Ground Water Resources Investigations in

Lumbini Zone, Western Tarai, Nepal

Prepared cooperatively by
the United States Geological Survey and the Department of
Irrigation and Hydrology, Ministry of Food and Agriculture, HMG, Nepal
under the auspices of
the United States Agency for International Development

Ground Water Resources Investigations in Lumbini Zone, Western Tarai, Nepal

by

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Interim Administrative Report
released by the
Capital Projects and Engineering Division, USAID, Nepal

July 1973

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Abstract

This interim report, based largely on field work from March 1969 to June 1972, describes the preliminary results of hydrologic studies and exploratory drilling to evaluate the water-bearing properties of alluvial deposits underlying the Tarai area of the Lumbini Zone of south-central Nepal. The investigation and drilling were jointly undertaken by His Majesty's Government of Nepal (HMG) and the U.S. Agency for International Development (USAID) with technical assistance of advisors from the U.S. Geological Survey.

The Lumbini Tarai comprises about 4,000 square kilometers of gently sloping cultivated lands and dry jungle lying between the Churia Hills on the north and the Indian border on the south. Monsoon rains occur from mid-June to October and the remaining months are largely dry. Most of the almost 595,000 people of the area live in villages and towns and subsist on crops grown during the monsoon and livestock. Dry season irrigation from streams and rivers is practicable in only a small part of the area.

Use of tubewells for irrigation in much of the Lumbini Tarai appears to present the best prospects for year-long irrigation and a three-crop economy. During ground-water exploration operations in the Lumbini area 99 test wells totalling roughly 41,000 feet were drilled on a 9-10 km (kilometers) east-west and a 5-6 km

north-south grid pattern. Aquifer tests to determine the hydraulic characteristics of the water-bearing beds were carried out at 26 selected test-well sites.

The best potential for large-yielding tubewells lies in the central part of the Lumbini Tarai. Wells drilled in the coarse-textured deposits of the Bhabar zone, which were laid down by streams debouching from the Churia Hills, have the highest yields. The water levels in these wells, however, are uniformly below land surface and pumps are required to lift the water. Wells drilled in the finer-grained sediments of the Gangetic zone elsewhere in the area often flow. Also, in much of this zone, the ground water is confined under high artesian pressure at relatively shallow depth below land surface.

Successful drilling in flowing artesian zone requires use of heavy barite based drilling mud to contain the artesian pressure until the aquifer can be fully penetrated by the drill and the well casing can be set and cemented. Without proper mud control and cementing, wells in this zone of the report area "blow out" resulting in uncontrolled flow from the annulus around the well and from the well itself.

The zone of optimum flow from artesian aquifers is centered north of Bhairawa near the Agriculture Research Farm. From this center, heads above land surface and yields in the artesian system decrease in all directions. The zone with poorest potential for irrigation from ground water lies in the southern and southwestern part of the Lumbini area.

The chemical quality of water from the artesian and semi-artesian aquifers in the area is generally good and suitable, with few exceptions, for domestic supply, livestock, industry, and irrigation.

Introduction

Purpose and Scope of Report

This interim report summarizes data collected during the first phase, extending from April 1969 to June 1972, of a project designed to explore the ground-water potential and to study the geohydrology of the Western Tarai region of Nepal. The report also presents preliminary conclusions regarding the occurrence, quantity, and chemical quality of ground water in the Gangetic alluvium and Bhabar zone deposits underlying the area of investigation. Accompanying tabulations presents part of the basic data on which a final interpretative report will be based. This information is released at this time in advance of the interpretative report, because of its value to prospective users of ground water in the area and most particularly to those concerned with tubewell construction.

The present investigation of the Western Tarai has been jointly sponsored by His Majesty's Government (HMG) Department of Irrigation and Hydrology, Ministry of Food and Agriculture and the United States Agency for International Development (USAID). Technical advisors were assigned to the project by the United States Geological Survey (USGS).

The Government of Nepal has been systematically strengthening its internal capability to appraise, develop and manage the nation's water resources. First efforts which were directed towards appraisal of surface-water resources began in 1962 and continued until the end of 1968 through a cooperative agreement between HMG and USAID that provided for technical assistance from the USGS. During this period, 57 permanent stream gaging stations along with 38 partial record stations were established throughout Nepal. In addition, numerous miscellaneous measurements were made at other sites. Moreover, sediment investigations, the study of material in suspension in streams, were initiated in 1964 under the same project. In 1965 the project was broadened when HMG, with the technical assistance of the United Nations, expanded the collection and evaluation of meteorological data. Establishment of the Ground Water Section in 1969 and the Quality of Water Section in 1971 within HMG, Department of Irrigation and Hydrology under the present project, completed the organization of an integrated national water-resources department.

Many aspects of training in the multi-disciplined science of hydrology are best accomplished on-the-job, working on actual field investigations. Accordingly, personnel from HMG Ground Water and Quality of Water Sections were assigned units of field and laboratory work involving either well inventory; hydrogeologic mapping, exploratory drilling, geophysical well logging, aquifer testing, determination of water quality or collection of observation well data. On becoming proficient in one skill, these personnel rotate to other tasks for additional training. As the ground-water resources of the Lumbini Tarai were relatively unknown, the major effort in the investigation was necessarily directed towards test drilling and aquifer testing. During the Ground Water Project field operations two combination rotary-percussion drilling rigs provided by US AID to the Government of Nepal were utilized for test drilling. Also, additional drilling serv'ces, including one rotary rig and one percussion rig, were provided to the project through contracts with Indian well-drilling companies. Another contract reverse rotary machine also worked on the project for a brief period.

Location and Extent of Area

The area of investigation lies entirely within the Lumbini Zone of Nepal and is located between 27°20' and 27°50' North Latitudes and 82°40' and 83°55' East Longitudes and covers approximately 4,000 sq. kms. (fig. 1). The Lumbini Tarai includes part of the Nawal Parasi and all of the Rupandehi and Kapilvastu Districts. The area extends about 120 km east-west and ranges in width from 20 to 45 kms north-south. The eastern limit of the area is formed by the Narayani River and the western limit by the Arrah River and a southward extension of the Churia (Siwalik) Hills. The northern limit lies along the base of the Churia Hills, and the southern limit is the Nepal-India border. The principal towns in the area are Bhairawa, Butwal, Parasi, Taulihawa, and Krishnagar.

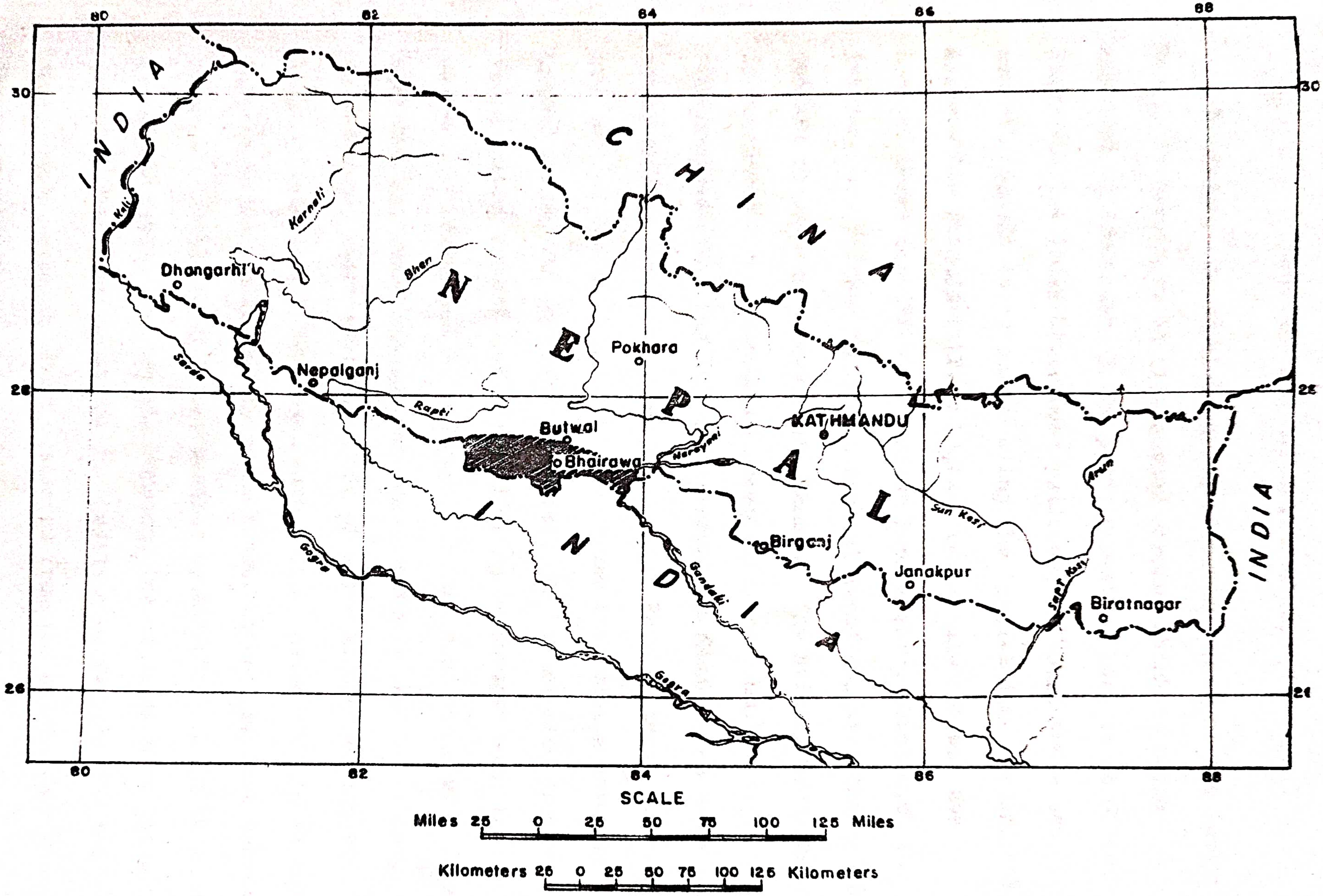


Figure I. Map of Nepal showing the area of study

Economic and Cultural Features

Bhairawa, the population and economic center of the Lumbini Tarai, is served by an all-weather airport which is being expanded to accomodate large jet aircraft. There is no direct link with the India Government railroad, although there are several transit entry points along the Nepal-Indian border. The all-weather Sonauli-Pokhara highway completely crosses the Lumbini Tarai and links the Indian border entry point with the intermontane Pokhara Valley in central Nepal and also the major centers of Bhairawa, Butwal and Tansen. The British Government is currently constructing a highway eastward from Butwal to Narayangarh and the Indian Cooperation Mission is building a road westward from Butwal to Nepalganj. Both of these roads are part of the east-west highway system that will eventually extend across the entire Nepal Tarai. Plans are also approved to construct a north-south road linking Krishnagar with the east-west highway via Bahadurgunj. A link road connecting Parasi with the east-west highway is under construction. There are, in addition, short surfaced roads of a few kilometers length linking Lumbini and Taulihawa with India. Aside from these roads, many of which are currently under construction, are dirt tracks, which are usable only in dry weather by all-wheel drive vehicles or bullock carts. During the monsoon, travel in much of the area is limited to foot or elephant. Drilling operations are not practicable, even at short distances from the all-weather roads, during the monsoon.

The 1971 census of Nepal indicates a population of 595,100 for the Nawal Parasi, Rupandehi, and Kapilvastu Districts of the more extensive Lumbini Zone. Part of the Nawal Parasi District lies outside of the Tarai and the area of this report. Nevertheless, most of the population live within the report area. Prior to the control of malaria, the year-long inhabitants of the area consisted largely of Tharus, a tribe that apparently had evolved a natural immunity to the disease. The other indigenous inhabitants, pre-dating malaria control, were for the most part indistinguishable from groups living immediately across the Indian border with whom, as is true today, they freely intermingle. With malaria controlled, however, people from the midlands and northern hills as well as Nepalese refugees from Burma have settled in the Tarai. Nowadays, the population is truly polygenetic and becoming increasingly mixed with additional settlement.

Lumbini, located roughly 15 km west of Bhairawa, is the birthplace of the Gautama Buddha who founded the Buddhist family of religions. The sacred site is a worldwide focus for Buddhist Pilgrims, who come to worship there.

Previous Investigations

The basis for planning the present investigation was provided by W. V. Swarzenski and H. M. Babcock (1968) who completed a reconnaissance study in early 1968 and proposed the present ground-water investigation of the Western Tarai. Previous ground-water investigations in Nepal have for the most part been limited to spot studies by consultants of specific areas, although some of these have been rather extensive. It is believed, however, that the Western Terai investigation is the first such study undertaken by HMG utilizing an appreciable number of Nepali technical personnel.

Acknowledgments

This report ultimately results from the combined efforts of all the personnel, past and present and of several nationalities, assigned to the Western Tarai Ground Water Project. It would be difficult to equate the relative contribution of such diverse yet interdependent activities as access track construction, well drilling, geophysical logging and chemical analysis of water samples, to name but a few examples. Messrs. Gregory Franz, Avery Beer, and Stephen Harper, U.S. Peace Corps Volunteers, were assigned to the project as geologists and were particularly helpful in the initial stages. One drilling contractor, N. B. Tubewells of India, consistently excelled in its work performance. Personnel of the Butwal Technical Institute built and repaired

many items of project equipment. The quality of their workmanship was consistently high. Messrs. Carl Schantz and James G. Blevins served as Well Drilling Advisors to the project. In addition, Mr. Blevins contributed substantially to the Mud Control and Cementing Sections of this report. Thanks are also due to the many government officials and private individuals who assisted the project from time to time.

Geography

Topography and Drainage

The Nepalese Tarai constitutes the piedmont zone of the vast Gangetic alluvial plain which extends south into India. The Tarai is an area of low relief characterized by gently sloping cultivated land interspersed with large tracts of subtropical or dry jungle. The northern limit of the Lumbini Tarai is formed by the east-west trending Churia Hills which rise abruptly from the plain to altitudes of 3,000 to 5,000 feet. In the Lumbini Tarai, coarse deposits of boulder and cobble gravel with sand form alluvial fans overlying and in part intercalated with the finer-grained Gangetic sediments where streams debouch from the Churia Hills. The coarse deposits constitute the Bhabar zone. These are extensive only along the larger rivers and streams and do not extend in a continuous piedmont belt as reported in the Indian Tarai. For example, the Bhabar zone extends southward from the Churia front to a maximum distance of 8 km along the Tinau River south of Butwal. East and west of this point the Bhabar zone deposits recede northward until they feather out against the flanks of the Churia Hills. In the Lumbini Tarai, this pattern persists east and west of the Tinau drainage where Bhabar deposits occur in elliptical alluvial fans opposite the points where streams debouch from the hills. The areal extent of the alluvial fans and associated Bhabar deposits is dependent on the size of the stream; the smaller the stream, the smaller the fan. Bhabar deposits are for the most part absent at the base of the Churia Hill in the interfluvial areas between larger streams. Aside from the Tinau drainage, the only other extensive area of Bhabar deposits in the Lumbini Tarai occurs along the Narayani River on the east.

Drainage in the Lumbini Tarai is southward and numerous abandoned stream meanders with oxbow cutoffs are indicative of low stream gradients south of the Churia Hills. Elevations range from 174.0 meters above sea level at Butwal on the northern edge of the Lumbini Tarai to 89.3 meters above sea level at Sombarsa on the south near the Indian border. The flow of all the streams in the area with the exception of the Naraya and Tinau Rivers is intermittent in the upper piedmont reaches of the Tarai from April to June. Towards the end of the dry season, the smaller streams cease to flow shortly after leaving the Churia Hills. Flow again resumes downstream after 1 to 3 km as underflow rises to the surface. In the intermittently dry reaches across the Bhabar zone water seeps downward from the stream channels and is recharged to ground water. Flow from points along the spring line likely represents rejected recharge. The configuration of the spring line generally reflects the same elliptical outline as the Bhabar zone deposits. South of the spring line streamflow is for the most part perennial although very low in the smaller streams during the dry season.

The amount of recharge to ground water is a critical factor in determining the water budget for an area. Accordingly, the Ground Water Project is currently (1973) conducting a study of the recharge in an area drained by the Bhaluhi Khola 8 km east of Butwal. Staff gages have been established in the river at locations upstream and downstream of reaches of perennial flow as well as in the intervening reach where flow ceases during the dry season. Observation wells with continuous water-level recorders are located close to the river bank near to the staff gages on the river itself. The staff gages are read three times a day and the water-level recorders operate continuously. Stream discharge is measured during periods of both high and low flow. Hopefully, the collection and interpretation of these data may make it possible to relate stream flow and runoff to recharge of the ground-water system.

The Surface Water Section of the Department of Irrigation and Hydrology established a gaging station on the Tinau River a short distance upstream of Butwal in 1964. Data from this station are summarized in table 1. All rivers and streams in Nepal increase spectacularly in flow during the monsoon at which time they also carry heavy sediment loads.

Table 1. Summary of Discharge of Tinau River, at Butwal

Catchment area in sq/km	Period of Record	Maximum flow in m^3/sec	Minimum Flow in m^3/sec	Average Annual Discharge m^3/sec
554	1964-69	2,220	1.0	23.5

Perennial natural lakes and ponds are rare in the Lumbini Tarai although some do occur in the northern part of the area, usually near the spring line. Most villages construct large earthern tanks to provide water for bathing during the dry season. These tanks fill with rain water during the monsoon and empty with use during the rest of the year. Only those villages with tanks deep enough to intersect the water table are assured of year round supply.

Climatic Features

The wet monsoon begins in the Lumbini Tarai in mid-June and continues to late September. Sporadic rains usually occur through October, but November and December are often completely without rainfall. January, February, and March are generally dry with only occasional rain. In April and May scattered storms are the rule as the monsoon builds up to the southeast.

Rainfall data for Butwal 1961-1972 and the Agriculture Research Farm near Bhairawa 1968-72 are shown in table 2. The limited data suggest an increase in rainfall near the Churia Hills front.

The maximum temperature observed in 4 years of record at Butwal was 44.9°C on August 1, 1963. Minimum temperature for the same period was 4.3°C on June 27, 1964. The daily mean temperature averages 25-26°C, however. Other stations in the Lumbini area, at Bhairawa Airport and the Bhairawa Agriculture Farm, record somewhat higher maximum temperatures, but the period of record is too short to derive averages. Average relative humidity ranges between 56-63 percent at Butwal and the limited records at the other stations suggest averages ranging between 25 and 84 percent.

Agriculture and Industry

An estimated 93 percent of the population of Nepal is engaged in agriculture or agriculturally related occupations. It is likely that the percentage of agriculture workers is even higher in the Lumbini area. The principal crops are paddy, wheat, maize, potatoes, oil seeds, gram, dal, and considerable variety, in season, of vegetables and fruits. Sugar cane, millet, barley, jute and tobacco are also raised but not extensively. Livestock and livestock products are major sources of agricultural income. Bullocks and water buffalo are the principal draft animals although small numbers of camels, horses, and donkeys are also used. Cattle and water buffalo are raised for milk. Sheep and goats together with chickens, ducks and some geese are the main meat sources. Fish and fish farming are becoming increasingly important.

Forest products are an important source of revenue for the area. An estimated one-quarter of the Lumbini Zone is in commercial forest. The Sal (Shorea robusta) is the most valuable single species.

Household crafts, such as weaving, basketry, blacksmithing, and small scale manufacture of leather goods provide sources of cash income for farm families. Major industries of the area include the sugar mill and distillery at Bhairawa, the workshop and plywood factory managed by the Butwal Technical Institute at Butwal, who also built and manage the hydroelectric project on the Tinau River. Local rice and oil seed mills, usually servicing several villages, are among the minor industries.

Irrigation

Without at least some irrigation, the growing of paddy and wheat is usually limited to one crop per year in the Lumbini Tarai. Construction of major irrigation works is currently (1973) in progress to utilize water from the Narayani River. Water will be distributed to the Nepal Tarai eastward outside of the Lumbini Tarai towards Birganj and westwards, in the Lumbini Tarai, to Bhairawa through the Parasi area by a system of canals constructed to a reported 0.75 foot to the mile grade. Whereas the irrigation water will be valuable to area farmers, lateral distribution by gravity flow will be limited with this slight gradient.

