotted between the number of wells and the head and the drawdown is indicated above the head of each pump in FIG 5.3. The total min head is varying from 26.37 to 29.88 m.

From Fig.5.3 it seems that the drawdown is not considered in the pumps 94RG, 123 RG, & 149 RG with the normal operating head so therefore in summer season the pumps will fail.

It seems that drawdown is considered in the pumps 99RG 179RG & 180RG so these pumps will work throughout the year without any problem.

We can see that the pump 209RG is a 20.50KW rating which is not required where we can use a 16.77 KW rating pump. As there are 12 wells in this category the parameters are presented in 2 tables. All the remaining parameters for the 4 wells are given in Table 5.4 and their variations are shown in Fig 5.4

In Fig.5.4 It seems that the drawdown is not considered for the pumps 218RG & 219RG

These pumps may not work in the summer season the pumps 161RG & 170RG will work without any trouble as it seems the drawdown is considered in these pumps.

5.2.3 For Discharge of 0.03829 m^3/sec

There are 3 wells in this category given in Table 5.5. For discharge of 0.03829m^3/sec in Table 5.5 the data for 3 tube wells are collected here the friction head h_f varies from 0.9792 to 1.0165m.

The depth of normal water level varies from 24.99 to 28.95m. The length of the pipe from top of the well to the discharge point is varying from 3 to 6.1 m. The total pipe length which is the depth of the normal water level + the length of the pipe from the top of the well to the discharge point varies from 27.60 to 29.84 m. The motor power for these 8 wells is in between 13.04 to 14.91K.W. The various parameters in the table are already discussed.

A graph is plotted between well number and the head of the wells and drawdown in indicated above the head.

From Fig.5.5 it seems that the drawdown is not considered for the pump 76RG and the remaining 2 pumps the drawdown is considered. So they will work fine.

5.2.4 For Discharge of 0.02726m³/sec

There are 10 wells in this category given in Table 5.6. For discharge of $0.02726m^3/sec$ in table 5.6 the data for 10 tube wells are collected here the friction head h_f varies from 0.449 to 0.487m.

The depth of normal water level varies from 24.99 to 28.95m. The length of the pipe from top of the well to the discharge point is varying from 3 to 6.1 m. The total pipe length which is the depth of the normal water level + the length of the pipe from the top of the well to the discharge point varies from 25.90 to 28.04 m. The motor power for these 8 wells is in between 14.91 to 18.64K.W. The various parameters in the table are already discussed.

A graph is plotted between well number and the head of the wells and drawdown in indicated above the head as show in Fig 5.6

From Fig.5.6 it seems that in the pumps 108RG, 113RG, 115RG, 144RG & 177RG the drawdown is not considered and these pumps are likely to fail in the summer season.

The pumps 89RG, 97RG &108RG with the normal operating head the drawdown is considered so there will not be any problem with these pumps through out the year.

5.2.5 For Discharge of 0.04089m^3/sec

There are 3 wells in this category given in Table 5.7. For discharge of 0.04089m^3/sec in table 5.7 the data for 10 tube wells are collected here the friction head h_f varies from 1.03 to 1.09 m.

The depth of normal water level varies from 24.99 to 26.82 m. The length of the pipe from top of the well to the discharge point is varying from 3 to 3.1 m. The total pipe length which is the depth of the normal water level + the length of the pipe from the top of the well to the discharge point vary from 28.09 to 29.82 m. The motor power for these 8 wells is in between 13.04 to 16.77K.W. The various parameters in the table are already discussed.

A graph is plotted between well number and the head of the wells and drawdown in indicated above the head as show in Fig 5.7

From Fig.5.7 it seems that drawdown is not considered for the pump 147RG this pump will not work satisfactorily. The pump 151RG will not work satisfactorily in the summer season. It seems that the drawdown is considered for the pump 201RG which will work satisfactorily without any problem throughout the year.

5.2.6 For Discharge of 0.0228m^3/sec

There are only 2 wells in this category given in Table 5.8. For discharge of 0.04089m^3/sec in table 5.8 the data for 10 tube wells are collected here the friction head h_f varies from 0.3525 to 0.3696 m.

The depth of normal water level varies from 27.42 to 28.95 m. The length of the pipe from top of the well to the discharge point is 3.2 m. The total pipe length which is the depth of the normal water level +

the length of the pipe from the top of the well to the discharge point vary from 30.63 to 32.15 m. The motor power for these 2 wells is 18.64K.W. The various parameters in the table are already discussed.

5.2.7 For Discharge of 0.00840m³/sec

There are only 2 wells in this category given in Table 5.9. For discharge of 0.00840m³/sec in Table 5.9 the data for 2 tube wells are collected here the friction head h_f varies from 0.0436 to 0.0479 m.

The depth of normal water level varies from 25.29 to 27.73 m. The length of the pipe from top of the well to the discharge point is varying from 2.82 to 3.2 m. The total pipe length which is the depth of the normal water level + the length of the pipe from the top of the well to the discharge point vary from 28.11 to 30.93 m. The motor power for these 2 wells is 13.04 and 18.64K.W. The various parameters in the table are already discussed.

5.2.8 For Discharge of 0.04625m³/sec

There is only one pump in this category given in table 5.10. For discharge of 0.00840m³/sec in Table 5.9 the data for one tube well is given with a motor power of 13.04KW.

5.2.9 For Discharge of 0.01929m³/sec

There is only one pump in this category given in table 5.11. For discharge of 0.01929m³/sec in Table 5.9 the data for one tube well is given with a motor power of 13.04KW.

5.2.10 For Discharge of 0.02569m^3/sec

There is only one pump in this category given in table 5.12. For discharge of 0.02569m^3/sec in Table 5.12 the data for one tube well is given with a motor power of 16.77KW.

Table 5.1: Summary of performance parameters of flow rate of 0.03577 $m^3/\sec$ with a discharge velocity of 2.0242(assuming friction factor of 0.02).

Parameters	W1 6RG	W2 25RG	W3 29RG	W4 60RG	W5 87RG	W6 120RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	0.7860	0.8374	0.8430	0.7860	0.8172	0.8374
Depth of normal water level (m)	24.99	26.82	26.82	24.99	25.90	26.82
Length of delivery pipe (m)	3	3	3.2	3	3.2	3
Total pipe length(m)	27.99	29.82	30.02	27.99	29.1	29.82
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	25.98	27.86	27.87	25.98	26.92	27.86
Motor Power(k.w)	13.049	16.77	16.77	13.049	14.914	14.914