Minor irrigation projects utilizing flow from smaller rivers have sometimes been disappointing in the Western Tarai. Considerable loss of irrigation water occurs, for example, in the Tinau irrigation system as the canal passes over the coarse deposits of the Bhabar zone south of the headgates. This leakage is considerable and water is not available at all points through the distribution system during the dry season. Another minor irrigation system is under construction on the Banganga River in the western part of the area. In addition, local farmers have constructed extensive hand-dug irrigation systems capturing flow from small streams. The man years of labor involved in such construction are truly prodigious. All these minor irrigation works require expensive repairs to the headworks and canals following the monsoon floods.

Use of ground water is, of course, an alternative to use of surface water in most areas requiring irrigation. Ground water can be developed with varying degrees of intensity and funding. Furthermore, water from wells has an immediate utility on a unit by unit basis whereas surface-water irrigation projects are usually expensive and not operable until the entire system is complete. A number of productive wells in the Lumbini area resulting from the present Ground Water Project have been turned over to HMG, Irrigation Department for use.

Well Numbering System

The test wells were drilled on a grid roughly 9 to 10 km eastwest and 5 to 6 km north-south, although, for reasons of access to sites, there are exceptions to this spacing. Numbering begins in the south east corner of the area and wells are numbered serially from south to north on each line. The 13 grid lines, in turn, are numbered serially from east to west. For example, well 6/4 near Bogri is the fourth well north of the southernmost drill site on the sixth line west of the eastern boundary of the area. Test well locations are shown in figure 2.

Table 3 is a cross reference between test well numbers used in this report and test well numbers used to file records in the HMG, Department of Irrigation and Hydrology and USAID. The file numbers reflect the chronology of the drilling program. For example, NB-7 in the file numbering system refers to the seventh well drilled by N.B. Tubewells for the project.

Table 3.-Cross Reference of Test Well Report Numbers and Test Well File Numbers.

Report No.	File No.	Report No.	File No.	Report No.	File No.	Report No.	File No.
1/1	HD-9	4/9	HD-28	6/4	NB-32	9/8	NB-42
1/2	H-8	5/1	NB-16	6/5	NB-28	9/9	NB-41
2/1	NB-15	5/2	NB-17	6/6	NB-21	10/1	HD-23
2/2	NB-13	5/3	NB-18	6/7	NB-58	10/2	HD-21
2/3	NB-12	5/4	NB-59	6/8	NB-22	10/3	HD-22
2/4	NB-14	5/5	NB-60	6/9	NB-25	10/4	HD-20
2/5	HD-7	5/6	HD-11	6/10	NB-23	10/5	HD-19
2/6	HD-5	5/7	NB-20	6/11	NB-24	10/6	HD-18
3/1	NB-11	5/8 Luxmi School		6/12	NB-26	11/1	NB-47
3/2	NB-10	5/9	ATW-3	6/13	NB-27	11/2	NB-46
3/3	NB-4	5/10	ATW-4	7/1	NB-33	11/3	NB-45
3/4	NB-5	5/11	HD-1	8/1	HD-12	11/4	NB-44
3/5	NB-6	5/12	HD-10	8/2	HD-13	11/5	NB-43
3/6	NB-7	5/13	NB-19	8/3	HD-14	12/1	NB-48
3/7	NB-8	5/14	ATW-2	8/4	HD-15	12/2	HD-24
3/8	NB-9	5/15	ATW-6	8/5	HD-16	12/3	NB-49
4/1	ND-2	5/16	ATW-7	8/6	HD-17	12/4	NB-50
4/2	NB-1	5/17	ATW-8 & HD-25	9/1	NB-35	12/5	NB-51
4/3	NB-3	5/18	ATW-9	9/2	NB-34	12/6	NB-52
4/4	HD-2	5/19	ATW-10	9/3	NB-36	13/1	NB-57
4/5	HD-3	6/1	NB-29	9/4	NB-37	13/2	NB-56
4/6	HD-4	6/2	NB-31	9/5	NB-38	13/3	NB-55
4/7	HD-26	6/3	NB-30	9/6	NB-39	13/4	NB-54
4/8	HD-27			9/7	NB-40	13/5	NB-53

HD = Hydrology Department
NB = N.B. Tubewells

Geohydrology

The northern limit of the Lumbini Tarai lies along the base of the Churia Hills, the Nepalese geographic designation for the Siwalik Range in the report area. Rocks exposed by streams cutting through the Churia Hills consist of interbedded fine-grained sandstone with clay vugs, shale, conglomerate, and fresh-water limestone all of Late Tertiary age. The formations dip generally northward and the entire range forms the outermost folded belt of the Himalaya. The Churia-Siwalik Formations are the source rocks of most of the stream-deposited alluvial materials underlying the Bhabar zone and the contiguous Gangetic Plain immediately to the south.

The Bhabar zone deposits and Gangetic alluvium south of the Churia foothills form the principal aquifers of the area. The Ground Water Investigation Project was designed, in part, to explore the areal extent and thickness of these aquifers. The deepest test hole drilled to date (1973) was a 1,512-foot slim hole, well 6/6, at Semri (table 4). Unconsolidated deposits of fluvial origin were penetrated throughout the entire depth of this hole. The only known penetration of Churia-Siwalik bedrock in the area occurred in a 69-foot well drilled in the British East-West Highway compound 2 km east of Butwal. This well is located about 500 m from a spur of the Churia foothills. However, the well is not generally indicative of depth to bedrock in the area.

The 1,000-foot test hole, well 3/8, at Sunwal is more typical of the thickness of alluvium relative to bedrock depth near the Churia-Siwalik front. This test hole is located roughly 750 m. south of the Churia foothills and penetrated alluvium throughout its entire 1,000-foot depth. The total thickness of the alluvium is not known. The logs from the northernmost drill holes, none of which reached bedrock, would suggest the presence of a considerable thickness of alluvium even near the contact with Churia-Siwalik Formations and also a major hinge-line fault, possibly still active, along the southern base of the Churia-Siwalik Range.

Water Bearing Characteristics

The Bhabar zone deposits consist of boulder, cobble and pebble gravel and coarse sand interbedded with some silt and clay. In the Lumbini Tarai, the Bhabar deposits occur in elliptical alluvial fans extending downstream from the points where larger streams debouch from the Churia foothills. The size of the fans are controlled by the volume of discharge and sediment loads of the streams, as only the larger streams develop large alluvial fans. The Bhabar deposits contain large quantities of ground water, and properly-constructed wells penetrating aquifers, theme deposits produce large yields. Well 5/17 at Driver Tola indicates that Bhabar deposits overlie older Gangetic alluvium at this site. The first 285 feet of this well were drilled by the percussion method in order to penetrate the coarse Bhabar deposits encountered in the upper part of the hole. Clay was penetrated at 285 feet and subsequently, drilling was completed to 820 feet by the direct rotary method. Nothing coarser than pebble gravel was encountered between 285 and 820 feet in the rotary section of the hole. The sediments below the depth of 285 feet are typical Gangetic alluvium. That the Bhabar deposits form a zone of recharge to ground water is evidenced by their position updip and largely overlying the Gangetic alluvium and by the fact that the coarse sediments readily accept infiltrating rainfall and stream runoff.

The Gangetic alluvium underlying, interfingering with, and bordering the Bhabar zone deposits consists of intercalated lenticular beds of silt, clay, sand, and pebble gravel. Near the Churia foothills, in the interfluvial areas, the proportion of silt and clay is greater than that of sand and gravel. The Gangetic alluvium is more extensive than the Bhabar zone deposits in the Lumbini Tarai and contains aquifers ranging from fine sand to coarse pebble gravel. The beds dip gently to the south from the Lumbini Tarai and are contiguous with the Gangetic alluvium of India.

The thickness and extent of aquifers in the Lumbini Tarai appears to be controlled by the ancient drainage pattern. The ancient drainage system, in turn, seems to be a subsurface reflection of the present-day river system in that, the thickest and coarsest-grained aquifers occur in the buried alluvial fans of the larger streams. East and west of the Tinau River, except where interrupted by deposition from other streams, the water-bearing materials become finer grained. Aquifers underlying the present-day river flood plains, however, are thickest and are generally composed of coarse gravel. As might be expected, the water-bearing beds are thin and fine-grained in the southern part of the Lumbini Tarai reflecting lower stream velocities south of the foothills at the time of deposition.

Ground Water Occurrence

The ultimate source of virtually all fresh ground water is precipitation and, with the exception of some desert regions, the ground-water reservoir is periodically recharged by infiltration from rainfall or from streams. Water enters an aquifer by downward percolation of rainfall or infiltration from streams through pore spaces in the soil to the zone of saturation, the upper surface of which is the water table. Water-table conditions exist where the aquifer is not confined by overlying impervious strata. Unconfined water occurs in the permeable sand and gravel resting on top of the first clay layer at depths ranging from 10 to 30 feet below land surface throughout the area. Most of the villages and small towns in the Lumbini Tarai obtain domestic water from shallow dug wells penetrating the water-table aquifer. The water in the zone of saturation, sometimes referred to as "phreatic water", moves by gravity flow from sources or points of recharge towards areas of discharge. This migration coupled with evapotranspiration and artificial withdrawal accounts for the seasonal fluctuation of water levels in dug wells tapping the water table. During the monsoon, the water table rises to near land surface or sometimes above to the point of water logging. Natural and artificial discharge together with migration downslope may result in a lowering of the water table of as much as 30 feet at some locations during the dry season, although the average decline is less.

Water in the alluvium also occurs under confined or artesian conditions. Artesian conditions occur where the water moving down-gradient through permeable water-bearing stata passes beneath impermeable strata that form a confining bed. If the materials beneath the water-bearing strata are also impermeable, water acquires a hydrostatic head related to the vertical distance between the altitude of land surface at the point of confinement, the slope of the potentiometric surface, and the bottom of the confining bed at the point of discharge. The stratigraphic distribution of Bhabar deposits and Gangetic alluvium in the Lumbini Tarai presents a nearly text-book example of an artesian system (fig. 4). Generally, permeable beds of sand, gravel, or coarser material extend up dip to the north where they can receive recharge. The water then moves down dip through the aquifers, passing beneath impermeable beds within the alluvium. As the aquifer fills and the pressure or potentiometric head of water within the aquifer is established. Where the potentiometric surface lies above land surface, as in much of the central part of the Lumbini area, wells penetrating the artesian aquifers will flow at land surface. Where th potentiometric surface is below land surface, as is the case in much of the remainder of the Lumbini area, wells will not flow and are termed "subartesian" as the water is still confined. The lenticular character of aquifers within the Bhabar zone and Gangetic alluvium indicates that water may also occur in these beds under partially or semi-confined conditions.

Artesian aquifers act as conduits conveying water from recharge

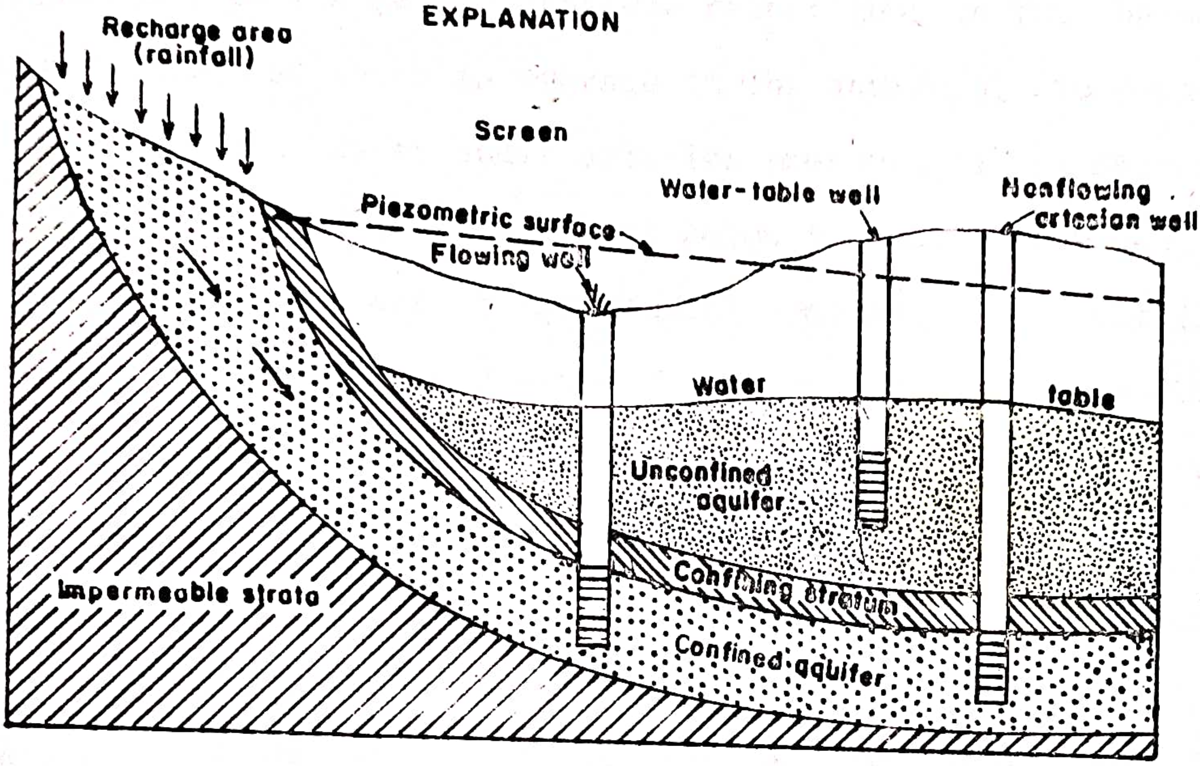


Figure 4. Diagrammatic representation of unconfined and confined aquifers.

areas to points of natural or artificial discharge and, consequently, the rise and fall of the potentiometric level is largely due to changes in pressure rather than to the changes in the amount of water in storage in the aquifers. To dewater a bed containing water under artesian pressure, it is necessary to lower the potentiometric level below the top of the aquifer. The flow-well aquifers of the Lumbini area are at present (1973) little exploited and to dewater these aquifers pumping would be necessary to draw down the potentiometric level below the top of the water-bearing beds. Artesian wells will cease to flow, however, when the potentiometric level declines to the datum of land surface. From February 1971 to March 1972 the head on well 5/11 at the Government Fish Farm declined 9 feet to 32 feet above land surface reflecting use and also discharge from uncontrolled flowing wells drilled nearby.

When a well penetrates an artesian aquifer, the pressure is relieved in all directions, creating a cone of pressure relief (cone of depression). Therefore, wells near other flowing wells of large yield, that is, near the inverted apex of the cone of pressure relief, commonly show a decline in pressure that is greater than the regional decline. The overall decline is; of course, a composite of many cones of pressure relief. Sufficient long-term data to evaluate the regional decline of the potentiometric surface are not yet available. Collecting such data is one purpose of the observation well program established by HMG, Ground Water Section in 1971.

Pressure levels in selected flowing and sub-artesian wells are monitored on a continuing basis. Some of these wells are equipped with continuous pressure-level recorders and others are measured monthly by a mercury manometer or pressure gage. Several years of such records should show regional and local trends of the potentiometric surface.

As an artesian aquifer is a pressure system, a well drilled into a confined aquifer registers the height of the potentiometric surface even when the aquifer is first penetrated. Yield by natural flow or by pumping increases as the aquifer is more fully penetrated by the well, but the artesian pressure may not change substantially with greater penetration. The discharge from a well flowing at land surface commonly decreases with time as the pressure level declines. Subsequent re-drilling, more fully penetrating the aquifer, often restores some of the lost yield. As artesian pressure is dissipated, however, the well will cease to flow when the potentiometric surface coincides with land surface, and deepening the well within the same aquifer will not restore flow.

Within the area of high artesian pressure of the Lumbini area only those wells drilled by the Ground Water Project, using mud control techniques later described in this report, have completely penetrated the confined high-pressure aquifers. Locally constructed hand-drilled wells, however, invariably reach only to the top of these aquifers, as do wells constructed by commercial drilling rigs not utilizing mud control. This type of construction results in leakage around the annulus between the open hole and the casing pipe, precluding any possibility of valving to conserve water and pressure head.

When the artesian pressure in an aquifer system is dissipated it is, for practical purposes, generally lost forever. Restricting yields from wells in the area will locally restore some head, but the regional decline of the potentiometric surface is usually long-termed. Relief of pressure down dip by discharging wells induces additional inflow to the aquifer system at points where the system is recharged. These points of recharge, however, are often at considerable distance from points of discharge. Friction loss and intervening variations of permeability within the aquifer limit the restoration of pressure head by increased recharge. The recharge zone for aquifers in the Lumbini Tarai, however, is everywhere relatively near to points where ground water is or could be discharged by wells. The proximity of sources of recharge presents the possibility, as yet unproven, that the aquifer may be "overdrawn" during the dry season only to be refilled by monsoon rains. Further, as the spring line is believed to represent rejected recharge, it is possible that increased exploitation of ground water will result in salvage of some of the spring line flow to recharge and ultimately to wells down dip. Several years accumulation of data from the observation well program and the recharge study will be necessary before these theories can be proved or disapproved.

There is at least some direct evidence that it would be practical to overdraw aquifers in the Bhabar zone during the dry season and then rely on infiltration from monsoon rainfall and runoff to refill the system. The well supplying the British East-West Highway compound is located on a stream bank roughly 4 km east of Butwal. Aquifers penetrated by this well are semi-confined and consist of coarse sand and gravel. The well supplies the highway compound and subsidiary villages of road workers and their families. Pumping levels remain stable in the well during the monsoon and begin first to decline during December-January, then more sharply during April-May as the dry season progresses. By the middle of May the pumping level approaches the bottom of the pump and the draft must be restricted. At this point, the water level in the well responds rapidly to any minor pre-monsoon rainfall indicating almost direct infiltration to the aquifer system. With the arrival of monsoon rains the aquifer fills rapidly and the static water level recovers to the initial pre-pumping level.

Figure 3 shows areas of high and low potential for yields from tubewells and also shows areas of flowing and non-flowing artesian conditions. Generally, wells in the central part of the area flow above land surface and have higher yields. Thereafter, yields and head decrease, often to below land surface in all directions around the perimeter of this area. Wells constructed in the semi-confined aquifers of the Bhabar zone have the highest yields, but water levels are below land surface and the wells require pumping.

History of Exploratory Drilling

The initial phase of the present groundwater investigation provided for exploratory drilling to evaluate the depth, thickness, and areal extent of potential aquifers in the Western Tarai Region of Nepal. Exploratory drilling by a contractor operated reverse rotary rig commenced in May 1969 at the Agriculture Research Farm near Bhairawa. The test hole encountered water under high artesian pressure, approximately 40 feet above land surface, at a depth of 164 feet. The well "blew out" and was partially cased and brought under control only with extreme difficulty. This experience proved by practical example that the reverse rotary method of drilling was unsatisfactory for use in the areas of high artesian pressure. The drilling machine was then moved to a site near Manigram, in what was then suspected and later proved to be a zone of non-flowing or unconfined water. Considerable drilling difficulty was encountered with the large pebbles, cobbles, and boulders characteristic of the Bhabar Zone. Successful well 5/14, was completed, however, to a depth of 158 feet, (table 7) after more than a month of drilling.

During the 1969-70 drilling season the drilling contractor provided one percussion drilling rig for use in the Bhabar zone and one direct rotary rig for use in the finer sediments of the Gangetic alluvium. The first test well, 5/9, drilled by direct rotary on the Agriculture Research Farm and completed May 8, 1970 was only partially successful. The weight of the drilling fluid was not sufficient to control the artesian pressure, and the well started to flow before casing and screen were installed. Well casing and screen were subsequently installed, however, even though the screen only penetrated a few feet of the aquifer. This well, 5/9, initially flowed about 1,000 gpm but subsequently the flow decreased to 500 gpm after several months of use. The second well, 5/10, completed on May 26, 1970 was considered successful. The artesian pressure was contained; the aquifer was completely screened; and the well was cased to the surface. The initial flow of the well was measured at 600 gpm with a pressure head of 30 feet above land surface. The third test hole drilled by this contractor was abandoned at 165 feet owing to inability to control pressure and to penetrate caving sand and gravel beds. A total of 5 test holes were drilled by the first drilling contractor during the 1969-70 season (fiscal year 1970) along the Bhairawa-Butwal road.

The drilling contract was awarded to another contractor in the 1970-71 field season (fiscal year 1971). Although the contract was awarded late, the contractor completed 19 test holes, several with depths up to 1,000 feet, between February and June 1971. The U.S. purchased drilling rigs arrived in Nepal in late December 1970. One rig was placed in operation in February 1971 and completed 10 test holes by the end of the 1970-71 field season. The percussion drilling rig operated by the previous year's contractor drilled 5 test holes, 5/15 to 5/19, in the Bhabar zone between Manigram to Butwal completing the last percussion well at Butwal in September 1971. The base-line traverse between Paklihawa-Bhairawa-Butwal was completed in the first 6 months of 1971 and the drilling operations moved eastward to complete a series of south to north traverses located approximately 10 km apart and extending from the Indian border to the Churia Hills. About 5 test holes were drilled on each traverse at 5 to 6 km north-south intervals. The final traverse in June 1971, designated number one in this report, was in the Bhabar zone near the Narayani River. The above drilling operations totalled 39 test holes for an aggregate of 14,000 feet and completed the exploratory drilling for the area from Bhairawa-Butwal road eastward to the Narayani River.

Drilling operations in the western part of the Lumbini area started in November 1971 and were completed by June 1972 for a total of 60 test holes. Both U.S. purchased drill rigs were operated by Nepali personnel and together completed 20 test holes during this period. The drilling contractor completed 40 test holes during the same period demonstrating the greater experience of their personnel as contrasted with the newly recruited HMG drilling crews. The drilling pattern in the western part of the Lumbini area was similar to that used the previous season except that the average depth of the wells was greater. A test hole, 6/6, at Semri, the deepest to date, was drilled to a depth of

1,512 feet. At least one 1000-foot test hole was drilled on each of the 8 western traverses and the remaining test holes averaged about 500 feet. By the end of the 1971-72 field season (fiscal year 1972) the project had drilled 99 test holes and test wells for a total of 41,700 feet. This included 14 large-diameter producing wells, 6 of which flow naturally, and approximately 50 small-diameter observation wells to be used for monitoring purposes.

Drilling Methods

A complete description of well-drilling methods is beyond the scope of this report. It is desirable, however, to describe briefly drilling methods used by the Ground Water Project and others concerned with tubewells particularly with reference to problems inherent to well construction in the area. The tubewells were drilled by the direct rotary, percussion (cable-tool), and reverse rotary methods employing either project or contract drilling rigs. Further, many small-diameter tubewells are drilled by local contractors for farmers by the "slugger" method utilizing simple home-built equipment.

The direct rotary method involves rotating a string of drill rods with attached bit in an open hole. Simultaneously, drilling fluid is circulated from an open mud pit by a mud pump down the hollow rods and out the openings in the bit to return back up the open hole to the mud pit. The returning column of drilling fluid carries material cut by the bit to land surface and thence to the mud pit near the well head. Drilling fluid consists of water mixed with mud and material used to increase the density (weight). The mud used should be bentonite, a volcanic clay, that has the property of flocculation (the ability to swell when wetted).

Most of the project wells were drilled by the direct rotary method. It was found to be the most satisfactory drilling method for construction of wells in the high-pressure artesian aquifers that occur at shallow depth. Direct rotary machines, however, are not satisfactory for drilling in areas like the Bhabar zone where pebbles, cobbles, and boulders are encountered. Both rock roller and drag bits are used in rotary drilling. Rock roller bits are best for drilling in sand and gravel and drag bits perform best in silt and clay.

The percussion (cable-tool) method of drilling involves raising and dropping a heavy string of drill tools consisting of a bit, drill stem and drilling jars attached to a steel cable. The cable passes from a collecting reel over a pulley wheel at the top of the derrick before connecting to the tool string. The string of tools is activated up and down by means of a pitman arm and the resulting blow crushes material down the hole under the bit. The crushed material is removed from the hole with a bailer and dumped. The percussion method often requires that the hole be drilled in several different diameters starting with the largest diameter at land surface. When it becomes difficult to advance the larger pipe the diameter of hole is reduced and drilling continued with a smaller bit. Several different diameters of well tubing may be necessary to complete the well.

Percussion drilling is particularly well suited to the very coarse sediments of the Bhabar zone. Accordingly, most of the project wells north of the spring line of grid line 5 (Paklihawa-Butwal) were drilled by the percussion method. Percussion drilling is much slower than rotary drilling in areas where considerable thicknesses of silt and clay are encountered. Because of difficulty in controlling artesian pressure, percussion methods are not suitable for drilling areas where high pressure artesian aquifers occur at a shallow depth. The project drilling rigs are combination direct rotary-percussion and can drill using either method. (figs. 5a, 5b).

The reverse rotary drilling method, as the name implies, reverses the direction of fluid flow in the conduit or hole made by drilling. Water flows by gravity down the open hole outside of the large diameter drill pipe through which it is returned by pumping to land surface. Large-diameter drag bits attached to the drill pipe provide the cutting action. Drill cuttings along with the drilling fluid ascend to the surface inside of the drill pipe and are settled out in a pit. As the hole is constantly full of water, circulation is accomplished by a large centrifugal pump. This method of drilling requires copius quantities of water; a limiting factor during the dry season in the Lumbini area. The reverse rotary method is further limited by the inherent inability to control the weight of drilling fluid making it unsuitable for drilling high-pressure artesian zones. Its use is also limited to areas of relative fine-grained sediments. It is, however particularly well suited to areas of fine grained sediments where non-flowing and water-table aquifers occur and where large-diameter gravel-packed holes are required. Much of the area outside of the flowing artesian zone of the Lumbini Tarai could likely best be drilled with reverse rotary machines particularly at locations where it is desirable to multi-screen and gravel-pack several aquifers in the same well for increased yield.

The simple equipment involved in the "slugger" method of drilling tubewells consists of a line of small pipe, usually 2 to 4-inches diameter, the bottom length of which may be reinforced with a coupling, and a tripod to facilitate raising and lowering the pipe. Some means of activating the drill pipe up and down in the open hole is also required and usually a simple "rocker" board suffices to provide the drilling action. The pipe is started in the hole and water is added for lubrication and to facilitate removal of drill cuttings. The driller's helper applies his hand to the top of the vertically placed drill pipe forming a nearly airtight seal as the pipe is raised. As the drill pipe is lowered, the hand is raised allowing water to escape from the top opening of the pipe. This flapping action works as a simple pump and drill cuttings ascend through the hollow drill pipe. Cutting action is provided by the rise and fall of the pipe. As crude as this method may seem, its application makes it possible to construct 2 to 6-inch diameter wells to depths of several hundred feet.

The low cost of this method, usually from 1 to 3 rupees (10 to 30 cents, U.S.) a foot exclusive of casing costs naturally appeals to Tarai farmers. By this method, however, it is impossible to control artesian flow and tubewells so constructed invariably leak around the annular space between the casing and the open hole. In areas of high artesian pressure, this method has the further disadvantage of being unable to fully penetrate the aquifer. In fact, "slugger" tubewells seldom penetrate even to the top of flowing aquifers as the confining layer usually "blows out" before the aquifer is reached. When "blow outs" occur the casing pipe is landed in clay 2 to 3 feet above the top of the aquifer. The clays immediately above, capping the water-bearing zone, are then continuously eroded by the upward artesian flow. Historically, the wells flow for awhile, but when the cavity in the clay topping the aquifer is enlarged to sufficient size the well will collapse often cutting off the flow entirely.

Although of large diameter than is generally common in the area a tubewell located 500 m west of the Bhairawa Airport illustrates the usual sequence of events to be expected with "slugger" drilled wells in high-pressure artesian areas. This well was drilled to 198 feet at a diameter sufficient to install 6-inch casing. About 3 feet above the aquifer, the few remaining feet of the confining clay layer could no longer contain the artesian pressure of the aquifer and the well "blew out". Some initial difficulty was experienced removing the clay plug forced into the bottom of the pipe by the "blow out". When the plug was removed, however, the well flowed at a rate of 1,350 gpm. The unconfined 6-inch column of water fountained roughly 7 feet above land surface. Due to the construction method, there was no possibility of valving off the well as this measure would have only increased leakage around the outside of the casing and accelerated the erosion and enlargement of exposed borehole walls down the hole. The initial flow continued for several months until what must have been a considerable cavity developed in the clay exposed between the bottom of the casing and the top of the aquifer. The well owner's afternoon nap was abruptly interrupted one day with the announcement that his spectacular well was finished. What in fact actually happened was that the cavity had collapsed cutting the flow to only 20 gpm and also causing considerable subsidence around the well head. Subsequent reworking the well with a bailer restored the flow to about 650 gpm whereupon shortly thereafter it again collapsed. Yield could likely be restored again, but considering that the cavity below the casing can only erode further, it is perhaps fortunate that the flow from the well has reduced to a trickle.

While the above events are more than usually spectacular, the same sequence of events commonly occurs in other wells constructed by this method in areas of high-pressure artesian aquifers. Water from "slugger" type wells runs to waste from both continuous flow out of the casing and from leakage around the uncemented annulus. "Slugger" type wells should not be constructed in areas of high artesian pressure since they waste both pressure head and ultimately the ground-water resource. Certainly, no official subsidies should be sanctioned that would encourage this type of drilling and well construction.

Specialized Drilling Procedures

Mud Control

The twin factors of high heads above land surface and shallow depths to aquifers combine to make control of artesian pressure, while drilling, difficult in much of the report area. Aquifers with heads exceeding 40 feet above land surface are encountered at the relatively shallow depth of 160 feet. An unweighted mud column does not have sufficient height at these depths to balance the hydrostatic pressure of the artesian aquifer. Without exception, holes drilled with unweighted mud under such conditions "blow out" and then flow uncontrolled often also with the attendant calamity of a stuck line of drill rods.

To achieve a balance between the height or the mud column and the hydrostatic pressure in the aquifer, it is necessary to increase the weight of the bentonite-based drilling fluid by introducing heavy additives. This is usually accomplished by the admixing of barium-based additives such as barite (native barium sulphate-$BaSO_4$) to the standard drilling fluid. The weight of drilling fluid necessary to simulate a balance fluid column is determined by calculating the hydrostatic pressure necessary to balance and, preferably slightly suppress, a given pressure at a given depth below land surface. The formula used for this calculation is as follows:

$$M = \frac{(H + D)\ W}{D}$$

(Plus 10% Safety Factor)

Where: M = Required mud weight

W = Weight of water or 8.33 lbs. per U.S. gallon

H = Artesian head above land surface

D = Depth to top of aquifer

For example, assume 42 feet of artesian head above land surface at a depth of 164 feet. Using the above formula:

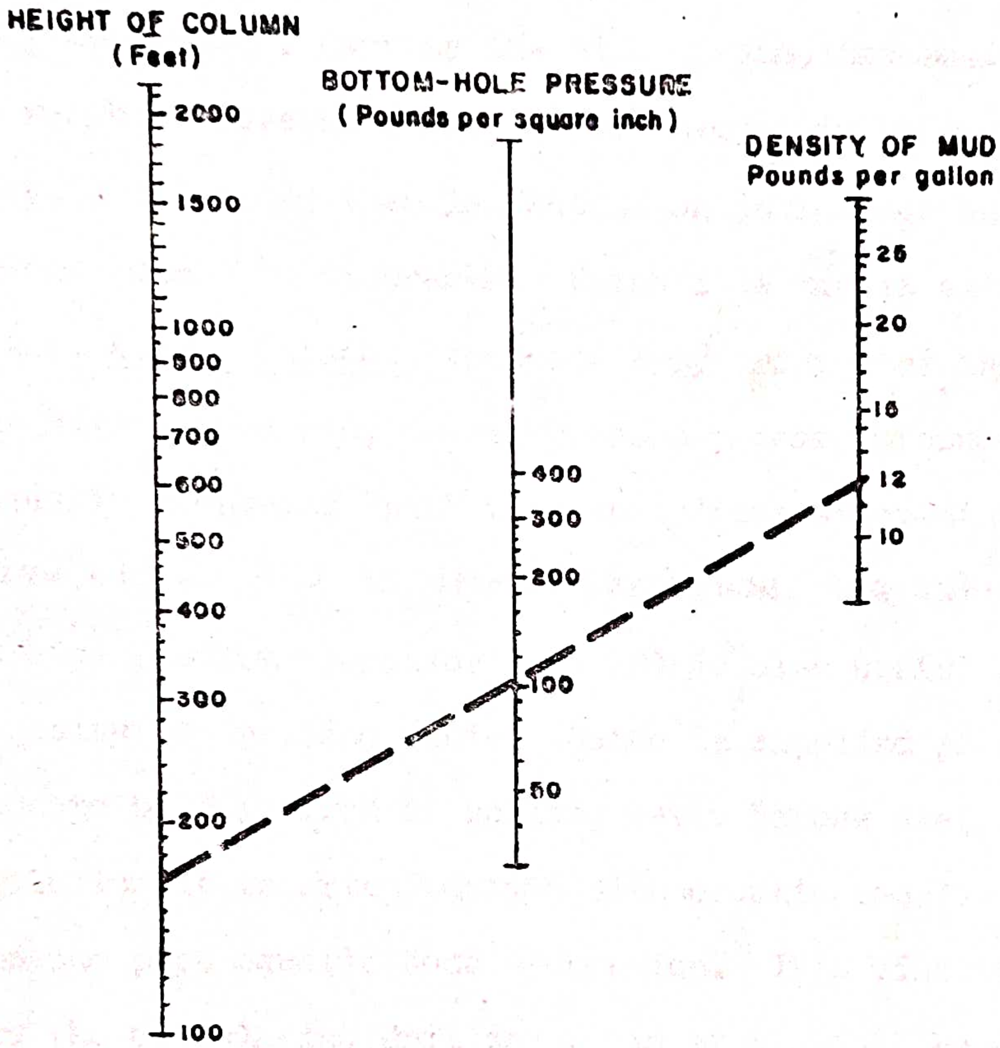
$$M = \frac{(42 + 164)\ 8.33}{164}$$

M = 10.52 + 10% safety factor

M = 11.62 or 11 1/2 lb. mud.

Determination of required mud weights in the field is often accomplished by using the chart shown in figure 6. Using the same example, depth of the hole below land surface is read on the left-hand column and the artesian head converted to pounds per square inch (227 feet x 0.433 = 98 lb/in^2) plotted on the middle column of the chart. A line connecting these two points and extended to intersect the right-hand column of the chart shows a required mud density of 11 1/2 lbs per gallon. The safety factor is already built into the chart. In areas where the relationship of head above land surface to depth to aquifer is known, a safety factor of 10 percent over and above the determined requirement is sufficient. In unexplored areas a greater safety factor is indicated and holes should be started and finished with mud weighing up to 12 pounds per gallon.

Barite has the advantage of providing the maximum increase in weight with the minimum increase in viscosity. Weight of drilling fluid cannot be determined by visual or tactile means. The common method of measuring the weight of drilling fluid is by means of a mud balance; a simple fulcrum scale, one type of which reads directly in pounds per U.S. gallon (fig.6). Weight of drilling fluid is often confused with viscosity particularly by drillers unfamiliar with the use of barite. Viscosity can increase to the degree where the mud pump has difficulty in circulating the drilling fluid. At this point, the fluid may or may not be weighted to the required specific gravity. Very viscous muds can have a specific gravity only slightly above that of water. Viscosity is measured by means of a "Marsh funnel", a funnel-shaped vessel of known volume with a calibrated orifice at its base. The time, in seconds, required to fill a quart container from this instrument is directly convertible to viscosity (fig. 7).



(After Baroid Data Book, p 500-18)

Figure 7. Chart to Determine Density of Drilling Mud in Pounds per gallon.

Viscosity generally though not necessarily increases with mud weight, and excessive viscosity can hamper drilling progress. It then becomes necessary to lower viscosity while maintaining a specific mud weight. This can be accomplished by the judicious addition of water to the drilling fluid, but this method, if not carefully controlled, carries the risk of simultaneously reducing the mud weight. Several chemicals are useful in controlling viscosity, chief among them is "kutch" an indigenous substance roughly equivalent to quebracho. Kutch is a tannin extract from the acacia, Acacia Catachu, tree and a by-product of the khair (katha in Hindi) producing industry whose primary product is a paste used in preparing "pan" that ubiquitous after-dinner digestive aid so much in demand throughout the sub-continent. Caustic soda (sodium hydroxide - Na OH) is also useful in reducing the viscosity of drilling fluid. Kutch is supplied in solid form and needs to be dissolved in boiling water before use. After it is in solution it is often admixed with caustic soda in a 10 part kutch to one part caustic soda proportion. This mixture is slowly added to the circulating drilling fluid at the well head. Under no circumstances should solutions of thinning chemical be dumped rapidly into the mud pit. After adding thinning chemicals it is necessary to monitor weight and viscosity at closely spaced intervals using the mud balance and Marsh funnel. These closely-spaced measurements will identify any sudden changes in mud weight in time to correct the problem by addition of barite.

when using thinning chemicals care must also be taken to balance the mud column by circulating the drilling fluid. It is possible for the drilling fluid in the mud pit to be of a different weight and viscosity than that of the mud down the hole in the drilling column. If the insufficiently weighted drilling fluid from the mud pit replaces the fluid in the hole without mixing the well can start to flow. Consequently, weight should be reduced slowly until mixing by circulation makes the drilling fluid homogeneous.

The viscosity of drilling fluid can be increased with the addition of hydrated or slacked lime (Ca (H)2) and also common corn (maize) starch. Both of these additives and the thinning chemicals are available in Nepal or nearby India.

Cementing

Unless at least some of the annular space between the tubewell casing and the open hole is sealed, leakage will occur on the outside of pipe in flowing artesian zones. At locations where the artesian head above land surface is small, it is often possible to plug the leakage with clay. Clay is not a satisfactory seal, however, in areas of high positive pressure. Several methods were used to cement tubewells in the Lumbini Tarai. The "positive displacement" and "tremie pipe" methods, termed thus for the purposes of this report, are the methods now adopted as standard on the Ground Water Project. Either of the methods require that the cement seal be placed opposite an impermeable layer. Usually it is best to place the cement seal in the confining layer above the water-bearing bed.

Positive Displacement Method As drilling continues inside the cemented casing in the positive displacement method, a pipe size should be selected that is compatible with the subsequent completion diameter of the well. The hole is first drilled to penetrate a tight clay, preferably the confining layer, and stopped at least 30 feet above the aquifer. The casing is then lowered to within a foot of the bottom of the hole and held by clamps at land surface. A known volume of cement is pumped by the mud pump into the casing string through a cementing head. The cementing head is simply a cap fitted to the top of the casing with arrangements for connecting to the mud pump, usually by way of the kelly hose (fig. 8). A 2-inch valve located between the hose and the well cap completes this assembly. The cement slurry is pumped into the well and displaced down the casing by a known volume of drilling fluid until it is subsequently forced out of the bottom of the open pipe. The drilling fluid and cement will not mix. At this point, the cement will ascend upwards through the annulus between the outside of the pipe and the open hole as additional fluid is pumped into the casing. Displacement by drilling fluid is continued until the cement arrives at the desired point in the well annulus or in the case of some wells, all the way to land surface. The 2-inch valve is then closed forming an airtight seal, and the cement and drilling fluid column stabilizes. The cement is then allowed to dry and set. After the cement seal drys, drilling is continued inside the cemented casing, still maintaining proper mud weight, until the artesian aquifer is fully penetrated.

Smaller diameter casing with attached screen is then lowered in the remaining open hole. Minimum standard specifications usually require 60 feet of overlap between the two casing strings installed by this method. In the Lumbini area, however, overlap on wells drilled by the project rigs was often less, due in part to an initial shortage of casing. A packer is also required to seal the annulus between the larger and smaller casing. This method of cementing has the advantage of being secure in the event the well should start to flow before planned. It is the best method to use with inexperienced drilling personnel.

Whereas it has not proved necessary in the Lumbini area, most drilling manuals recommend following the cement slurry with a soft wooden plug. In this method, the wooden plug is supported in the cementing head until the slurry enters the casing. Provision is made on the side of the cementing head to withdraw the support freeing the plug in the casing string. Subsequent displacement with drilling fluid forces the plug to the bottom of the hole. This method, when successful, possibly provides more positive displacement of the slurry and also wipes the inside of the casing free of cement.

The well casing available to the project, however, is not always of uniform inside diameter. On several wells, the wooden plug hung on irregularities in the casing before reaching the bottom of the hole. This sometimes requires a time consuming and expensive reaming operation and could lead to the loss of the well unless circulation could be reestablished to allow a second cementing operation. Under prevailing circumstances use of cementing plugs appears impractical.