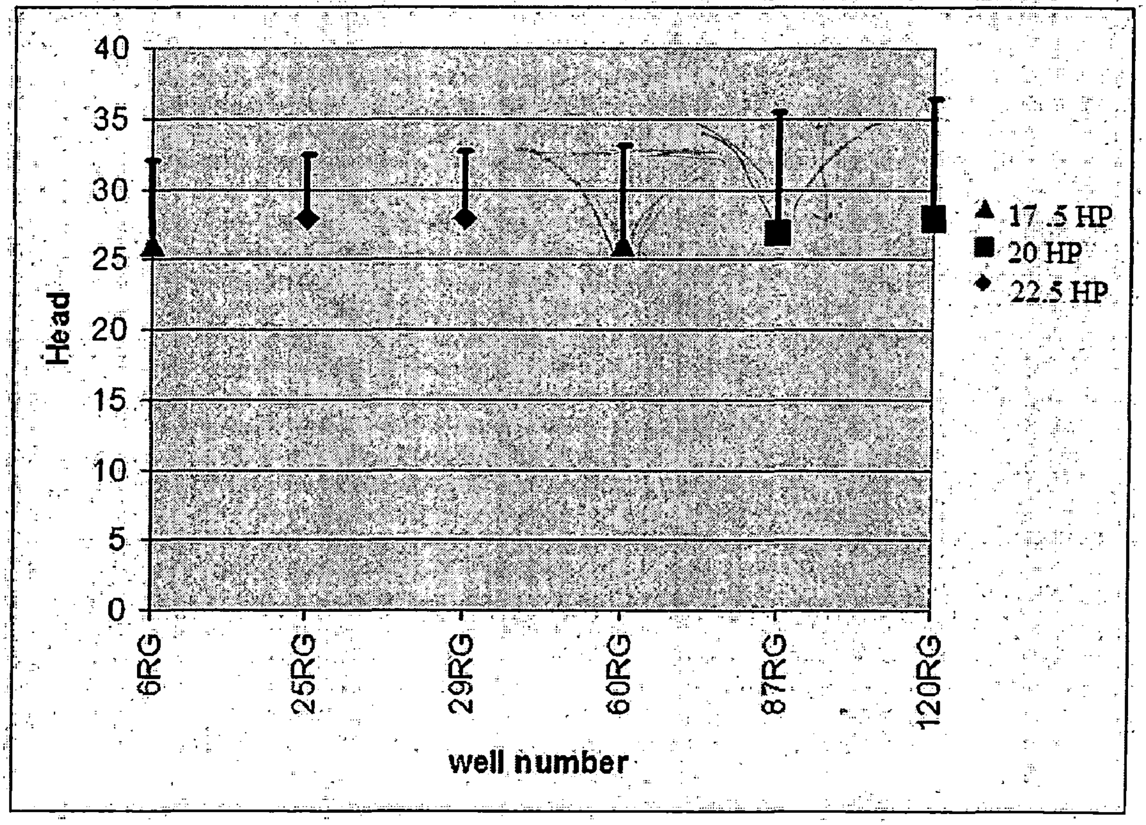

Fig.5.1: Variation of total pumping head requirements for ground water pumping from different tube wells of flow rate of $0.03577 m^3/sec$.

Table 5.2: Summary of performance parameters of flow rate of 0.03577 $m^3/\sec$ with a discharge velocity of 2.0242(assuming friction factor of 0.02).

Parameters	W1 143RG	W2 157RG	W3 158RG	W4 159RG	W5 171RG	W6 192RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	0.7717	0.8773	0.8374	0.7745	0.9028	0.8602
Depth of normal water level (m)	24.38	26.82	28.04	24.38	28.95	27.43
Length of delivery pipe (m)	3.1	3	3.2	3.2	3.2	3.2
Total pipe length(m)	27.48	29.82	31.24	27.58	32.15	
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	25.36	29.1	27.86	25.36	30.06	28.49
Motor Power(k.w)	13.04	16.77	20.50	13.04	20.50	18.64