<u>Tremie Pipe Method</u> This method of cementing is best suited for setting a single continuous string of casing and screen. The well is drilled to total depth, completely penetrating the aquifer and with careful attention to mud control. The casing string with attached screen is lowered with a packer placed on the outside of the casing string at an interval to coincide with the bottom of the zone to be cemented. The packer should be

located on the casing string to place it in the confining layer 30 feet above the aquifer. One method to assure a seal by the packer is to locate it at a point where hole diamter has been reduced. The packer, often a solid iron ring fitting around the outside of the casing pipe, can then be firmly landed on the shoulder created by the reduction of hole size.

Centering guides consisting of 3 straps of metal each 1/4 x 1 1/2 x 12 inches are welded at equidistant intervals outside of the casing pipe with the long axis vertical. Sets of these guides should be located above and below the aquifer and near the bottom of the hole. The use of centering guides assures a uniform thickness of cement grout around the casing pipe. Without guides the casing pipe can rest against the side of the bore hole making a complete seal impossible. The small diameter tremie pipe is sufficiently flexible to bypass the guides.

A small diameter 1 1/2 to 2-inch tremie pipe is lowered into the annular space between the outside of the casing and open hole to within 6 inches of the packer. Obviously, the hole to be cemented must be of sufficient diameter to allow simultaneous accomodation of both the casing and tremie pipe. A calculated volume of cement is then pumped through the tremie pipe by means of the mud pump displacing drilling fluid upward in the annular space outside the casing pipe. The tremie pipe is then withdrawn and the cement seal allowed to set.

Both cementing methods involve calculations to determine the amount of cement required to fill a given annular space. There are tables in well-drilling manuals to assist in determining annular space, fluid volume per unit of length of casing pipe and other factors necessary for well cementing. Although these manuals provide all of the information required to cement a well successfully, it is good practice to make independent calculations.

Before attempting to cement a well, there are several constant volume measurements to be determined. Chief among these is the volume of the tank in which the cement is mixed and the fluid capacity of the suction hose, mud pump and all other hoses and pipes carrying drilling fluid to the well head. The capacity of the cementing tank is determined as follows:

Capacity = Width x Length x Height x 7.5 (U.S.gals. per cubic foot).

In the case of the tanks used by the project:

Capacity = 3 feet x 8 feet x 3 feet x 7.5

C = 540 U.S. gals.

Dividing the 540 gallons by 36 inches gives the capacity per inch of depth, in this case, 15 gallons.

The simplest and perhaps most accurate method of determing the fluid capacity of the mud pump and all the attached drilling fluid lines located between the mud pit and the well head is by displacement. Clean water should be circulated through the pump and lines until practically no trace of drilling mud remains. The suction hose is then placed in the calibrated tank which has been partially filled with drilling fluid and the volume of fluid noted. The pump should be operated with the discharge (kelly) hose open at the well head. When drilling fluid appears at the end of the discharge hose the pump is stopped and the calibrated tank measured again. The amount of fluid removed from the tank is the capacity of the mud pump and attached hoses. The pump and hoses on drilling rigs used by the project have a fluid capacity of 34.8 U.S. gallons. This figure as well as the capacity of the cementing tank will remain constant on all cementing operations unless the hoses are changed.

It is now necessary to calculate the volume of cement necessary to fill the annular space between the outside of the casing and the borehole wall. The formula for determining cement requirement is as follows:

$V = Vb - Vc$

V = Volume of cement required)
Vb = Volume of borehole) in U.S. gallons
Vc = Volume displaced by casing)

For example, to determine the cement requirement for 100 feet of 12 inch borehole when setting casing with 8.625 inch outside diameter (O.D.):

$V = Vb - Vc$

$$\therefore \left(V = \pi r^2 h = \frac{\pi d^2 h}{4} = 0.7854 d^2 h\right)$$

$$V = \frac{(12^2 \times 0.7854)\,100}{144} - \frac{(8.625^2 \times 0.7854)\,100}{144}$$

V = 37.9 cubic feet

V = 37.9 ft^3 x 7.5 (ft^3/gal) = 284.3 U.S. gal.

It is often desirable to add 10 percent to the volume of cement to cover possible increases in the borehole diameter due to caving. If this additional cement is not required, it can be run to waste when it appears at the well head.

It is now necessary to displace the cement slurry down the casing pipe and upwards in the annulus outside the pipe. This is done by following the cement slurry with enough drilling fluid to accomplish the displacement. The fluid requirement is calculated to allow a 5-foot cement plug to remain inside the casing to assure a seal at the bottom end of the pipe.

Thus: $$V = \frac{(\text{inside diameter})^2 \times 0.7854 \times 95}{144}$$

V = 33.16 cu. ft.

V = 33.16 ft^3 x 7.5 (ft^3/gal.) 248.7 gal.

plus 34.8 (capacity of pump and mud lines)

V = 283.5 U.S. gals.

In areas such as the Lumbini Tarai with several artesian aquifers occurring at different depths, it is often necessary to pour several plugs of cement grout. Such multiple grouting might be required to seal off the bottom of a deep test hole and subsequently screen an aquifer at a shallower depth. In another case, it might be desirable to screen the second or third aquifer penetrated by a borehole and to seperate by cementing this aquifer from the one up the hole. The upper aquifer could still start to flow around the well annulus unless twin grout plugs are poured. This multiple grouting requires the use of a tremie pipe.

For example, assume a 12-inch diameter borehole drilled to a depth of 385 feet and requiring cement plugs from 160 feet to 200 feet and from 270 feet to 330 feet. To calculate the fluid volume between the outside of the casing and the borehole wall:

V = volume of hole - volume of casing

$$V = \frac{(12^2 \times 0.7854)-(6.625^2 \times 0.7854)}{144} \times 1$$

$$V = \frac{113.09 - 34.47 \times 1}{144}$$

V = .5459 cu. ft. per foot

V = .5459 x 7.5 (U.S. gals. per cu. ft.) 4.09 U.S. gal/ft.

To calculate the U.S. gallons of cement required for each plug.

160 feet to 200 feet = 40 feet x 4.09 = 163.6 gals.

270 feet to 330 feet = 60 feet x 4.09 = 245.4 gals.

The tremie pipe is first lowered in the annular space between the casing and borehole wall to a depth of 330 feet and drilling fluid is circulated to assure that the conduit system is open. The entire cement requirement is mixed at one time; that is, 163.6 + 245.4 gals = 409 gals. The first plug of 245 gals

is then pumped through the treme pipe. Immediately following this operation the tremie pipe is raised to the 200-foot level and the remaining 163 gallons of cement is pumped into the annulus. The mud pump and drilling lines are then cleared of cement by displacing with 34 gallon of drilling fluid. The tremie pipe is then raised to 155 feet and drilling fluid circulated freely. This procedure will clear the tremie pipe of cement. The amount of cement lost in the tremie pipe is negligible. An additional 5-foot plug of cement is usually poured by hand around the well head at land surface to complete construction.

The cement is mixed in the calibrated tank by using the drilling mud mixer or the bypass hose on the mud pump to agitate the slurry. Water is first added to the tank in the predetermined amount required for the cementing procedure. Individual bags of cement are then added until the slurry reaches specified weight. The ratio of water to cement for a suitable grout is 5.4 U.S. gallons to a 94 pound sack of cement. With the variable quality of cement available in Nepal, however, no formula will prove satisfactory for determining a cement to water ratio. Cement should be mixed with water until a weight of 15 pounds to one U.S. gallon is obtained. The weight ratio can be determined by using the same weight balance used in measuring mud weight.

After the cementing procedure is completed, it is good practice to clean the mud pump and lines by circulating drilling fluid and later, clear water through the pumping system. The joint on the mud hose is broken at the well head and the fluid pumped to waste away from the mud pit. This is necessary since cement causes drilling fluid to deteriorate. The mud pump should then be opened and thoroughly washed with clear water to remove any residual cement.

Ordinarily, the cement grout is allowed to dry for 48 hours before drilling continues or the well is developed. The drying process of the cement can be hastened by addition of commercial quick-hardening chemicals--usually calcium chloride ($CaCl_2$). The quick hardening chemicals are added to the cement slurry immediately before pumping into the borehole and will speed the hardening process by 24 hours. In all cases, a small sample of the cement is kept separate as an indicator of the degree of hardening.

After the cement grout has hardened, the well is developed by washing out the heavy drilling fluid. Even though the heavy drilling fluid leaves a considerable mud cake on the borehole walls in the aquifer section, wells in high pressure artesian zones usually develop rapidly when the mud weight is reduced and flow starts. The well is allowed to flow initially until completely sand free. Further development can be facilitated by opening and closing the valve creating a surging effect.

Aquifer Tests

Two major hydraulic characteristics that affect the development of an aquifer are its ability to transmit water and its capacity to yield water from storage. These characteristics, which affect the water levels or artesian pressures and yields of tubewells, are called the transmissivity, first defined by Theis (Ferris and others, 1962, p. 72-73), and storage coefficient (Ferris and others, 1962, p 74-78), respectively. More recently these terms have been redefined by Lohman and others (1972). When these aquifer characteristics are known for an aquifer or part of an aquifer, it is possible to forecast approximate water-level or artesian pressure trends at different rates of withdrawal from producing tubewells.

To establish the transmissivities and storage coefficient of aquifers in the Lumbini Tarai, 29 aquifer tests were made at selected sites. The tests were made on both flowing artesian and non-flowing (subartesian) tubewells. The results of these tests are summarized in table 5 and are described in more detail in the following pages.

Pasauli Site - An aquifer test was conducted on well 2/3 at the Pasauli site on April 10 and 11, 1972. The Theis recovery method was used, owing to apparent lack of hydraulic continuity with the nearby observation well. Tubewell 2/3, screened in a fine to medium sand with gravel from 105 to 130 feet, indicated an average to low transmissivity of 23,690 gpd/ft. The well was pumped for a period of 12 hours at 473 gpm (US) with a diesel powered turbine pump. The drawdown after 12 hours pumping was 44.1 feet.

Visnupura and Sitlapur Sites--Aquifer tests were made on the flowing artesian tubewells at Visnupura (4/1) and Sitlapur (4/2) using the Theis recovery method as no observation wells were available. Tubewell 4/1 at Visnupura, screened in a fine to medium sand with some gravel from 190 to 206 feet, was allowed to flow at 8 gpm for a period of 24 hours. The pressure head recovered 0.74 feet after the well was shutoff, to the static head of 3.6 feet above land surface and indicated a relatively low transmissivity of 12,820 gpd/ft.

well 4/2 at Sitlapur, which had a static head of 42 feet above land surface, flowed for 24 hours at 24 gpm with a decline in head of 1.13 feet. The indicated transmissivity of 21,340 gpd/ft is within the average to low range.

Both the above tests holes are cased with 1 1/2-inch casing and screen and friction loss along this small diameter pipe may account partially for the low transmissivities.

Belahia Site--On March 24 and 25, 1972 an aquifer test was conducted at Belahia using two flowing artesian wells. Tubewell 4/4, screened in a fine to coarse sand and gravel from 225 to 245 feet, flowed for 24 hours at 261 gpm. During this period the pressure declined 3.64 feet in observation well 4/3 located 325 feet away. The recovery rate coincided with drawdown to indicate a moderately high transmissivity in the range of 54,380 to 68,460 gpd/ft. The storage coefficient ranged from 1.69 x 10^{-4} to 5.85 x 10^{-5}. The hydraulic characteristics of the aquifer were computed using the Theis non-equilibrium and Cooper-Jacobs modified formulas.

Kerwani Site--The Theis recovery method was used to determine the transmissivity of the aquifer penetrated by tubewell 4/6 at Kerwani. Tubewell 4/6, screened in sand and gravel from 400 to 420 feet, was pumped for 24 hours at 40 gpm with a drawdown of 3.64 feet. The plotted recovery data indicated an average transmissivity of 32,150 gpd/ft. The specific capacity of the well was about 11 gallons per foot of drawdown.

Paklihawa Site--Two Theis recovery tests were conducted on flowing artesian wells at the Paklihawa site. Tubewell 5/2, screened in a siltstone gravel from 265 to 275 feet, flowed at 50 gpm for 48 hours. The pressure recovery was 12.3 feet after 48 hours of shutdown. A low transmissivity of 3,430 gpd/ft was indicated. Tubewell 5/3, screened from 475 to 505 feet in sand and gravel, indicated a pressure decline of 20.6 feet after flowing for 48 hours at the rate of 223 gpm. The plotted recovery indicated a relatively low transmissivity of 8,410 gpd/ft. The transmissivity indicated by both the tests of Paklihawa is considerably less than that of the more shallow zone tested in the near vicinity.

Bhairawa (S.P. Camp)--The aquifer test conducted at the S.P. Camp indicates that the transmissivity of the second artesian zone is in the moderately high range in this area. The test was run from June 16 to 20, 1972 using tubewell 5/5 as the producing well and tubewell 5/4, located 75 feet away as the observation well. During the discharge cycle well 5/5 flowed at 200 gpm for 48 hours. The pressure decline in observation well 5/4 stabilized at 2.94 feet after 35 hours of discharge. The recovery rate coincided with the drawdown to indicate a moderately high transmissivity in the range of 48,250 to 55,730 gpd/ft. and a storage coefficient of 3.0×10^{-4} to $6.8\ 10^{-4}$. These wells were screened in gravel from 240 to 253 ft.

Bhairawa Airport Site--An aquifer was test made on the flowing artesian well 5/6 at Bhairawa Airport from June 26 to 30, 1972. The well screened in gravel from 192 to 206 feet in the upper artesian zone, flowed for 48 hours at 416 gpm with a pressure decline of 6.7 feet. The plotted recovery by the Theis recovery method indicates a relatively high transmissivity of 105,100 gpd/ft.

Agriculture Research Farm Site--Well 5/9 at the Agriculture Research Farm which had a static head of 30 feet above land surface, was allowed to flow for 48 hours at 420 gpm with a pressure decline in head of 1.6 feet. The Theis recovery method indicated a transmissivity of 236,020 gpd/ft. which appears unusually high for an artesian aquifer. The gravel samples however, were very coarse and the initial yield from the well was reported to be 1,000 gpm or more. The well was screened in coarse gravel from 160 to 164 feet in the top part of the artesian aquifer.

Government Fish Farm Site--An aquifer test was conducted on March 15 and 16, 1972 at the Government Fish Farm using two flowing artesian wells. Tubewell 5/10 screened in a medium to coarse gravel from 158 to 178 feet, flowed for 24 hours at 490 gpm. During this period the pressure declined 2.38 feet in observation well 5/11 located 350 feet away. The recovery rate coincided with the drawdown to indicate an unusually high transmissivity for an artesian aquifer in the range of 192,700 to 191,500 gpd/ft, whereas, the storage coefficient indicated a range of 1.1×10^{-4} to 3.38×10^{-5}. The hydraulic characteristics were computed by both the Theis and Cooper-Jacobs methods and were of the same magnitude as those found in the Agriculture Research Farm 2 miles to the south.

Manigram Site--Aquifer tests were made on the non-flowing tubewells at the Manigram site in June 1971 and in February and March 1972. For the tests a diesel powered turbine pump was installed in tubewell 5/14 which was pumped for 15 to 36 hours. The decline in water level was recorded in observation wells 5/15 and 5/16, located 50 and 100 feet away, respectively. In March 1972 tubewell 5/14 was pumped at a rate of 1,210 gpm for a period of 36 hours with a drawdown of 6 feet. The water level decline in the observation well, 100 feet away, stabilised at 0.92 feet. The computed transmissivity values cover a wide range. The Theis non-equilibrium and Hantush leaky aquifer methods indicated similar values of 1,100,000 and 1,300,000 gpd/ft, whereas, the Cooper-Jacob method indicated 1,900,000 gpd/ft. The most plausible solution for this test, however, appears to be that using Boulton's delayed yield formula which indicated a transmissivity of 815,000 gpd/ft and a storage coefficient of 0.15 for long-term pumping under unconfined conditions. The storage coefficients of the other solutions, which ranged from 2.19×10^{-4} to 4.1×10^{-5}, may give evidence of the semi-confined nature of the aquifer.

The wells were screened from 80 to 150 feet in very coarse gravel, pebbles, cobbles, and boulders. Although high transmissivity values are to be expected in the very coarse sediments of the Bhabar zone, the above values are considered to be exceptionally high. These high values may be due in part to hydraulic continuity between the water table and the semi-confined aquifer through the thick gravel packing. The transmissivity indicated at Jogikuti well 5/18 may, therefore, be more representative of the Bhabar zone deposits.

<u>Driver Tole Site</u>--Well 5/17 at Driver Tole completely penetrated the Bhabar zone deposits at 285 feet and is screened from 310 to 350 feet in coarse sand and gravel of the underlying Gangetic alluvium. An aquifer test was conducted on June 22-24, 1972 using the Theis recovery method. The well was pumped at 317 gpm for 24 hours at which time the drawdown stabilized at about

20.5 feet. The plotted recovery curve indicated a transmissivity of 236,900 gpd/ft. This is a relatively high value but it is considered of the right magnitude, however, owing to the coarse nature of the sediments and thickness of the aquifer. It compares favorably with more shallow artesian tests near Fish Farm well 5/10 and Agriculture Research Farm well 5/9.

Jogikuti and Butwal Sites--The wells at Jogikuti, 5/18, and Butwal, 5/19, are both drilled and screened within the Bhabar zone deposits near the Churia foothills. Well 5/18 at Jogikuti was screened from 77 to 142 feet in cobbles, pebbles, gravel and coarse sand. This well was pumped at 390 gpm for 24 hours with a drawdown of 4.2 feet. The Theis recovery method indicated a high transmissivity of 435,000 gpd/ft. Although the above value appears to be high it is believed to be reasonable owing to the very coarse nature of the screened aquifer materials.

The Theis recovery test conducted on tubewell 5/19 at Butwal indicated a transmissivity of 188,200 gpd/ft. The well, screened in coarse sand and gravel, was pumped for 24 hours at 334 gpm with a drawdown of 10.6 feet.

Aquifer tests tapping wells in the Bhabar zone deposits of antecedent streams debouching from the Churia Hills indicate exceptionally high transmissivities ranging from 200,000 to 800,000 gpd/ft. The specific capacities of the wells reflect the same high transmissivities, ranging from 30 to 200 gallons of yield per foot of drawdown.

Bogri Site--The aquifer test conducted on tubewells 6/3 and 6/4 at Bogri indicates a relatively low transmissivity of 12,000 to 14,300 gpd/ft in the shallow non-flowing zone. Well 6/4 was pumped at 50 gpm for 48 hours with a drawdown of 7 feet. The measured decline in the water level in the observation well 6/3, 100 feet away was 3.55 feet after 48 hours. Both wells were screened in fine to coarse sand with gravel from 100 to 120 feet. The computed storage coefficients were 2.16×10^{-4} and 3.93×10^{-4}. The low transmissivity indicates a decrease in aquifer permeability toward the south.

Semri Site--At Semri a test by the Theis recovery method was made on tubewell 6/7 which is screened from 215 to 240 feet in a coarse sand and gravel aquifer. During the test the well flowed at 80 gpm for 24 hours. Following shutdown the mercury manometer indicated a pressure increase of 1.02 feet after 24 hours of recovery, returning to the static head of 43.66 feet above land surface. The test indicated a moderately high transmissivity of 82,820 gpd/ft.

Chapia Sites--Two aquifer tests were conducted near Chapia between April 16-18 and May 6-10, 1972 on two separate producing zones. At Chapia (Baidauli) well 6/10 discharged by artesian flow at 450 gpm for 24 hours. After 16 hours of flow the pressure decline stabilized at 3.36 feet in observation well 6/11, located 100 feet away. The recovery rate coincided with drawdown to indicate a high transmissivity in the range of

128,920 to 150,570 gpd/ft. The computed storage coefficients were 6.23×10^{-5} and 5.21×10^{-5}. The wells were screened in medium to coarse gravel between 171 to 187 feet.

The second test at Chapia (Chilia) was in wells screened in sand and gravel from 70 to 100 feet. Well 6/8 was pumped at 50 gpm for a period of 60 hours with a drawdown of 4.3 feet. The decline of water level in observation well 6/9 250 feet away was 1.44 feet at the end of the discharge cycle. The data, computed by the Theis and Cooper-Jacob methods, indicates a transmissivity ranging from 28,400 to 31,830 gpd/ft, with storage coefficients of 1.65×10^{-4} and 1.28×10^{-4}. Both aquifers are capable of supplying water for irrigation, at least on a limited scale.

Bhujauli Site--A flow test was made on test hole 6/12 near Bhujauli on April 22, 1972. After flowing for a period of 70 hours at 22 gpm, the pressure head declined about 0.34 feet, and when shut in then recovered to the original static head of 13.53 feet after 32 hours. Analysis of the data by the Theis recovery method indicated a moderately high transmissivity of 64,530 gpd/ft. The low yield of the well does not reflect the relatively high transmissivity value, owing largely to the small size (1 1/2-inch diameter) of the casing and screen.

Mughla Site--Aquifer tests were conducted using two flowing artesian wells near Mughla from May 1 to 7, 1972. Well 8/3 screened in gravel and coarse sand from 500 to 520 feet, initially flowed at 450 gpm. During the tests, however, the discharge had to be controlled to maintain a constant rate, owing to decline in yield with prolonged flow. During the test well 8/3 was allowed to flow at 335 gpm for 24 hours, and in this period the pressure head declined 17.2 feet in observation well 8/2 located 100 feet away. The recovery rate coincided closely with the drawdown to indicate a relatively low to moderate transmissivity in the range of 12,900 to 21,000 gpd/ft. The storage coefficient ranged from 1.1×10^{-3} to 3.25×10^{-4}. The relatively low values suggest a decrease in transmissivity of the aquifer to the west of Mughla. The aquifer could supply water for irrigation, however, if production wells are judiciously spaced and utilized.

Asnia Site--Flowing well 8/5, near Asnia, screened in a coarse sand and gravel from 215 to 237 feet, was tested on April 4, 1972. The well was allowed to flow at 115 gpm for 28 hours with a pressure decline of 3.4 feet. After shutdown the pressure head returned to the original static head of 27.5 feet above land surface. The plotted recovery indicates an average transmissivity of 27,600 gpd/ft and suggests a decrease in transmissivity toward the west.

Rehara Site--An aquifer test made on the non-flowing tubewells near Rehara indicates the aquifers in this area have low transmissivities. On May 19, 1972 tubewell 9/5 was pumped for 48 hours at the rate of 50 gpm with a drawdown of 12.9 feet.

A decline in water level of 4.96 feet was recorded in observation well 9/4 located 180 feet away. The drawdown and recovery data were plotted and indicated transmissivities in the range of 7,160 to 7,400 gpd/ft and a storage coefficient of 9.35×10^{-5}.

<u>Motipur Site</u>-- An aquifer test using two flowing artesian wells was made May 7-9, 1972 at the Motipur site. Well 9/8 screened in sand and gravel from 131 to 167 feet, was allowed to flow at 618 gpm for 24 hours. In observation well 165 feet away, the pressure declined 9.01 feet from a static head of 27.81 feet above land surface. The recovery rate coincided with the drawdown to indicate a moderately high transmissibity in the range 59,020 to 61,000 gpd/ft with a storage coefficient of 1.01×10^{-4}.

<u>Taulihawa Site</u>--An aquifer test conducted in tubewells at Taulihawa suggests that some of the aquifers in western Kapalvastu District have very low transmissivity. Although the wells at Taulihawa flow with a static head of about 8 feet above land surface, a pump was installed in well 10/3 to increase the yield and subsequent effects on the adjacent observation well 10/2. Well 10/3 was pumped at 36 gpm for 24 hours, with a total drawdown of 56 feet. The pressure decline in the observation well 75 ft away attained a maximum of 5.98 feet below land surface. The computed transmissivity for the drawdown and recovery cycles indicates a very low range of 2,080 to 2,210 gpd/ft. The storage coefficients, however, were 1.25×10^{-4} and 1.67×10^{-4} or very similar to storage coefficients elsewhere in the same aquifer system. The low values of transmissivity

suggest poor potential for intensive irrigation from aquifers.

Champapur Site--A Theis recovery test was conducted on small flowing well 11/5 at Champapur on May 12, 1972. The well was allowed to flow for 24 hours at 13 gpm. After the well was shut off for 22 hours the pressure head recovered a total of 3.81 feet to the original static head of 13.19 feet above land surface. The plotted data indicated a low transmissivity of 6,520 gpd/ft, characteristic of the western part of the study area.

Dharamnagar Site--The aquifer test conducted on two flowing wells near Dharamnagar again demonstrates the low transmissivity values encountered in the western part of the Lumbini Tarai. During the test the well 12/5 screened from 190 to 210 feet, in fine to coarse sand and fine gravel, was allowed to flow at 26 gpm for 24 hours. A pressure decline of 3.75 feet was observed in the observation well located 50 feet away. The recovery rate coincided with the drawdown to indicate a low transmissivity in the range of 5,410 to 6,550 gpd/ft computed by the Theis non-equilibrium and Jacob-Cooper modified formulas. The storage coefficients were in the 10^{-4} range.

Shivanagar Site--A Theis recovery aquifer test was conducted on well 13/2 at Shivanagar, June 2, 1972. The well was pumped with a small turbine pump at 42 gpm for a period of 24 hours, with a resultant drawdown of 19.6 feet. The recovery when plotted indicated a relatively low coefficient of transmissibity of

13,040 gpd/ft. The well was screened from 210 to 227 feet in fine siltstone gravel.

The water-bearing beds in most of the Tarai area of the Lumbini Zone range from 10 to 30 feet thick. The transmissivity of these aquifers ranges from less than 10,000 to more than 200,000 gpd/ft in the artesian zone and from 200,000 to 800,000 gpd/ft in beds of the Bhabar zone near the antecedent streams. Well yields and drawdowns vary with the magnitude of the transmissivity coefficients. In many instances yields of production wells could be increased by multiple screening of two or more aquifers in the same well. Caution needs to be used, however, in screening artesian aquifers, if there is a considerable head differential since the aquifers under higher head will leak through screened sections into aquifers of lower head. The actual yield, could even decrease at least initially, until the head differential equalizes.

Well Interference and Spacing

In areas of artesian flow, especially where the confined water is just beginning to be utilized, it is beneficial for the water economy to space tubewells to maintain optimum flow yields with minimum interference effects between wells. Failure to space wells propertly results in premature decline of artesian pressure and loss of free flow in the boreholes. It is equally important in areas of non-flow to space wells so as to minimize decline of water levels and concurrent increased pumping lifts. The hydraulic characteristics and other hydrological data obtained from the aquifer tests indicate a wide range in the water-yield capacity of the aquifers of the Lumbini Tarai. Using data obtained from the aquifer tests it is possible to estimate approximately how long a well will flow or can be pumped at a given rate and also what the interference effects will be with respect to nearby tubewells in the same area.

Relatively small drawdown effects were noticed in the boreholes tested north of Bhairawa near Fish Farm well 5/10 where the artesian aquifer has a high transmissivity. At the Fish Farm a single well flowing at the rate of 500 gpm would cause a decline in artesian head or pressure of 7.37 feet at a distance of 10 feet from the tubewell after 5 years. After flowing for 30 years at the same rate, the total decline would be only 8.0 feet. If the flow were increased to 1,000 gpm, however, the decline in pressure head at a distance of 10 feet from the tubewell would be 14.7 feet (fig.9) after 5 years of continuous flow.

Single producing tubewells are not the rule, however, in any given area. More commonly, boreholes are clustered in groups of two or more so that the head in any one tubewell is the sum of its own drawdown plus the interference effects of other producing tubewells nearby. Graphs (fig. 10) have been constructed using a method (Lang, 1961) that modifies the Theis non-equilibrium formula. This method helps resolve problems related to the proper spacing of two tubewells of the same construction and yield that tap a common aquifer. Thus two tubewells near the Fish Farm each flowing at 100 gpm would have a combined pressure decline of 2.45 feet if spaced 1,000 feet apart or 2.16 feet if located 10,000 feet from each other when flowing continuously for 100 days (fig. 10). Likewise, if the discharge of the well were increased to 1,000 gpm the combined pressure decline in each tubewell would be 24.5 feet if spaced 1,000 feet apart. As shown above the total decline in head resulting from prolonged discharge will be the sum total of the well interference figures of all wells within the area of influence of each well. The pressure decline can be minimized by optimum spacing of wells and the judicious use of water. In other areas where the transmissivities are more than 100,000 gpd/ft such as the Agriculture Farm and Chapia (Baidauli), the

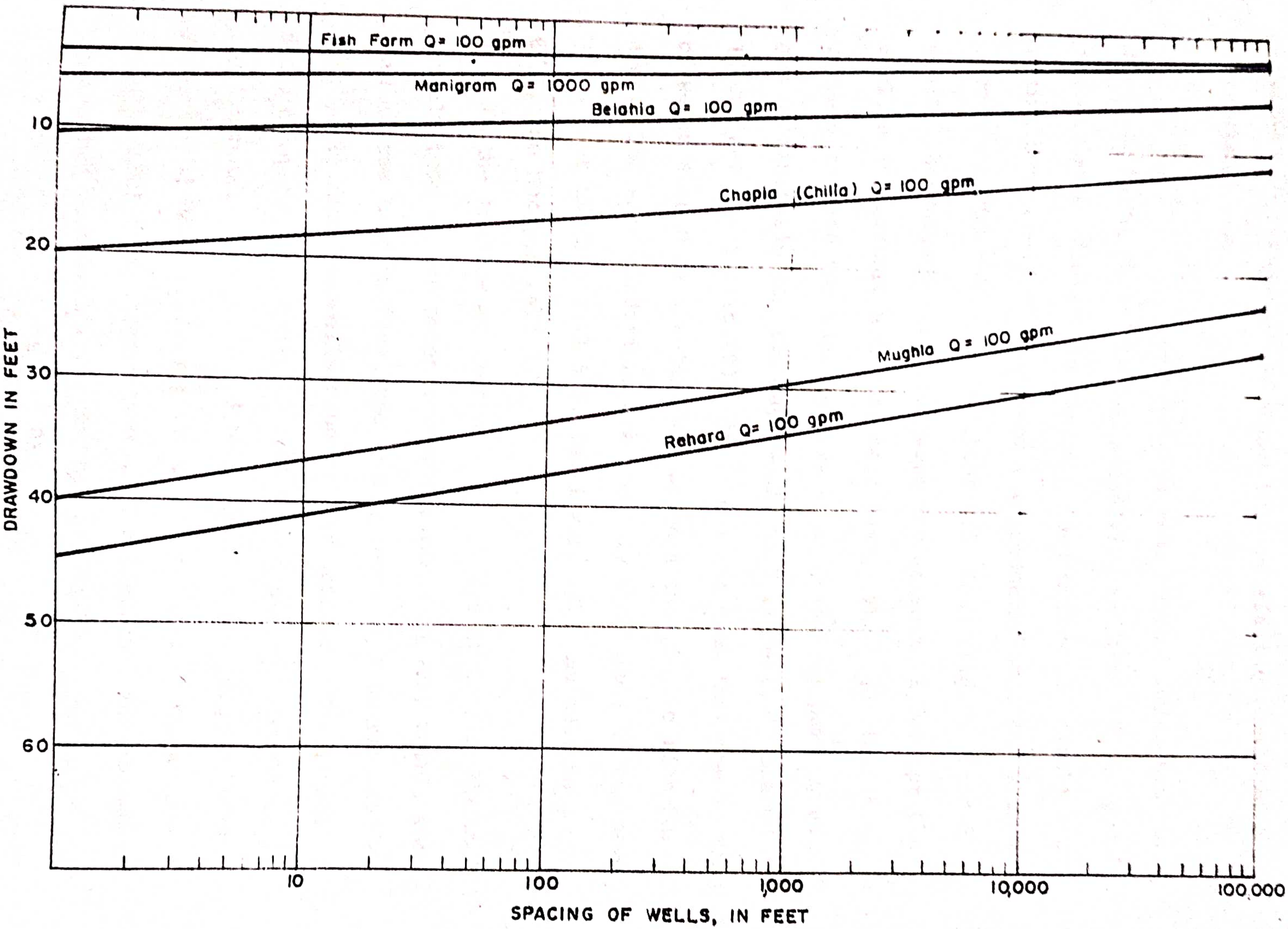


Figure 10. Graph showing Predicted Interference between 2 Tubewells Spaced at Varying Distances after 100 days continuous Discharge.

declines in pressure head would be very similar to those described above.

Near well 4/4 in the Belahia area about 6 miles east of the Fish Farm, where the transmissivity is about 60,000 gpd-ft, the estimated decline in pressure head that would result from a single tubewell 10 feet from the producing well and yielding a constant 200 gpm would be about 8.82 feet (fig. 9) after 5 years. Likewise if the flow were increased to 1,000 gpm the decline in pressure would be 44.1 feet. The predicted interference between two identical wells in this area pumping at 100 gpm continuously for 100 days would be 7.14 feet, if spaced 1,000 feet apart (fig.10). It is evident then that the spacing of wells should be greater near Belahia than in the Fish Farm area. The same conditions are probably applicable in the same areas near S.P. Camp well 5/5, Semri well 6/7, Bhujauli well 6/12, and Motipur well 9/7.

In the shallow aquifer of tubewell 6/8 at Chapia (Chilia) the altitude of the potentiometric surface is very nearly the same as the land surface, therefore, pumps will be required to lift water from tubewells tapping this aquifer. The estimated decline that would result 10 feet from a single tubewell yielding a constant 200 gpm would be about 15.5 ft. (fig. 9) after 5 years. If the yield were increased to 500 gpm the decline would be 39.1 feet after 5 years. The predicted interference between two identical wells in the same aquifer pumping at

100 gpm continuously for 100 days would be 12.75 feet (fig. 10) if spaced 1,000 feet apart. This analysis further indicates that the distance between wells should increase as the transmissivity of the water-bearing formations decreases. The transmissivity of the shallow aquifer at Chapia (Chilia) is about 30,600 gpd/ft. Similar conditions may also be encountered in the areas near Pasauli well 2/3, Sitlapur well 4/2, Kerwani well 4/6, and Asnia well 8/5 as transmissivities at these sites range from 20,000 to 30,000 gpd/ft.

Aquifer tests conducted at Bogri well 6/3 and Mughla well 8/2 indicate transmissivities in the relatively low range of 12,000 to 15,000 gpd/ft. The estimated decline in head that would result 10 feet from tubewell, near Bogri, yielding a constant 100 gpm, would be about 13.2 feet after 5 years. Likewise the decline at Mughla would be about 11.4 feet (fig. 9) during the same period. The predicted interference between two identical wells in each of these two areas yielding 100 gpm continuously for 100 days would be about 27.7 feet at Bogri and 27.4 feet at Mughla (fig. 10), if each were spaced 1,000 feet apart. Similar conditions could be encountered in aquifers near Vishnupura well 4/1 and Shivanagar well 13/2 where the transmissivity appears to be in the same general range.

A number of test sites, located mostly in the western part of the study area, indicate unusually low transmissivity values of less than 10,000 gpd/ft. Aquifer tests conducted at Rehara well 9/4 and Dharamnagar well 12/4 indicate transmissivity values in the low range of 5,000 to 7,000 gpd/ft. The estimated decline in head that would result 10 feet from a tubewell near Rehara yielding a constant 100 gpm would be about 30.4 feet (fig. 9) after 5 years. Likewise the head decline in a well at Dharamnagar would be about 37.1 feet during the same period. The predicted interference between two identical wells, at each of these locations yielding 100 gpm continuously for 100 days at a distance of 1000 feet apart, would be about 48.0 feet at Rehara (fig. 10) and 58.3 feet at Dharamnagar. It is evident from these figures that the yields of wells in the western part of the report area are quite low and the interference effects between wells would be high. These conditions limit the potential of the aquifers to supply sufficient water for extensive irrigation.

Aquifer tests conducted on wells penetrating the Bhabar zone south of Butwal indicate exceptionally high transmissivity values ranging from 200,000 to 2,000,000 gpd/ft. At Manigram well 5/14 site, using an indicated transmissivity of 815,000 gpd/ft, a single well discharging at a rate of 1,000 gpm would have a water-level decline of about 2.4 feet at a distance of 10 feet from the well after 5 years of continuous pumping (fig. 9). The predicted interference between two wells pumping at 1,000 gpm continuously for 100 days would be 3.69 feet with the wells spaced 1,000 feet apart (fig. 10). Similarly, a single well at the Jogikuti well 5/18 site discharging at a rate of 1,000 gpm would cause a decline in water level of 4.4 feet at a distance of 10 feet from the well after pumping continuously for 5 years. Predicted declines in water level and attendant interference between wells are minimal in this area of Bhabar zone deposits and should present few or no problems with well spacing.

Owing to lack of information at this writing all the previously predicted declines in water levels and pressure heads are based upon conditions at a specific time and have not taken into consideration annual recharge to the aquifers. During high rainfall of the monsoon in the Lumbini Tarai, the recharge is undoubtedly of considerable magnitude. Future monitoring of water levels and water use should provide information on the amount of recharge that may occur to the aquifer systems of the Lumbini Tarai.

Chemical Quality of Water

The chemical quality of water from the artesian and semi-artesian aquifers of the Lumbini Tarai is generally good and is suitable, with a few exceptions, for domestic supply, livestock, and irrigation. Analyses of water from 33 tubewells (table 6) show that all the water is potable and that most of the ion concentrations are below the maximum limits suggested by the U.S Public Health Service (1961) for drinking water. The water from the aquifers in the report area is generally moderately hard usually from 100 to 250 parts per million (ppm) total hardness as $CaCo_3$.

The water from the aquifers of the Lumbini Tarai is suitable in chemical quality for irrigation on many types of soils. Most of the water analyses, when plotted on the classification diagram (fig. 11), indicate a low to very low sodium hazard and a medium salinity hazard. Water samples from tubewells near Shivanagar and Krishnagar in the extreme south-west section of the report area indicate a low sodium and medium to high salinity hazard. The effect of the salinity hazard may be overcome by leaching of cultivated soils by excess irrigation or naturally with rainfall. The artesian water is predominantly a bicarbonate type with varying proportions of calcium, magnesium and sodium ions. The bicarbonate ion concentration is for the most part relatively high, ranging from 200 to 450 gpm.

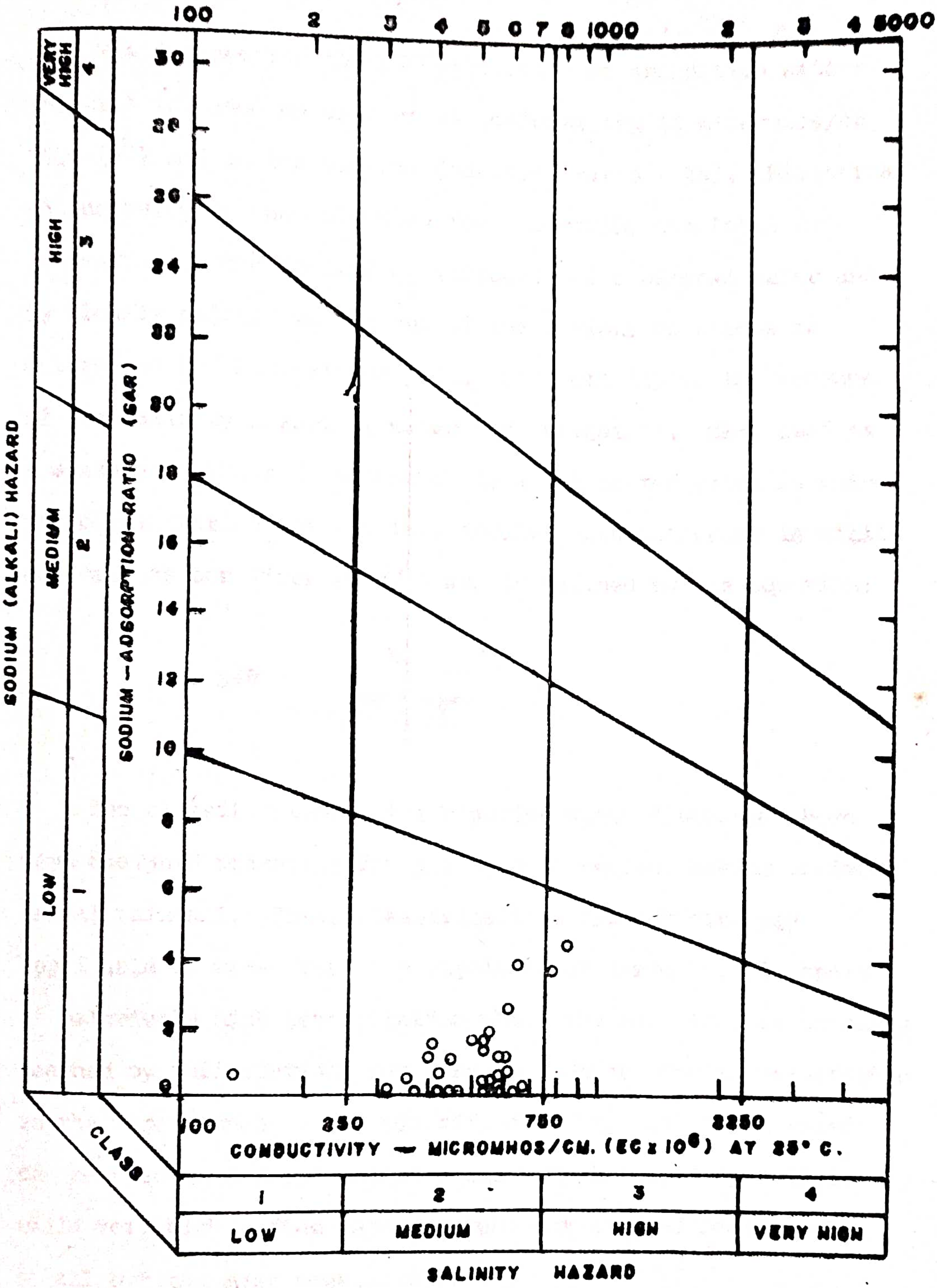


Figure 11. Diagram showing classification of waters from Tubewells in Lumbini Zone, Western Tarai, with Respect to Suitability for Irrigation.