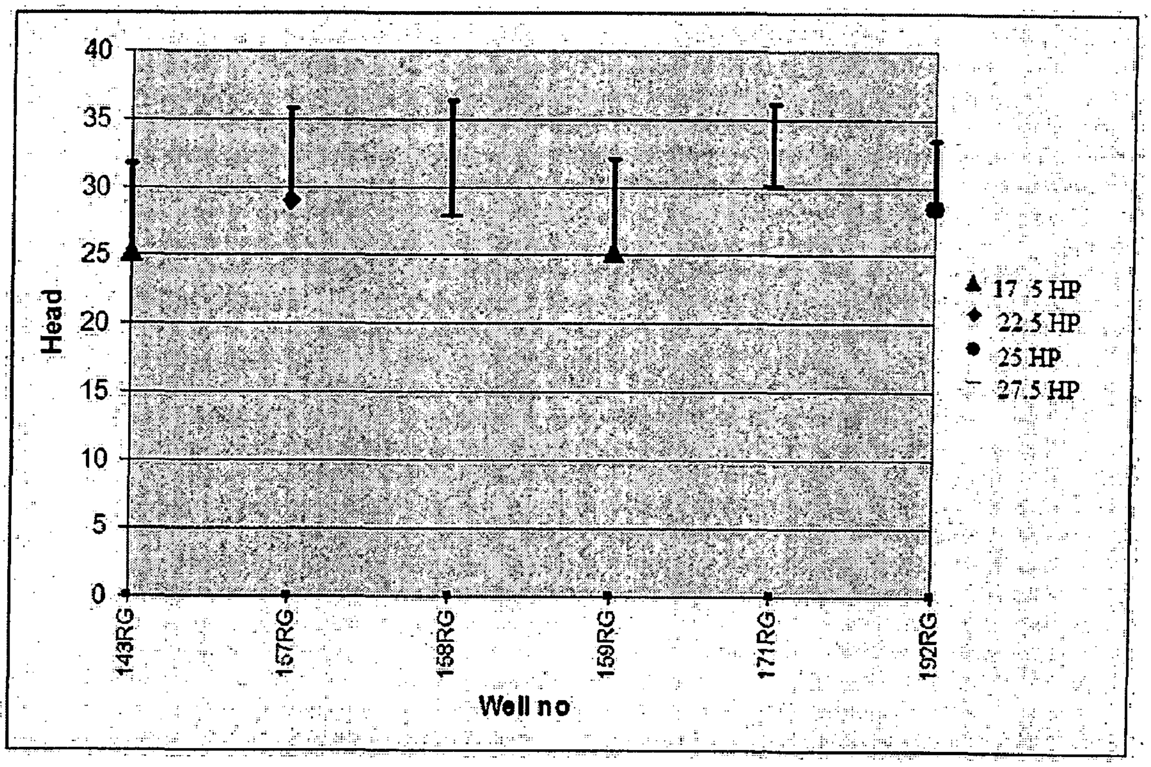

Fig.5.2: Variation of total pumping head requirements for ground water pumping from different tube wells of flow rate of $0.03577 m^3/sec$.

Table 5.3: Summary of performance parameters of flow rate of $0.03103\,m^3/\sec$ with a discharge velocity of 1.75 (assuming friction factor of 0.02).

Parameters	W2 94RG	W3 99RG	W4 123RG	W5 149RG	W6 179RG	W7 180RG	W8 209RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	0.6107	0.6602	0.5894	0.6150	0.6302	0.6302	0.7407
Depth of normal water level (m)	25.90	28.04	24.99	25.90	26.82	26.82	28.95
Length of delivery pipe (m)	3	3.2	2.9	3.2	3	3	6.1
Total pipe length(m)	28.90	31.24	27.89	29.1	29.82	29.82	35.05
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	26.70	28.89	25.77	26.70	27.64	27.64	29.88
Motor Power(k.w)	14.914	18.64	16.77	14.914	13.04	16.77	20.50

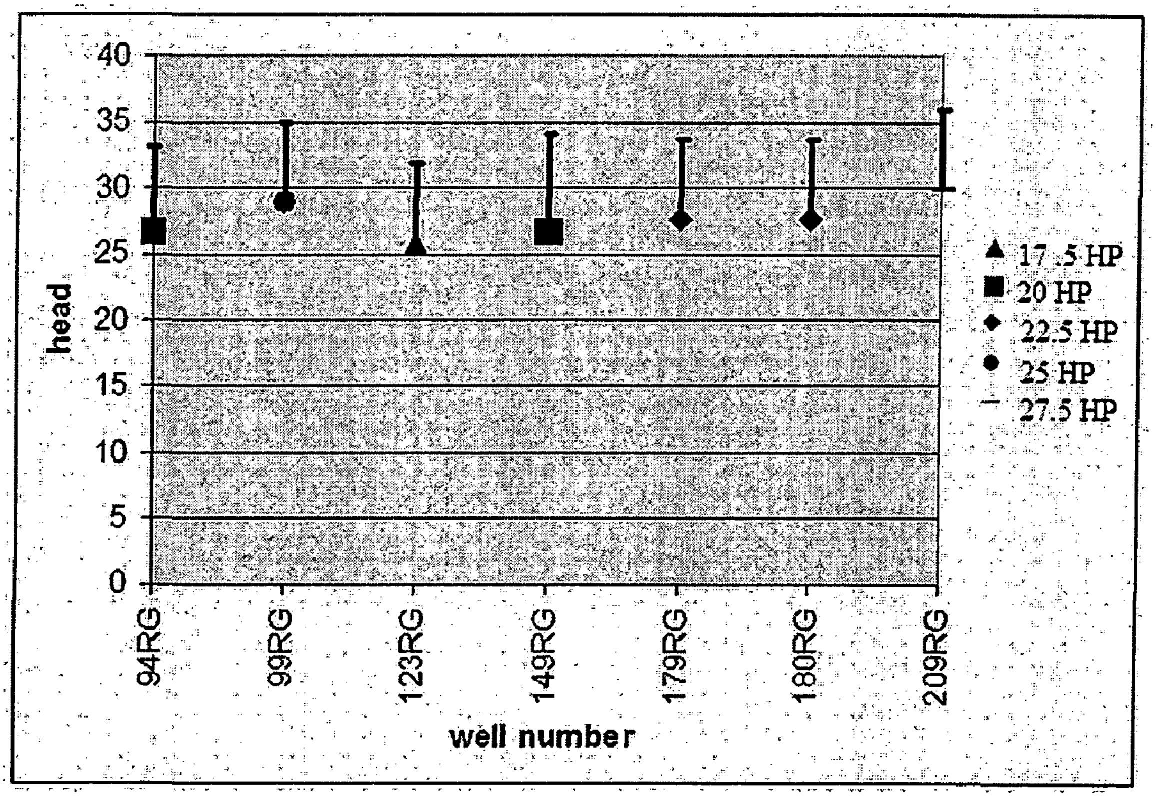

Fig.5.3: Variation of total pumping head requirements for ground water pumping from different tube wells of flow rate of $0.03577 m^3/sec$.