The diagram for the classification of irrigation waters (fig.11) is based on electrical conductivity in micromhos/cm (ECx 10^6) and on the sodium-adsorption ratio (SAR). Electrical conductivity is commonly used for indicating the total concentration of the ionized constituents of a natural water and is closely related to the sum of the cations or anions as determined by chemical analysis. Conductivity is the measure of the salinity hazard of water for irrigation. SAR, used as a measure of the sodium hazard, is a calculated value in which the concentrations of the ions involved are expressed in milli-equivalents per liter (meq/l) and is defined by the equation:

$$SAR - \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

The classifications of irrigation water discussed above were designed primarily for use in arid regions having minimal annual rainfall. These classifications are not directly applicable to water used for supplemental irrigation in areas of relatively high percipitation where the root zone is annually leached by infiltration from monsoon. Under conditions existing in the report area, water classified as high salinity hazard can be used on a supplemental basis with little danger to crops, while very high sodium hazard waters can be used occasionally on all but the most sensitive crops.

Areas of Ground Water Potential for Utilization

The following discussion is an amplification of the information presented in figure 12.

Zone 1--The Bhabar zone south of Butwal, is an area where aquifers have extremely high transmissivity values indicating that high yields can be obtained from properly-constructed tubewells with relatively small drawdowns. Spacing of wells drilled in this area are not as critical as elsewhere in the Lumbini Tarai as interference effects between wells will be minimal. Further, recharge to the aquifer system likely occurs annually. The static water levels, however, are below land surface and pumps will be required to life water for irrigation. Zone 1 conditions also exist in the eastern part of the Lumbini Tarai near the Narayani River and to a less extent along consequent streams where they leave the Churia Hills and enter the Tarai.

Zone 2--The optimum area for flowing artesian aquifers (fig. 3) is centered north of Bhairawa near the Agriculture Research Farm and the Government Fish Farm. From this center, the zone of high transmissivity radiates outwards diminishing to 60,000 gpd at Belahia to the east, to 50,000 gpd at the S.P. Camp south near Bhairawa, and to an average of 60,000 gpd on a line between Semri and Bhujuali to the west. The high transmissivity values for the artesian area also appear to extend beneath the Bhabar zone to the north as indicated by the well at Driver Tole. Well spacing near the center of this zone would not be overly critical. Towards the outer limits of this zone, however, well spacing and judicious use of water would be matters of increasing concern.

Zone 3--Areas with transmissivity values of 25,000 to 60,000 gpd/ft are included in zone 3. Wells in this zone could be used for irrigation, however, interference between wells would be more pronounced than in zones 1 and 2. Production wells should, therefore, be spaced father apart to minimize cumulative drawdown effects and attendant increase of pumping lifts.

Zone 4--In this area the aquifers generally have low transmissivities of 10,000 to 25,000 gpm/ft. Production wells in this zone would also probably have relatively low specific capacities, but could be used for small-scale or supplemental irrigation.

Zone 5--Aquifers in this area have generally very low transmissivities of less than 10,000 gpd/ft. Wells in this zone should be limited generally to domestic and public-supply use, or specialized industrial use where high unit cost could be absorbed.

Wells in zones, 3, 4, and 5 should likely be constructed to screen several aquifers in order to produce the maximum possible yield at a given location.

General Conclusions and Recommendations

Conclusions

1. The area where tubewells can be successfully developed for irrigation are not uniformally distributed in the Lumbini Tarai. Generally, the Bhabar zone and the mid-central part of the report area are best suited to large-scale ground-water exploitation.

2. Except for aquifers in the coarse deposits of the Bhabar zone, aquifers elsewhere in the report area occur in relatively thin layers of sand and gravel interstratified with clay layers of variable thickness. The water-bearing beds dip generally to the south throughout the report area.

3. Although the Bhabar zone has the best potential for ground water development, the water levels are everywhere below land surface and pumping will be required to lift water for irrigation.

4. The area of maximum flow-well artesian pressure is centered about 2 to 3 miles north of Bhairawa. Heads above land surface as well as yields decrease gradually in all directions from this center.

5. The extreme southern and the southwestern parts of the Lumbini Tarai are the poorest with respect to potential for ground-water development.

6. Initial artesian head above land surface generally declines rapidly with use, but flow usually stabilizes at roughly one-half of the initial yield after several months.

7. The chemical quality of both flowing and non-flowing ground water in the report area is generally good and suitable, with few exceptions, for domestic supply, livestock, industry, and irrigation. The bicarbonate ion concentration, however, is for the most part relatively high.

Recommendations

1. The observation well program established by the Ground Water Project in the Lumbini Tarai should be continued. Data obtained from this monitoring program will become increasingly important as the ground-water resource is developed and utilized. Whereas aquifer test data provide a basis for planning a production well program, long-term observations of water levels and pressure head are necessary for optimum management of the ground-water resource. This is particularly true

relative to achieving the optimum utilization of the resource and balancing by natural and artificial discharge with recharge to the aquifer systems.

2. Generally, most tubewells drilled for irrigation use should be located in zones 1, 2, and 3 of the Lumbini Tarai (fig. 12). Spacing of tubewells should be planned to minimize interference between wells.

3. All tubewells constructed in the flowing artesian area should be properly cemented, and the yield and flow regulated by control valves. Yields from flowing wells should be limited to the amount of water actually required for the crop. After the irrigation requirement is satisfied, valves on the wells should be closed and remain closed until the next irrigation requirement. Conservation of pressure head and the ground-water resource by preventing needless waste of water will entail government supervision and enforcement.

4. The present common practice of putting down low-cost "slugger-type" wells in area of artesian flow should be curtailed and then prohibited as soon as other sources of water either from modern tubewells or canals can be provided to Tarai farmers. The slugger-type wells are wasteful of the ground-water resource, bleed off artesian head unnecessarily, and create local water-logging problems.

5. Generally, new production wells should be preceeded by a pilot "slim hole" to verify geohydrologic conditions at a new site. This same slim hole can subsequently be reamed to the planned diameter of the production well.

6. A number of wells resulting from the Ground Water Project investigations in the Lumbini Tarai have yields sufficient for irrigation. These have been turned over for use to the HMG Department of Irrigation. Some of these wells are already in use. Considering, however, the almost total lack of data on the economics of irrigation from tubewells in Nepal, it is suggested that three small pilot irrigation projects be established in the Lumbini Tarai utilizing three selected wells. These projects would include two of the flowing wells (one in zone 2 and one in zone 3, fig. 12) and one pumping well in the Bhabar zone (zone 1, fig. 12) requiring pumping. All other auxiliary installations such as pumps, canals, drainage, crop protection, etc. should be provided. After a year or more of operation, it should be possible to evaluate the economics of tubewell irrigation in the report area. On the encouraging side, however, is the fact that privately-owned tubewells

immediately south of the Lumbini Tarai in Uttar Pradesh, India have proved economically viable.

7. Yields from tubewells drilled in the less productive aquifers of zones 4 and 5 (fig. 12) as well as in better aquifers of zones 2 and 3 can be increased by screening several aquifers. Caution needs to be exercised, however, in screening several artesian aquifers in the same well where considerable head differential exists between aquifers. In such case, the yield may decrease at least until the head differentials equalize and may be less than initial yield even after equalization.

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Explanation to accompany Tables 4, 5 and 6

1. Numbers are assigned to a series of north-south trending traverses beginning at the eastern boundary of the Lumbini Zone and progressing westward at 10 km intervals. Test holes are numbered in sequence in each traverse from the Indian border northward. Example: traverse 3, borehole 2 is numbered 3/2.

2, Name of village near which corresponding test hole is located.

3. Approximate elevations, in feet above mean sea level, have been transferred from the benchmark at Bhairawa Airport using transit or theodolite. Figures are to the nearest foot.

4. Depth of test hole in feet below land surface.

5. Day, month and year the borehole was completed.

6. API line pipe (mild steel tubing) was used to case most of the boreholes and extends from the borehole head near land surfac to the top of screen.

7. a. The screen set in most boreholes is perforated pipe.
b. Depth in feet below land surface, to top and bottom of perforated pipe or well screen.
c. Type of material screened, (s) sand, (g) gravel; (f,m,c) fine, medium, coarse.

8. Pressure head at time well was drilled, in feet above (+) or below (-) land surface datum.

9. Yield, in U.S. gallons per minute (gpm) by natural flow (f), by airlift (a), or pump (p) measured after initial development.

10. Drawdown, decline in head or potentiometric surface, in feet, resulting from pumping or natural flow.

11. Specific capacity, ratio of gallons per minute of yield per foot of decline in head resulting from pumping or natural flow of a well.

12. Other Information:

A. Abandoned hole, casing pulled and hole plugged

12. (continued)

- T: Flow or pumping test carried out at borehole
- F: Foxboro pressure recorder installed
- S: Stevens water-stage recorder installed
- G: Geologic log in table 7
- E: Electric log in files
- C: Chemical analysis in table 6

13. Remarks

Table 7 Well Logs

Test Hole No.: 1/1

Location: Nandnagar

Drilled by: Hydrology Dept.

Altitude of Land Surface: ____________________

Static Water level (Head): ____________________ LSD

Drilling Started 15/5/71

Completed 15/5/71

Log by: S. M. Shrestha

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	1	1
Sand, gray, fine, with mica	9	10
Sand, coarse	1	11
Boulders, with sand, yellowish gray	1	12

Hole abandoned

Table 7 Well Logs

Test Hole No.: 1/2

Location: Fenahawa

Drilled by: Hydrology Department

Drilling Started 10/5/71

Completed 13/5/71

Log by: S. M. Shrestha

Altitude of Land Surface: 340 ft (103.6 m)

Static Water level (Head):__________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, gray, sandy	1	1
Sand, yellow, very fine	9	10
Sand, gray, coarse	7	17
Sand	13	30
Sand, medium, well sorted with qtz. & mica, possibly pebbles	5	35
Sand, coarse, well sorted, mostly qtz.	2	37
Sand, very coarse	3	40
Boulders with gravel & coarse sand	1	41

Hole abandoned

Table 7 Well Logs

Test Hole No.: 2/1
Location: Harakpura
Drilled by: N.B. Tubewells
Altitude of Land Surface: 338 ft. (103.0 m)
Static Water level (Head): -14 ft. LSD

Drilling Started 10/5/71
Completed 16/5/71
Log by: G.P. Chaturvedi

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil	7	7
Clay, gray w/sand and gravel	8	15
Clay, gray, sticky	15	30
Sand, gray, fine to medium	20	50
Gravel, w/sand	29	79
Clay, gray	3	82
Gravel	8	90
Clay, gray and yellow	10	100
Gravel	32	132
Clay, gray w/fine sand	5	137
Sand, w/gravel	3	140
Sand, fine	10	150
Clay, gray, w/fine sand	60	210
Gravel, w/medium sand, water bearing	15	225
Clay, w/gravel	10	235
Clay, gray, plastic	15	250
Clay, gray w/sand	20	270
Clay, gray, w/sand and some gravel	10	280
Clay, gray	10	290
Sand, fine to medium	5	295
Clay, gray w/fine sand	35	330
Clay, yellow and gray, plastic	130	460
Clay, yellow, sticky w/siltstone	20	480
Clay, yellow, sticky	40	520
Clay, yellow w/fine sand	10	530
Clay, gray, plastic	53	583
Sand, coarse w/gravel	19	602
Clay, yellow w/gravel	8	610
Clay, yellow w/fine sand	42	652
Clay, gray, plastic	20	672
Sand, gray, fine	18	690
Clay, gray, plastic	95	785
Clay, gray, w/fine sand	10	795
Clay, gray, plastic	95	890

Well Completion Data

Casing - 235 ft. 6 in.
Screened Zone - 209-226 ft.
Yield

Table 7 Well Logs

Test Hole No.: 2/2

Drilling Started 5/5/71

Location: Pasauli

Completed 6/5/71

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi

Altitude of Land Surface: 331 ft. (100.9 m)

Static Water level (Head): -12 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Subsoil, light yellow	6	6
Gravel, angular to subangular	6	12
Clay, gray, plastic	8	20
Sand, gray, fine to medium	30	50
Gravel, subrounded to angular w/sand	10	60
Clay, gray plastic w/sand and gravel	45	105
Gravel, angular to subrounded w/fine sand, water bearing	25	130
Clay, gray, plastic w/fine sand	30	160
Clay, gray, plastic	40	200

Well completion data

Casing: 135 ft/10 in. to 6"
Screened Zone: 105-135 ft/6 in.
Yield 473 GPM (Pumped)
Drawdown 44.1 ft.

Table 7 Well Logs (3)

Test Hole No.: 2/3

Drilling Started 3/5/71

Location: Pasauli

Completed: 4/5/71

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi

Altitude of Land Surface: 332 ft. (101.3 m)

Static Water level (Head): -13 ft. LSD 97.23 m

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil, yellow, sandy clay	5	5
Clay with fine sand	5	10
Sand, medium	60	70
Clay, gray, plastic with fine sand	40	110
Gravel with fine to medium sand, water bearing	30	140
Clay, gray, plastic with sand	50	190
Clay, yellowish-gray, plastic	40	230
Clay, gray, plastic with fine sand	30	260
Clay, dark gray, plastic	50	310
Sand, very fine	10	320
Clay, grayish-yellow, plastic	70	390
Gravel, fine, angular to sub-rounded with fine sand	20	410
Clay, gray with fine sand	10	420
Clay, gray, plastic	10	430
Gravel, angular to sub-angular	10	440
Clay, gray, plastic	60	500

Well completion data

Casing 148 ft/1½ in.
Screened Zone: 118 - 128 ft. 35 – 39
Yield

Table 7 Well Logs

Test Hole No.: 2/4

Location: Sishania

Drilled by: N.B. Tubewells

Drilling Started 8/5/71

Completed 10/5/71

Log by: S. B. Kansakar

Altitude of Land Surface: 338 ft. (103.1 m)

Static Water level (Head): -10 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil, grayish-yellow	5	5
Clay, light yellow w/fine sand	15	20
Sand, fine	10	30
Sand, w/gravel, well sorted	20	50
Clay, gray w/sand	30	80
Sand, fine	10	90
Gravel, rounded to subrounded w/sand	10	100
Clay, gray w/sand	10	110
Sand, very fine	12	122
Gravel, angular to sub-rounded, w/fine sand, water bearing	28	150
Clay, gray, plastic	35	185
Clay, gray, plastic w/sand and gravel	55	240
Clay, dark gray, plastic	20	260
Clay, yellow, sticky w/sand and gravel	20	280
Clay, yellowish-gray, plastic	15	295
Clay, gray, w/sand and gravel	25	320
Clay, gray, sticky	40	360
Clay, gray, w/sand	110	370
Gravel, well sorted w/fine sand	10	380
Clay, gray, sticky	40	420
Clay, gray, w/very fine sand	5	425
Gravel, w/fine sand	20	445
Clay, gray, plastic	55	500

Well completion data

Casing: 168 ft/ $1\frac{1}{2}$ in.
Screened Zone: 138 - 148 ft.

Table 7 Well Logs

Test Hole No.: 2/5

Drilling Started 7/5/71

Location: Bhataulia

Completed 12/5/71

Drilled by: Hydrology Dept.

Log by: S. B. Kansakar

Altitude of Land Surface: 360 ft. (108.6 m)

Static Water level (Head): -15 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, gray and yellow, sticky	15	15
Sand, yellow, very fine to fine	21	36
Clay, gray, sticky	4	40
Sand, with quartz, biotite muscovite and other minerals	48	88
Clay, gray with some siltstone fragments	38	126
Sand, yellow, with qtz., biotite & muscovite	16	142
Sand, yellow with sandstone & siltstone particles	5	147
Clay, gray with siltstone fragments	2	149
Gravel & pebbles, angular, with layers of fine to coarse sand	22	171
Clay with fine sand	2	173
Gravel, coarse	2	175
Clay, gray, sticky	55	230
Clay, gray & black, sticky, hard with sand	50	280
Clay, gray & yellow, sticky, sandy, with siltstone particles	108	388
Gravel & pebbles, water bearing	50	438
Gravel & pebbles with thin layer of clay at 440 ft.	7	445
Clay, yellow & gray, sandy	27	472
Gravel & pebbles with thin layer of clay at 493 ft.	25	497

Well completion data

Casing: 440 ft/1½ in.
Screened Zone: 420 to 430 ft.

(6)

Table 7 Well Logs

Test Hole No.: 2/6

Location: Vijayapur

Drilled by: Hydrology Department

Drilling Started 12/4/71

Completed 15/4/71

Log by: S. B. Kansakar

Altitude of Land Surface: 384 ft. (117.0 m)

Static Water level (Head): ______________ ISD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, grayish-yellow	4	4
Clay, yellow, sandy	12	16
Sand, yellow, fine, clayey	12	28
Sand, coarse	32	60
Clay, gray & yellow, sticky with clayballs and siltstone fragments	180	240
Clay, gray with thin sand and silt layers	10	250
Clay, gray & yellow, sticky	70	320
Clay, gray & yellow, sandy with clayballs	40	360
Clay, gray & yellow, sticky	20	380
Gravel	20	400

Well construction data

Casing: 386 ft/1½ in.
Screened Zone: 381-386 ft. 116 - 117.6

Table 7 Well Logs

Test Hole No.: 3/1

Location: Hardi

Drilled by: N.B. Tubewells

Drilling Started 28/4/71

Completed 29/4/71

Log by: G. P. Chaturvedi

Altitude of Land Surface: 337 ft. (102.7 m)

Static Water level (Head): -10 ft. LSD

91.67 m

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil, grayish yellow, sandy	5	5
Sand, fine to medium with gravel	15	20
Clay, grayish yellow, plastic with sand	12	32
Gravel with sand, fine to medium	28	60
Clay, gray, plastic	5	65
Gravel	15	80
Clay, gray with fine sand	20	100
Clay, gray plastic	60	160
Gravel, coarse	3	163
Clay, gray, plastic	17	180
Sand, fine with gravel	40	220
Clay, gray with fine sand	20	240
Sand, fine	20	260
Clay, gray, sticky	30	290
Sand, fine to coarse with gravel, water bearing	25	315
Clay, gray, sticky	45	360
Gravel, sandstone, with fine sand	20	380
Clay, gray, plastic	40	420
Clay, gray with fine sand	40	460
Clay, gray, plastic	40	500

Well completion data

Casing: 315 ft/1½ in.