Table 5.4: Summary of performance parameters of flow rate of $0.03103\, m^3/\sec$ with a discharge velocity of 1.75(assuming friction factor of 0.02).

Parameters	W1 161RG	W2 170RG	W3 218RG	W4 219RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	0.6302	0.7407	0.6570	0.6570
Depth of normal water level (m)	26.82	28.95	24.99	24.99
Length of delivery pipe (m)	3	6.1	6.1	6.1
Total length(m)	29.82	35.05	31.09	31.09
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	27.60	29.84	25.80	25.80
Motor Power(k.w)	14.91	13.04	14.91	14.91

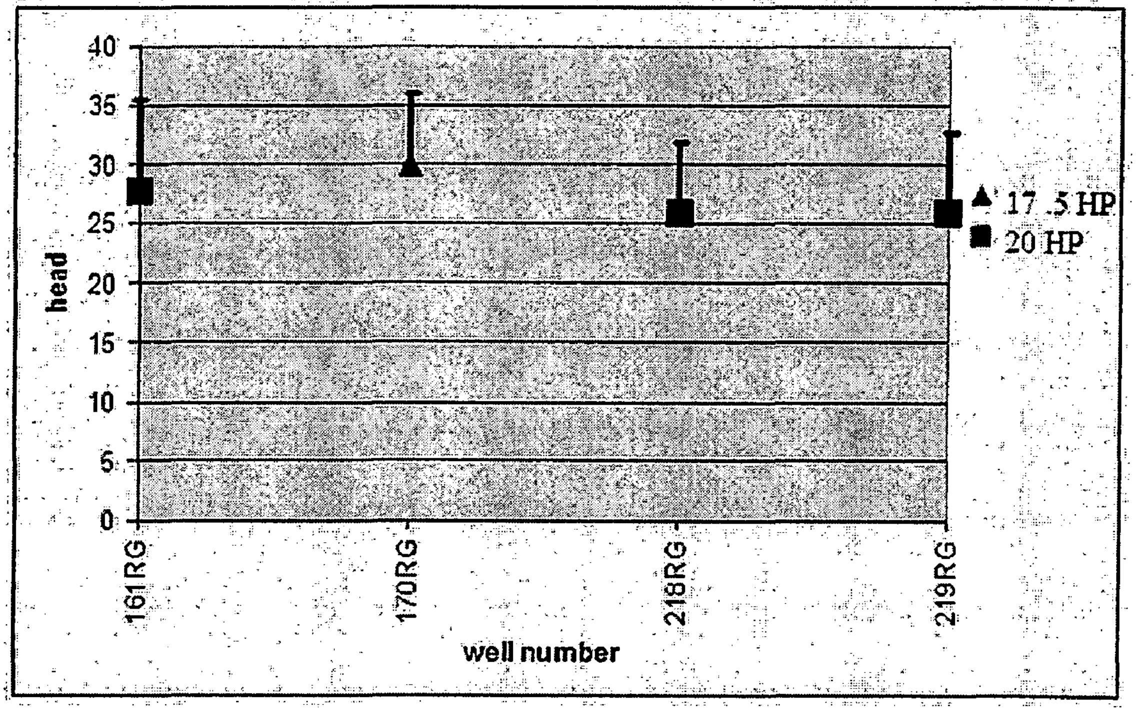

Fig.5.4: Variation of total pumping head requirements for ground water pumping from different tube wells of flow rate of 0.03103 $m^3/\sec$.

Table 5.5: Summary of performance parameters of at flow rate of $0.03829 m^3/sec$ with a discharge velocity of 2.1668m/s (assuming friction factor of 0.02).

Parameters	W1 76RG	W2 92RG	W3 168RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	0.9792	0.9856	1.0165
Depth of normal water level (h_s)	27.43	27.43	28.04
Length of delivery pipe (m)	3	3.2	3.2
Total pipe length(m)	30.43	30.63	31.24
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	28.64	28.65	29.64
Motor Power(k.w)	16.77	16.77	18.64

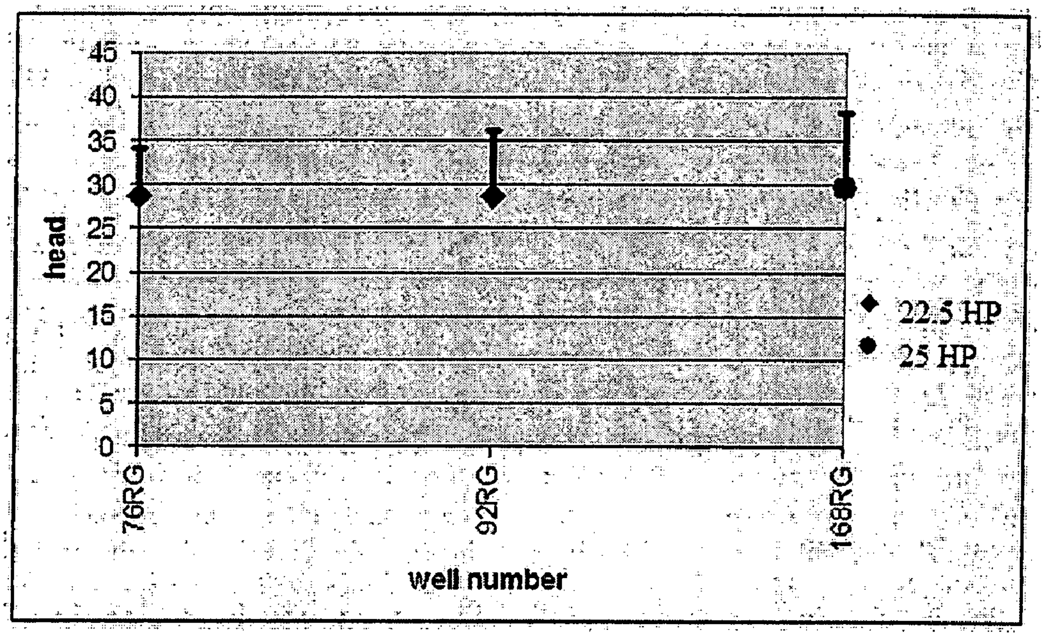

Fig.5.5: Variation of total pumping head requirements for ground water pumping from different tube wells of flow rate of 0.03829 m^3/sec.

Table 5.6: Summary of performance parameters of flow rate of 0.02726 m^3/sec with a discharge velocity of 1.51(assuming friction factor of 0.02).

Parameters	W1 33RG	W2 89RG	W3 97RG	W4 107RG	W5 108RG	W6 113RG	W7 115RG	W8 128RG	W9 144RG	W10 177RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	0.4496	0.4640	0.4735	0.4751	0.4512	0.4560	0.4543	0.4877	0.4655	0.4638
Depth of normal water level (m)	25.90	26.82	27.43	27.43	25.90	26.21	25.90	28.04	26.82	26.51
Length of delivery pipe (m)	2.9	2.9	2.9	3	3	3	3.2	3.2	3	3.2
Total pipe length (m)	28.80	29.72	30.33	30.43	28.90	29.21	29.10	31.24	29.82	29.71
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	26.46	27.40	28.02	28.02	26.46	26.78	26.47	28.64	27.40	27.09
Motor Power(k.w)	14.914	16.77	16.77	18.64	14.914	14.914	14.914	16.77	16.77	16.77