Screened Zone: 297-307 ft. 90.5 – 93.5

Table 7 Well Logs ✓ 8

Test Hole No.: 3/2

Location: Jokwar

Drilled by: N.B. Tubewells

Drilling Started 24/4/71

Completed 27/4/71

Log by: S. B. Kansakar

Altitude of Land Surface: 344 ft. (104.7 m) 103.02 m

Static Water level (Head): -6 ft. LSD 1.8

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, dark brown	6	T 6 1.8
Clay, yellow w/sand	6	C 12
Clay, gray, sticky	18	30 9.1
Gravel, fine w/sand	10	40
Clay, gray, plastic	10	50
Gravel, well sorted w/sand & siltstone fragments	10	GWC 60
Clay, gray, plastic	7	67
Gravel, well sorted w/coarse sand	11	78 23.7
Clay, gray, plastic	5	83
Clay, gray w/sand.	27	C 110
Clay, gray, sticky	30	140
Clay, gray, w/sand	30	170 51.8
Gravel, w/coarse sand	2	172
Clay, dark gray, plastic	13	185
Gravel, w/gray clay	15	CWG 200
Clay, gray w/gravel	30	230 70.1
Clay, yellowish gray	20	CW 10s 250
Sand, medium to coarse w/gravel	8	258 78.6
Clay, gray, plastic	34	C 292
Sand, gray, coarse w/gravel, rounded to subrounded, water bearing	18	SCWG 310 89
Clay, gray, plastic w/fine gravel	20	330 94.5
Sand, very fine	10	CW 10s 340
Clay, dark gray, plastic	50	390 103.6
Gravel, w/sand	6	C 396
Clay, gray, plastic w/gravel	34	430
Clay, gray, plastic	70	500 152.4

Well completion data

Casing: 315 ft/$1\frac{1}{2}$ in.

Screened Zone: 298-308 ft. 90.8 – 94

Table 7 Well Logs

Test Hole No.: 3/3

Location: Parasi

Drilled by: N.B. Tubewells

Altitude of Land Surface: 355 ft. (108.2 m)

Static Water level (Head): -8 ft. LSD 2.4

Drilling Started 20/3/71

Completed 23/3/71

Log by: G. P. Chaturvedi

105.76 m

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil	4	4
Clay, fine with sand & gravel	4	8
Sand, gray with medium gravel	22	30
G ravel & medium grained sand	2	32
Sand, gray, coarse grained with muscovite & biotite	38	70
Clay, yellow with gravel, sub-rounded to angular and sand	10	80
Clay, black & yellow, sticky	50	130
Clay, gray & yellow with siltstone	10	140
Clay, yellow & gray with silt	8	148
Silt, fine, compact, cemented	15	163
Clay, gray with silt bed from 196 to 199	57	220
Clay, gray & silt	10	230
Clay, gray, sticky	11	241
Sand, fine grained	16	257
Clay, gray & yellow, sticky with silt bed from 276-280	23	280
Clay, gray & yellow, sticky	8	288
Sand, fine to coarse with gravel from 300 ft., water bearing	28	316
Clay, gray sticky	5	321

Well completion data

Casing: 8 in. to 90 ft/ 4 in. to 321

Screened Zone: 291 - 321 ft/ 4 in. 88.7 – 97.8

Yield: 450 GPM (est., Air lift)

Table 7 Well Logs

Test Hole No.: 3/4

Location: Parasi

Drilled by: N.B. Tubewells

Drilling Started 26/3/71

Completed: 27/3/71

Log by: G. P. Chaturvedi

Altitude of Land Surface: 353 ft. (107.6 m)

105.16 m

Static Water level (Head): -8 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	6	6
Clay, yellow with fine sand	6	12
Sand, fine with gravel, carbonaceous material at 28 ft.	18	30
Sand, gray, fine to medium with muscovite & garnet	11	41
Clay, with fine sand	19	60
Sand, medium to coarse with gravel	10	70
Clay, yellow with sand & gravel	10	80
Clay, yellow & gray, sticky	30	110
Clay, gray-yellow, sticky with silt	50	160
Clay, grayish yellow	15	175
Sand, gray, fine grained	7	182
Clay, yellow, sticky with gravel	11	193
Sand, fine with muscovite	7	200
Clay, yellow, sticky with gravel & sand from 220 to 230	40	240
Sand, fine with silt	10	250
Clay, with gravel, fine to coarse	20	270
Clay, gray to yellow with very fine sand	10	280
Clay, gray & yellow, sticky with silt & gravel	30	310
Clay, dark gray with very fine sand	10	320
Clay, gray, sticky	10	330

Well completion data

Casing 330 ft/1½ in.
Screened Zone: 295-305 ft.
Yield: 25 GPM (Air lift)

Table 7 Well Logs

Test Hole No.: 3/5

Location: Swathi

Drilled by: N.B. Tubewells

Drilling Started 29/3/71

Completed 4/4/71

Log by: Driller

Altitude of Land Surface: 380 ft. (115.8 m)

Static Water level (Head): -5 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	5	5
Sand, fine	18	23
Clay, gray with wood fragments from 23 to 25 ft.	25	48
Sand, coarse	3	51
Clay, gray with gravel	4	55
Clay, yellow with kankar	10	65
Clay, yellow, sticky	35	100
Clay, loose with kankar	39	139
Clay, gray with kankar from 152 ft.	21	160
Clay, sandy	30	190
Gravel	17	207
Clay with kankar	23	230
Clay	90	320
Sand, coarse	5	325
Clay	73	398
Clay, sandy with kankar	19	417
Clay, loose with kankar	11	428
Sand, medium-coarse with fine gravel	18	446
Clay, loose with kankar from 458-466 ft.	127	573
Sand, with gravel from 580	12	585
Clay, loose	25	610
Clay, sandy	17	627
Sand, coarse with gravel	23	650
Clay	25	675
Sand, coarse with gravel	15	690
Clay	29	719
Clay, sandy, soft	31	750
Clay, sticky, soft	58	808
Clay, sandy	10	818
Clay, sticky, soft	88	906
Clay, sandy	9	915
Clay	5	920
Clay, sandy	10	930
Clay	20	950
Clay, sandy	15	965
Clay	35	1000

Well completion data

Casing: 648 ft/1½ in.

Screened Zone: 628-648 ft.

Yield: 20 GPM (Air lift)

Table 7 Well Logs

Test Hole No.: 3/6 — Drilling Started 7/4/71

Location: Khairini — Completed: 10/4/71

Drilled by: N.B. Tubewells — Log by: G. P. Chaturvedi

Altitude of Land Surface: 397 ft. (121.1 m)

Static Water level (Head): + 12 ft. LSD   124.66 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellowish gray with clay	5	5
Sand, yellow, v. fine with clay	7	12
Clay, light yellow	8	20
Sand, coarse with fine sandstone & siltstone gravel	10	30
Gravel, medium, well sorted, rounded	10	40
Sand, gray, medium with mica	30	70
Clay, gray	20	90
Clay, dark gray with gravel, rounded to sub-rounded	10	100
Clay, yellow, hard with siltstone fragments	20	120
Gravel, with sandstone & siltstone fragments	18	138
Gravel, with clay	10	148
Clay, yellow, sandy with gravel	10	158
Gravel, fine to medium	10	168
Clay, yellow, sandy	7	175
Clay, yellow, gray, plastic	10	185
Clay, gray, sandy	25	210
Clay, with gravel	20	230
Sand, light gray, fine	10	240
Sand, gray with clay	10	250
Clay, gray & yellow, sticky	10	260
Clay, yellowish-gray with silt and v. fine sand	20	280
Gravel, mostly of sandstone with medium sand, water bearing	30	310
Clay, gray, plastic	5	315

Well completion data

Casing: 315 ft./$1\frac{1}{2}$ in.
Screened Zone: 285-305 ft.   86.8 – 92.9
Yield: 15 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 3/7 | Drilling Started 10/4/71

Location: Sunwal | Completed: 12/4/71

Drilled by: N.B. Tubewells | Log by: S. B. Kansakar

Altitude of Land Surface: 419 ft. (127.7 m)

Static Water level (Head): +8 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	10	10
Clay, brownish-yellow, sandy	10	20
Gravel, medium with many sandstone fragments	20	40
Clay, dark gray with gravel	10	50
Gravel, fine to medium with many sandstone fragments	10	60
Clay, dark gray with sand near top	63	123
Sand, medium with gravel	7	130
Gravel with sand & silt layers	10	140
Sand, gray, medium with gravel, water bearing	20	160
Gravel	8	168
Clay, dark gray to yellow with gravel	17	185
Gravel with sand & siltstone fragments	7	192
Clay, dark gray with gravel	28	220
Clay, dark gray, plastic	12	232
Clay, gray, plastic	8	240
Clay, gray, plastic with gravel	30	270
Sand, gray, medium to coarse	40	310
Clay, yellow, sandy	10	320
Gravel, with medium to fine sand	8	328
Clay, yellow-gray, plastic	12	340
Clay, gray, plastic	20	360
Clay, gray, plastic with medium sand	10	370
Sand, gray, coarse	34	404
Sand, fine with gravel & siltstone fragments	16	420
Clay, gray, plastic	45	465
Clay, yellow-gray, plastic with gravel	7	472
Clay, gray, very plastic	28	500

Well completion data

Casing: 160 ft/1½ in.
Screened Zone: 140-150 ft. 137-147 ft.
Yield: 10 GPM (flowing)

Table 7 Well Logs (12)

Test Hole No.: 3/8 | Drilling Started 14/4/71

Location: Sunwal | Completed 21/4/71

Drilled by: N.B. Tubewells | Log by: G. P. Chaturvedi

Altitude of Land Surface: 419 ft. (127.7 m) 130.76 m

Static Water level (Head): +10 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, grayish-yellow with fine sand	5	5
Sub-soil, yellow with sand	15	20 6.09
Gravel, angular & sub-rounded with sand & siltstone fragments	40	60 18.2
Clay, dark gray with sand & some gravel	60	120 36.5
Gravel, well sorted with sand & siltstone fragments	20	140
Gravel, well sorted with coarse sand	28	168
Clay, yellow with sand	10	178 51.2
Clay, yellow with sand & gravel	7	185
Gravel, well sorted with coarse sand & siltstone fragments	7	192
Clay, yellowish gray, plastic with fine sand	38	230 70.1
Clay, gray, plastic with gravel, fine	50	280 85.3
Gravel, well sorted with coarse sand, water bearing	30	310 94.5
Clay, yellowish gray, plastic with fine sand	90	400
Clay, gray, plastic	65	465
Clay, yellow with gravel & coarse sand	20	485
Clay, yellowish gray, slightly sticky	75	560
Clay, gray, plastic with sand	40	600
Clay, yellowish gray, sticky with sand & siltstone fragments	30	630
Clay, gray	30	660
Clay, gray, sticky with coarse sand, & gravel	20	680
Gravel with clay, gray & sticky	10	690
Clay, yellowish gray, sticky	10	700
Clay, yellow with fine to medium sand	12	712
Clay, yellowish gray with fine sand	128	840
Clay, yellowish gray, sticky with gravel & sand	6	846 257.9
Gravel, well sorted with siltstone fragments & sand	29	875
Clay, gray with sand	12	887 266.7
Clay, gray, plastic	113	1000 304.8

Well completion data

Casing: 305 ft/1½ in. 89.3

Screened Zone: 283-293 ft. 86.2

Yield: 12 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 4/1

Drilling Started 11/3/71

Location: Vishnupura

Completed 13/3/71

Drilled by: N.B. Tubowells

Log by: S. B. Kansakar

Altitude of Land Surface: 333 ft. (101.6 m)

Static Water level (Head): +3.5 LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow-brown, fine	7	7
Sand and clay	13	20
Clay, yellowish-brown, very sticky	10	30
Clay, yellow, sticky w/sand	8	38
Clay, gray w/silt	45	83
Clay, gray with fine sand and siltstone fragments	17	100
Clay, dark gray & yellow, sticky	10	110
Clay, gray with medium sand	30	140
Clay, gray & yellow	30	170
Clay, gray with silt	22	192
Clay, gray, loose with silt	16	208
Gravel, medium, rounded, with coarse sand, water bearing	12	220
Clay, gray with silt.	19	239

Well completion data

Casing: 210 ft/1½ in.
Screened Zone: 190–206 ft.
Yield: 8 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 4/2
Location: Sitlapur
Drilled by: N.B. Tubewells
Altitude of Land Surface: 345 ft. (105.4 m)
Static Water level (Head): +42 ft. LSD

Drilling Started 22/2/71
Completed 7/3/71
Log by: S. B. Kansakar

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, brown with clay & fine sand	6	6
Sand, brown, very fine with some mud, quartz, feldspars	9	15
Clay, gray, sticky with mud and coarse angular sand	19	34
Sand, very fine, with gray clay	11	45
Clay, gray with medium to coarse sand	55	100
Clay, grayish brown	20	120
Clay, grayish brown with sand and gravel	69	189
Sand, medium to coarse with gravel, angular to rounded	17	206
Clay, grayish brown with medium sand	14	220
Sand, medium to coarse with gravel	18	238
Clay, gray-brown to brown with medium sand	30	268
Sand, brown, fine, with fine gravel	6	274
Clay, brown, with fine gravel	16	290
Clay, brown	45	335
Gravel, fine to coarse, water bearing	12	347
Clay, brown	33	380
Gravel & sand with some clay	8	388
Clay, gray-brown	22	410
Gravel	5	415
Clay, gray	43	458
Gravel, fine with coarse sand	8	466
Clay, gray	24	490
Gravel and sand	12	502
Clay, gray	18	520
Clay, with sand and gravel	10	530
Clay, black & yellow, sticky	80	610
Clay, gray, sticky with sand & gravel	10	620
Clay, gray	20	640
Sand, fine to coarse	40	680
Clay, gray with some sand	30	710
Sand, coarse with clay	7	717
Clay, gray	33	750
Sand, fine to coarse with gravel and clay	18	768
Clay, gray with sand & gravel layers.	32	800

Well completion data

Casing: 360 ft/1½ in.
Screened Zone: 330–350 ft.
Yield: 24 GPM (flowing)

Table 7 Well Logs (13)

Test Hole No.: 4/3

Location: Belahia

Drilled by: N.B. Tubewells

Drilling Started 15/3/71

Completed 17/3/71

Log by: S. B. Kansakar

Altitude of Land Surface: 343 ft. (104.5 m)

Static Water level (Head): +40 ft. LSD 12·1   116.74 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow, clayey with fine sand	6	6
Clay, yellow, sticky	2	8
Sand, fine to very fine	3	11
Gravel, fine to medium with coarse sand	31	42
Clay, gray with fine sand	8	50
Clay, gray, sticky	10	60
Clay, yellow, with gravel	20	80
Clay, gray, sticky with gravel	120	200
Clay, gray with some gravel	26	226
Sand & clay, alternate layers	12	238
Sand & gravel, water bearing	2	240
Sand & clay, alternate layers	10	250
Sand & gravel, fine	10	260

<u>Well completion data</u>

Casing: 260 ft/1½ in.

Screened Zone: 235-255 ft.   71.6 — 77.7

Yield: 100 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 4/4

Location: Belahia

Drilled by: Hydrology Department

Drilling Started 6/3/71

Completed 15/3/71

Log by: Avery Beer, PCV

Altitude of Land Surface: 343 ft. (104.4 m)

Static Water level (Head): +40 ft. LSD

116.74 m

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, tan, sandy	5	5
Sand, fine to very coarse	5	10
Gravel, fine, well sorted	35	45
Gravel fine with clay	5	50
Clay, light gray with gravel	20	70
Sand, fine	12	82
Gravel, fine with sand, very hard	13	95
Sand, with fine gravel	43	138
Clay with fine gravel and sand	10	148
Sand, medium, with gravel	10	158
Gravel with medium sand	10	168
Sand,fine to medium with gravel	20	188
Sand, fine to coarse	22	210
Sand, fine with clay	10	220
Clay, with fine sand	7	227
Sand, fine to coarse with some clay	8	235
Sand, gray, coarse	5	240
Sand, brown, medium to coarse	15	255
Gravel, fine, many rock fragments	5	260
Gravel, medium to coarse	4	264

Well completion data

Casing: 10" to 81 ft./6" from 60' to 267 ft.
Screened Zone: 225-245 ft.
Yield: 500 GPM (flowing)

NOTE: Predominance of sand and gravel may result from contamination from caving formations.

Table 7 Well Logs

Test Hole No.: 4/5

Location: Petrabania

Drilled by: Hydrology Department

Altitude of Land Surface: 373 ft. (113.7 m)

Static Water level (Head): ____________ LSD

Drilling Started 19/3/71

Completed 1/4/71

Log by: Avery Beer, PCV

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, tan, sandy	14	14
Sand, brown, medium	1	15
Sand, brown, coarse	9	24
Gravel, fine with some pebbles	8	32
Gravel, fine with gray clay	10	42
Clay	12	54
Clay with medium gravel	20	74
Sand, brown, medium to coarse	26	100
Clay, sticky with gravel	9	109
Sand, with fine gravel	3	112
Gravel, fine, with fine sand	16	128
Clay, gray-black, with gravel	9	137
Gravel, coarse, sub-angular to subrounded with black clay	3	140
Clay, with coarse gravel and sand	15	155
Gravel, very coarse with some clay	5	160
Clay, brownish-gray, with gravel	10	170
Clay	18	188
Gravel	10	198
Pebbles, small with gravel	3	201
Gravel, medium with pebbles	9	210
Sand	7	217
Gravel with some clay	6	223
Sand, coarse	6	229
Clay with coarse sand	6	235
Clay, tan	30	265
Clay, brown, sandy	20	285
Clay, gray	20	305
Clay, black, greasy	20	325
Sand, coarse	28	353
Clay, with sand and gravel	30	383
Gravel	4	387

Test hole - uncased

Table 7 Well Logs

Test Hole No.: 4/6 — Drilling Started 5/4/71

Location: Kerwani — Completed 12/4/71

Drilled by: Hydrology Department — Log by: S. B. Kansakar

Altitude of Land Surface: 422 ft. (128.7 m)

Static Water level (Head): -25 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Clay	10	10
Sand, fine to medium	13	23
Sand, clayey	36	59
Clay, yellow with siltstone fragments	7	66
Clay, gray, sticky	12	78
Clay, gray, sandy	14	92
Clay, black & gray, sticky	18	110
Clay, gray, black & yellow, sticky with some gravel	10	120
Clay, yellow	10	130
Clay, gray	4	134
Clay, gray and black	24	158
Sand, fine to coarse with gravel	2	160
Clay, gray, yellow & black	78	238
Clay with sand and gravel	7	245
Clay, gray, yellow & black	154	399
Gravel and sand with interbedded clay, contains chert	23	422
Clay, yellow and gray	18	440
Clay, sandy	20	460
Clay, gray & yellow, sticky	40	500

Well completion data

Casing: 8" to 80 ft/4" from 60 to 430 ft.
Screened Zone: 400-420 ft/4 in.
Yield: 400 GPM (Air lift)

Table 7 Well Logs

Test Hole No.: 5/1

Location: Paklihawa

Drilled by: N.B. Tubewells

Altitude of Land Surface: 342 ft. (104.3 m)

Static Water level (Head): +30 ft. LSD

Drilling Started 20/5/71

Completed 30/5/71

Log by: D. C. Parajuli

113·38 m

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil	3	3
Kankar	6	9
Clay, gray, plastic	35	44
Clay, gray, w/siltstone fragments and fine sand	6	50
Clay, dark gray, plastic	45	95
Gravel, rounded to sub-rounded	35	130
Clay, gray, plastic	17	147
Gravel	8	155
Clay, plastic	20	175
Gravel	2	177
Clay, gray and yellow, plastic	13	190
Sand, gray, medium	15	205
Clay, yellow and gray, plastic	60	265
Gravel	10	275
Clay, gray and yellow, plastic	63	338
Gravel, angular to sub-angular	2	340
Clay, gray w/sand	10	350
Clay, grey, sticky	20	370
Clay, gray, w/sand	20	390
Clay, gray, sticky	30	420
Clay, gray, w/fine sand	30	450
Clay, gray, w/sand and silt	30	480
Gravel, sub-rounded, and coarse sand, water bearing	30	510
Clay, yellow, sticky, w/sand	30	540
Gravel, w/coarse sand	10	550
Clay, yellow and gray, sticky	40	590
Sand, coarse, w/gravel	18	608
Clay, gray and yellow, sticky	132	740
Sand, coarse w/gravel	10	750
Clay, gray, sticky	46	796
Sand, coarse w/siltstone gravel	14	810
Clay, gray, plastic	104	914
Clay, gray, w/coarse sand and gravel	16	930
Clay, gray, sticky	70	1000

Well completion data

Casing: 520 ft/1½ in.
Screened Zone: 490-500 ft.
Yield: 32 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/2

Drilling Started 1/6/71

Location: Paklihawa

Completed 5/6/71

Drilled by: N.B. Tubewells

Log by: D. C. Parajuli

Altitude of Land Surface: 342 ft. (104.3 m)

114.21 m

Static Water level (Head): +35 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil, w/fine sand	5	5
Kankar	11	16
Sand, medium	14	30
Clay, gray, plastic	20	50
Clay, w/silt, compacted	30	80
Clay, gray, plastic	15	95
Gravel, siltstone w/coarse sand	35	130
Clay, yellowish gray, plastic	17	147
Gravel, sub-rounded to sub-angular	7	154
Clay, gray, plastic	36	190
Gravel, well sorted, water bearing	20	210
Clay, gray, plastic	41	251
Gravel, w/siltstone fragments, water bearing	19	270
Clay, gray, plastic	3	273

Well completion data

Casing: 6 in. to 220 ft/4 in. to 280 ft.
Screened Zone: 265-273 ft.
Yield: 50 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/3

Location: Paklihawa

Drilled by: N.B. Tubewells

Drilling Started: 6/6/71

Completed: 13/6/71

Log by: D.C. Parajuli

Altitude of Land Surface: 342 ft. (104.3 m)

120.70 m

Static Water level (Head): +54 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil, w/fine sand	3	3
Clay, w/fine sand	2	5
Kankar	5	10
Clay, gray, plastic	52	62
Gravel, w/coarse sand	13	75
Clay, gray, plastic	20	95
Gravel, w/fine sand	5	100
Clay, gray, sticky	12	112
Gravel, w/sand	8	120
Clay, w/sand	20	140
Clay, gray, plastic	50	190
Gravel, well sorted w/coarse sand	20	210
Clay, gray and yellow, sticky	43	253
Gravel, well sorted, rounded	25	278
Clay, gray, plastic	37	315
Gravel, well sorted, sub-angular to sub-rounded	17	332
Clay, yellow and gray, plastic	43	375
Gravel, sub-rounded w/coarse sand	8	383
Clay, gray, sticky	102	485
Gravel, well sorted, sub-angular to sub-rounded	6	491
Clay, yellow, plastic	19	510

Well completion data

Casing: 510 ft./6 in.
Screened Zone: 475-505 ft.
Yield: 223 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/4

Location: Bhairawa (S.P. Camp)

Drilled by: N.B. Tubewells

Altitude of Land Surface: 350 ft.