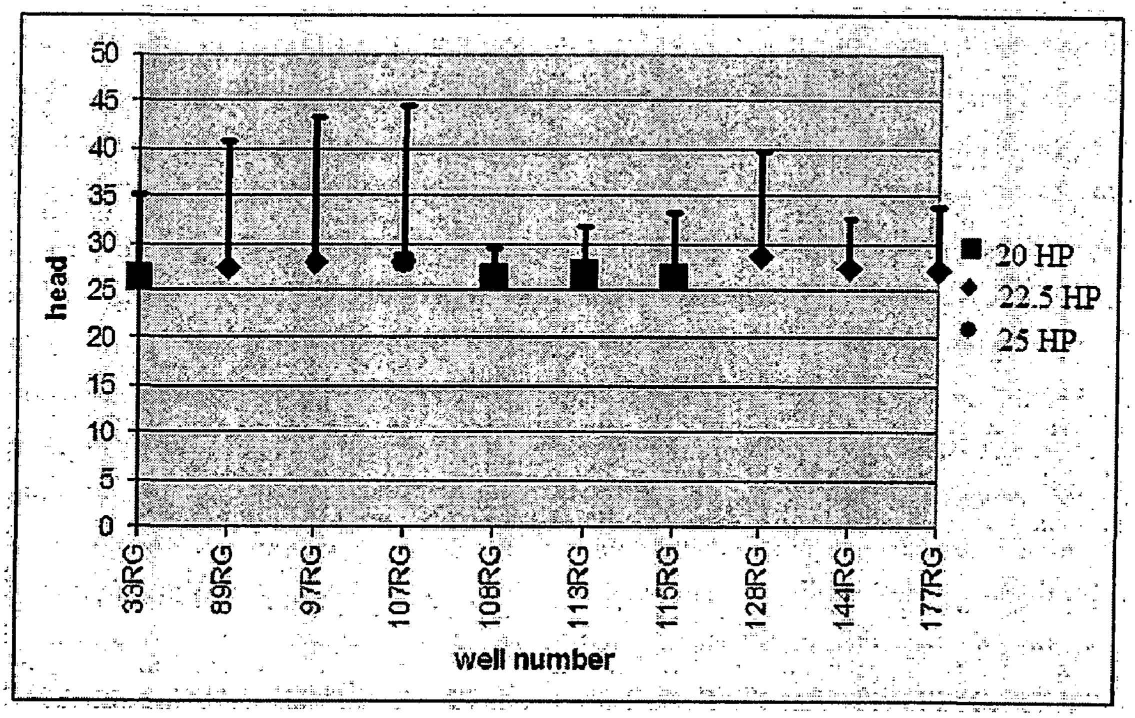

Fig.5.6: Variation of total pumping head requirements for ground water pumping from different tube wells of flow rate of 0.02726 m^3/sec.

Table 5.7: Summary of performance parameters of flow rate of $0.04089\,m^3/\sec$ with a discharge velocity of 2.31(assuming friction factor of 0.02).

Parameters	W1 147RG	W2 151RG	W3 201RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	1.0311	1.0608	1.0946
Depth of normal water level(m)	24.99	25.90	26.82
Length of delivery pipe (m)	3.1	3	3
Total pipe length (m)	28.09	28.90	29.82
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	26.29	27.23	28.18
Motor Power(k.w)	13.04	14.91	16.77

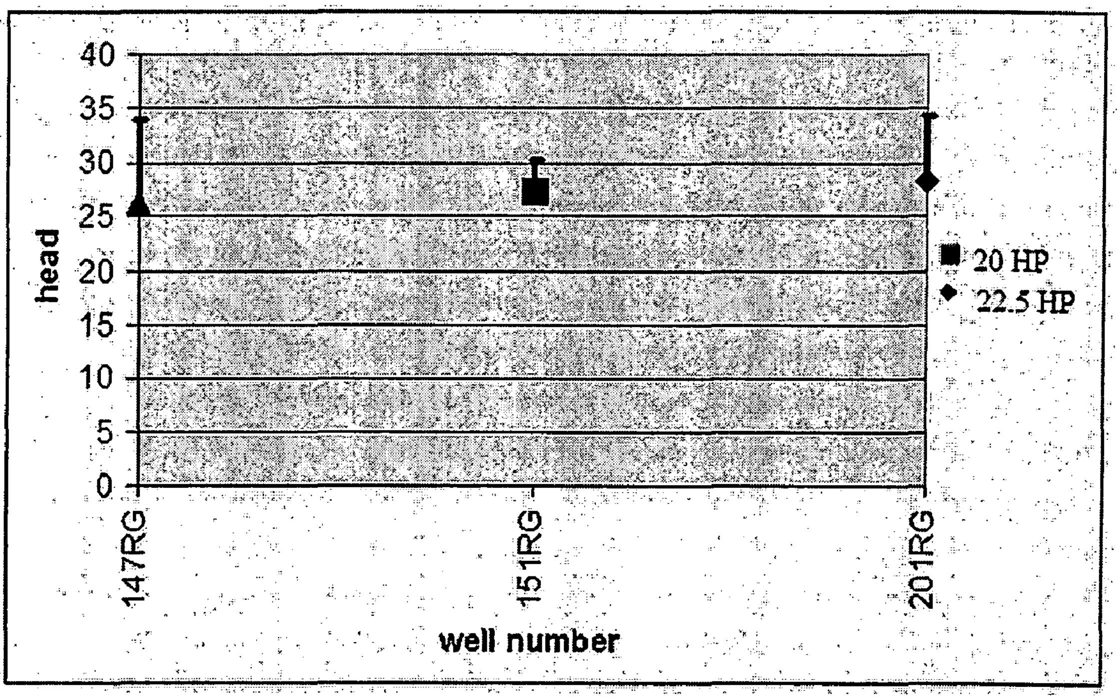

Fig.5.7: Variation of total pumping head requirements for ground water pumping from different tube wells of flow rate of 0.04089 $m^3/\sec$.

Table 5.8: Summary of performance parameters of flow rate of 0.0228 $m^3/\sec$ with a discharge velocity of 1.29(assuming friction factor of 0.02).

Parameters	W1 83RG	W3 141RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	0.3525	0.3696
Depth of normal water level (m)	27.43	28.95
Length of delivery pipe (m)	3.2	3.2
Total pipe length(m)	30.63	32.15
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	28.02	29.53
Motor Power(k.w)	18.64	18.64

Table 5.9: Summary of performance parameters of flow rate of $0.00840 m^3/\sec$ with a discharge velocity of 0.475 (assuming friction factor of 0.02).

Parameters	W1 35RG	W2 102RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	0.0436	0.0479
Suction Head (h_s)	25.29	27.73
Length of delivery pipe (m)	2.82	3.2
Total pipe length(m)	28.11	30.93
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	25.36	27.80
Motor Power(k.w)	13.04	18.64

Table 5.10: Summary of performance parameters of flow rate of $0.04625 m^3/\sec$ with a discharge velocity of 2.6172 (assuming friction factor of 0.02).

Parameters	W1 212RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	1.4624
Depth of normal water level(m)	24.38
Length of delivery pipe (m)	6.1
Total pipe length(m)	30.48
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	26.8616
Motor Power(k.w)	13.049

Table 5.11: Summary of performance parameters of flow rate of $0.01929 m^3/\sec$ $m^3/\sec$ with a discharge velocity of 1.0916 (assuming friction factor of 0.02).

Parameters	W1 206RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	0.2509
Suction Head (h_S)	27.43
Length of delivery pipe (m)	3.2
Total pipe length(m)	30.63
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	27.8316
Motor Power(k.w)	13.049

Table 5.12: Summary of performance parameters of flow rate of $0.02569\, m^3/\sec$ with a discharge velocity of 1.45(assuming friction factor of 0.02).

Parameters	W1 32RG
Friction Head (h_f) $h_f = \frac{fLQ^2}{12d^5}$	0.4312
Suction Head (h_s)	26.51
Length of delivery pipe (m)	3.1
Total pipe length(m)	29.61
Total Head H (m) $T_H = h_{suct} + h_f + \frac{V_d^2}{2g}$	27.2089
Motor Power(k.w)	16.77

Chapter 6

CONCLUSIONS

Based on the present work, following conclusions can be drawn:

1) The draw-down is an important parameter to be considered for selection of the pump.
2) The pump fails to pump the water when the head required is increased due to draw-down during the summer season.
3) The pump selected based on the draw-down consideration works well during the whole year. However it may give lower efficiency during winter and rainy seasons as the head requirement is low in theses days.
4) The pump power requirement is 16.77KW for discharge rate of 0.03577 m^3/sec and maximum head of 27.87 m.
5) The pump power requirement is 16.77 KW for discharge rate of 0.03103 m^3/sec and maximum head of 29.84 m.
6) The pump power requirement is 16.77 KW for discharge rate of 0.03829 m^3/sec and maximum head of 28.65 m.
7) The pump power requirement is 16.77 KW for discharge rate of 0.02726 m^3/sec and maximum head of 28.02 m.
8) Out of all the pumps, 15 pumps are not working satisfactorily or failed.

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