Static Water level (Head): +35 ft. ISD

Drilling Started 4/6/72

Completed: 5/6/72

Log by: Keshab K.C.

117.35 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow	2	2
Clay, yellow, sticky	8	10
Clay, gray, sandy	11	21
Clay, yellow, sandy	9	30
Clay, gray, sticky	10	40
Clay, yellowish-gray with siltstone particles	19	59
Clay, grayish-yellow	22	81
Gravel, rounded to sub-rounded	14	95
Clay, gray, sandy	3	98
Gravel with broken pieces of pebbles	22	120
Clay, yellow, sticky with thin layers of sand and gravel	10	130
Clay, gray, sticky	10	140
Clay, gray, sticky	10	150
Clay, grayish-yellow, sticky	30	180
Clay, gray, sticky	20	200
Gravel, sub-rounded to sub-angular with coarse sand	15	215
Clay, gray, sticky	21	236
Clay, gray with coarse sand	4	240
Gravel, sub-rounded to sub-angular	13	253
Clay, yellow with sand	7	260
Clay, grayish-yellow, plastic	8	268

Well completion data

Casing: 259 ft/ 4 in.
Screened Zone: 240-253 ft.
Yield: 60 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/5

Location: Bhairawa (S.P. Camp)

Drilled by: N.B. Tubewells

Altitude of Land Surface: 350 ft.

Static Water level (Head): + 35 ft. LSD

Drilling Started 7/6/72

Completed 10/6/72

Log by: Keshab K.C.

117.35 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow, clayey	3	3
Clay, yellow, sticky	7	10
Clay, gray, sandy	11	21
Clay, yellow, sandy	7	28
Clay, yellowish-gray with siltstone particles from 42 feet	35	63
Clay, grayish-yellow	17	80
Gravel, rounded to sub-rounded	12	92
Clay, grayish-yellow, sandy	10	102
Gravel with broken pieces of pebbles	17	119
Clay, yellow, sticky	51	170
Clay, grayish-yellow with sand	10	180
Clay, gray, sticky	15	195
Gravel, subrounded	17	212
Clay, gray, sticky	10	222
Clay, gray with coarse sand	12	234
Gravel, sub-rounded	19	253
Clay, yellow with sand	12	265

Well completion data

Casing: 258 ft/ 6 in.
Screened Zone: 240-253 ft.
Yield: 200 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/6

Drilling Started 21/10/71

Location: Bhairawa Airport

Completed 27/10/71

Drilled by: Hydrology Department

Log by: S. M. Shrestha

Altitude of Land Surface: 344 ft. (105.0 m)

Static Water level (Head): +37 ft. LSD

116.13 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	2	2
Clay	10	12
Sand, fine	3	15
Gravel and sand	45	60
Clay, gray, sticky	105	165
Clay, gray, sandy	27	192
Gravel, water bearing	14	206
Clay, dark gray	5	211

Well completion data

Casing: 211 ft/ 6 in.
Screened Zone: 192-206 ft.
Yield: 416 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/7

Location: Bhairawa)Water tank)

Drilled by: N.B. Tubewells

Altitude of Land Surface: 352 ft. (107.3 m)

Static Water level (Head): +31 ft. LSD

116.74 m

Drilling Started 7/11/71

Completed 11/11/71

Log by: G. P. Chaturvedi, D. C. Parajuli

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellow with fine sand	10	10
Gravel with siltstone and fine to medium sand	10	20
Clay, gray, plastic	22	42
Gravel, sub-rounded to sub-angular	3	45
Clay, gray, plastic	60	105
Sand, coarse	7	112
Gravel with coarse sand	10	122
Clay, gray, plastic with gravel	28	150
Clay, gray, plastic with fine sand	10	160
Clay, dark gray, sticky	5	165
Clay, gray, plastic with gravel	25	190
Clay, gray, plastic	10	200
Clay, yellowish-gray, very sticky	4	204
Gravel with medium to coarse sand, water bearing	10	214
Clay, yellowish-gray, plastic	6	220

Well completion data

Casing: 10" to 130 ft./8" from 100 to 220 ft.
Screened Zone: 200-220 ft.
Yield: 125 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/8

Location: Bhairawa (Luxmi School)

Drilled by: N.B. Tubewells

Drilling Started 17/1/72

Completed 20/1/72

Log by: G. P. Chaturvedi

Altitude of Land Surface: 352 ft. (107.3 m)

Static Water level (Head): +31 ft. LSD

116.74 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow	5	5
Clay, yellow	18	23
Clay, gray with silt	7	30
Clay, yellow with silt	20	50
Clay, gray with silt	5	55
Clay, gray with fine sand	18	73
Clay, gray	7	80
Clay, gray with gravel	5	85
Clay, gray	18	103
Gravel, angular to sub-angular	20	123
Clay, gray	26	149
Gravel, sub-angular with sand	2	151
Clay, gray with sand	29	180
Clay, yellowish-gray with sand	10	190
Clay, yellowish-gray	13	203
Gravel, coarse to fine, angular, sub-angular with sand	10	213
Clay, yellowish-gray, sticky	10	223
Gravel and sand, coarse to fine, water bearing	30	253
Clay, gray, very sticky	7	260
Clay, gray, sticky	22	282

Well completion data

Casing: 256 ft/ 6 in.
Screened Zone: 230 to 250 ft.
Yield: 400 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/9

Location: Ag. Research Farm

Drilled by: Associated Tubewells

Drilling Started 2/5/70

Completed 8/5/70

Log by: B. D. Kharel

Altitude of Land Surface: 358 ft. (109.0 m)

Static Water level (Head): +40 ft. LSD

121.31 m

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellow, with fine sand	19	19
Sand, grayish-green with black specks and some yellow clay	10	29
Sand, coarse with greenish clay	1	30
Clay with kankar	25	55
Clay, greenish yellow, sandy	10	65
Clay, yellow, sandy with quartzite	10	75
Sand	5	80
Clay, green with some sand	10	90
Sand, greenish black with some clay	10	100
Clay, with some gravel	20	120
Clay, gray with black specks	20	140
Clay, black	24	164
Gravel, medium to fine, semi-rounded with sand	5	169
Sand, coarse with quartzite pebbles, water bearing	10	179

Well completion data

Casing: 169 ft/ 8 in.
Screened Zone: 164-169 ft.
Yield: 1,000 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/10

Location: Govt. Fish Farm

Drilled by: Associated Tubewells

Altitude of Land Surface: 363 ft. (110.6 m) 119.79 m

Static Water level (Head): +30 ft. LSD

Drilling Started 15/5/70

Completed 26/5/70

Log by: B. D. Kharel

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellow	7	7
Sand, brownish, fine to medium	12	19
Sand, brownish, medium to very coarse with qtz., chert, shale	24	43
Gravel, fine (5mm)	6	49
Clay, black, mixed with coarse sand and gravel	11	60
Gravel	8	68
Clay, black and yellow	10	78
Gravel with some clay	3	81
Clay with coarse sand	10	91
Clay, black, plastic with kankar	64	155
Clay, yellow	2	157
Gravel, water bearing	21	178
Clay, yellow	2	180

Well completion data

Casing: 180 ft/ 6 in.
Screened Zone: 158-178 ft.
Yield: 600 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/11

Drilling Started: 12/2/71

Location: Govt. Fish Farm

Completed: 28/2/71

Drilled by: Hydrology Department

Log by: S. B. Kansakar

Altitude of Land Surface: 362 ft. (110.2 m) 120.09 m

Static Water level (Head): +32 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, brown, fine, clayey	5	5
Sand, brownish-gray, very fine with some clay	5	10
Sand, brown, fine and clay	2	12
Sand, brown, medium to coarse, angular, silicious to feldspathic with some clay	3	15
Sand, brownish-gray, medium to coarse, qtz. and feldspar with dark mineral	3	18
Gravel, brown, fine, feldspar, qtz., dark mineral	4	22
Gravel	2	24
Gravel, coarse, rounded, composed of chert and sandstone pebbles; coarse sand	6	30
Clay, bluish-green, sandy	5	35
Clay, blue and fine sand	6	41
Clay, bluish-brown with fine to medium sand, poorly sorted	4	45
Clay, bluish-green	6	51
Sand, green, very fine	4	55
Sand, green-gray, very fine	30	85
Clay, loose, with some sand	15	100
Clay, gray, sticky with some fine sand	5	105
Clay, gray	40	145
Clay, gray with gravel chips (kankar)	11	156
Gravel, fine to medium, sub-rounded, chert mostly	4	160
Gravel	4	164
Gravel, medium to coarse, sub-rounded to rounded	3	167
Gravel	10	177

<u>Well completion data</u>

Casing: 8" to 100 ft./4" from 70 to 175 ft.
Screened Zone: 156-175 ft/ 4 in.
Yield: 490 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/12

Drilling Started 28/5/71

Location: Madhaulia

Completed: 3/6/71

Drilled by: Hydrology Department

Log by: S. M. Shrestha

Altitude of Land Surface: 382 ft. (116.5 m) 121.92 m

Static Water level (Head): +18 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellow	3	3
Sand, fine to coarse with some clay	9	12
Gravel with pebbles, cobbles & angular stone fragments	18	30
Clay, black	10	40
Sand with gravel & pebbles	9	49
Clay, yellow to black, sticky	11	60
Sand, fine to coarse with gravel	5	65
Clay, black to yellow, sticky	15	80
Sand, coarse with gravel	10	90
Clay, yellowish, sandy	10	100
Gravel with pebbles & cobbles	15	115
Clay, black, sticky with some yellow clay	30	145
Gravel with pebbles	5	150
Clay, sandy	5	155
Gravel and pebbles	10	165

Well completion data

Casing: 10" to 60 ft./6" from 0 to 160 ft.
Screened Zone: 150-160 ft.
Yield: 100 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/13

Drilling Started 16/6/71

Location: Manglapur (Bhalwari)

Completed: 21/6/71

Drilled by: N.B. Tubewells

Log by: D. C. Parajuli

Altitude of Land Surface: 398 ft. (121.2 m)

124.36 m

Static Water level (Head): +10 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil, dark gray w/sand	3	3
Clay, dark gray, plastic	4	7
Sand, gray, medium to fine	3	10
Gravel, well sorted w/pebbles	20	30
Clay, yellow and gray, plastic	28	58
Gravel, well sorted w/coarse sand and pebbles	22	80
Clay, yellow, sticky w/sand	15	95
Gravel, well sorted w/coarse sand, water bearing	30	125
Clay, yellow w/fine to medium sand	20	145
Gravel w/sand	45	190
Clay, yellow w/gravel, angular to sub-angular	10	200
Gravel, round to sub-rounded w/sand	40	240
Clay, yellow, sticky	20	260
Gravel, w/coarse to medium sand and clay	20	280
Clay, yellow w/very fine sand	50	330
Sand, coarse w/gravel	5	335
Gravel, w/sand and clay	45	380
Clay, yellow and gray w/sand and gravel	40	420
Gravel, sub-rounded to angular w/coarse sand	10	430
Clay, gray and yellow, sticky	40	470
Clay, yellow w/gravel and sand	10	480
Gravel, sub-rounded to sub-angular w/clay and sand	20	500
Clay, yellow, w/fine to medium sand, and gravel	60	560

Well completion data

Casing: 125 ft/1½ in.
Screened Zone: 105-115 ft.
Yield: 15 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 5/14

Location: Manigram

Drilled by: Associated Tubewells

Altitude of Land Surface: 422 ft. (128.6 m) 125.27 m

Static Water level (Head): -11 ft. LSD

Drilling Started 10/6/69

Completed: 10/7/69

Log by: T. M. Singh

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellow, sandy with gravel	5	5
Gravel with cobbles, pebbles, boulders	35	40
Clay, yellow	5	45
Gravel with cobbles, pebbles, boulders	15	60
Sand, medium to coarse with gravel	3	63
Gravel with cobbles, pebbles, boulders	12	75
Gravel and sand	5	80
Gravel with cobbles, pebbles, boulders	5	85
Sand, gray with gravel	7	92
Clay, yellow	6	98
Gravel, fine to medium	7	105
Gravel	38	143
Sand, grayish-black, coarse with gravel	5	148
Clay, sandy with gravel	4	152
Cobbles, pebbles, boulders	6	158

Well completion data

Casing: 14" to 80 ft/8" to 155 ft.
Screened Zone: 80 to 155 ft.
Yield: 1210 GPM (pumped)
Drawdown: 6 ft.

Table 7 Well Logs

Test Hole No.: 5/17

Drilling Started: 10/12/70

Location: Driver Tole (Naya Mill)

Completed: 22/1/71

Drilled by: Associated Tubewells

Log by: R. L. Dass, S. B. Kansakar

Altitude of Land Surface: 444 ft. (135.4 m)

Static Water level (Head): -42 ft. LSD

122.53 m

Lithologic Description	Thickness (feet)	Depth (feet)
(Drilled by Percussion Method)		
Soil, brown, loamy	5	5
Clay, brown	5	10
Cobbles, pebbles, boulders-quartzite and chert	16	26
Sand, brown, medium with some pebbles ($\frac{1}{4}$" - 3/4" dia)	6	32
Clay, brown	19	51
Cobbles, pebbles, boulders - angular to sub-angular, some coarse sand intermixed	45	96
Clay, dark brown with sand and gravel	4	100
Gravel, and cobbles	22	122
Clay, with kankar	4	126
Gravel and sand with cobbles & pebbles	30	156
Clay, dark tan with red specks	1	157
Boulders - quartzite	35	192
Clay, yellowish-brown, sandy	7	199
Gravel, sub-angular to sub-rounded	2	201
Sand, medium to coarse	29	230
Clay, brown, sandy	16	246
Pebbles, cobbles, boulders	4	250
Sand, coarse to very coarse with gravel	35	285
Clay, yellowish-brown	20	305
(Continued by Direct Rotary Drilling Method)		
Gravel and pebbles, water bearing	55	360
Clay, brown, sandy	10	370
Sand, fine to coarse	30	400
Clay, brown, sandy	10	410
Sand, fine to coarse	26	436
Clay, brown, sandy	3	439
Sand, fine to coarse with gravel from 445 ft.	16	455
Sand, medium to coarse	40	495

Continued....

Table 7 Well Logs

Test Hole No.: 5/17

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, brown, sandy	17	512
Sand and gravel, fine to coarse with pebbles	33	545
Clay, brown, sticky	15	560
Clay, with alternating layers sand & gravel	17	587
Clay, yellow, sticky	7	594
Gravel	9	603
Clay: with alternating layers of gravel	7	610
Clay, yellow, sticky	4	614
Gravel	7	621
Clay, yellow	16	637
Sand & gravel	7	644
Clay, yellow, sticky with thin layers of gravel from 657-662	26	670
Clay, brown, sticky	7	677
Sand	8	685
Clay, yellow, loose	13	698
Sand & gravel	6	704
Clay, yellow, loose	5	709
Gravel & coarse sand, with pebbles	23	732
Clay, yellow, sandy	8	740
Gravel and pebbles with thin layers of clay	60	800
Clay, yellow, sandy	20	820

NOTE: First 305 feet of well drilled and cased with percussion rig and deepened later by direct rotary method.

Well completion data

Casing:	10" to 300 ft/6" from 260 to 374 ft.
Screened Zone:	310-350 ft.
Yield:	317 GPM (pumped)
Drawdown:	21 ft.

Table 7 Well Logs

Test Hole No.: 5/18

Drilling Started: 28/1/71

Location: Jogi Kuti

Completed: 29/4/71

Drilled by: Associated Tubewells

Log by: R. L. Dass

Altitude of Land Surface: 487 ft. (148.4 m)

135.94 m

Static Water level (Head): -41 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellow	3	3
Pebbles	8	11
Clay, sandy, yellow	4	15
Boulders, cobbles & gravel	13	28
Sand and gravel	10	38
Clay, yellowish-brown	7	45
Cobbles, boulders, gravel with some coarse sand	85	130
Sand, coarse	12	142
Clay, sandy	8	150

Well completion data

Casing: 10" to 78 ft./8" from 78 to 150 ft.
Screened Zone: 77-142 ft.
Yield: 396 GPM (pumped)
Drawdown: 4 ft.

Table 7 Well Logs

Test Hole No.: 5/19

Drilling Started: 19/5/71

Location: Butwal

Completed: 22/9/71

Drilled by: Associated Tubewells

Log by: R. L. Dass

Altitude of Land Surface: 571 ft. (174.0 m)

161.24 m

Static Water level (Head): -42 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	3	3
Clay with gravel & boulders	12	15
Gravel and boulders	10	25
Boulders, cobbles, pebbles, & gravel	50	75
Sand and gravel, coarse, with cobbles & pebbles	63	138
Clay, brown with kankar	7	145
Clay, with gravel, cobbles & pebbles	30	175
Clay, brown	20	195
Sand, fine with clay	5	200
Clay, with gravel and boulders	20	220
Clay with kankar and boulders	30	250
Sand, fine with gravel	10	260
Clay	3	263
Sand	7	270
Gravel and sand, cemented	3	273
Clay and kankar	23	296

Well completion data

Casing: 14" to 81 ft./8" from 81 to 216 ft.
Screened Zone: 83-138, 190-206, 246-265/8 in.
Yield: 335 GPM (pumped)
Drawdown: 10.6 ft.

Table 7 Well Logs

Test Hole No.: 6/1

Location: Jigna

Drilled by: N.B. Tubewells

Drilling Started 25/1/72

Completed: 31/1/72

Log by: G. P. Chaturvedi

Altitude of Land Surface: 300 ft. (91.4 m)

Static Water level (Head):________________LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	5	5
Clay, yellow, sticky	10	15
Sand, yellow, fine to medium	5	20
Sand, blackish-gray, medium	20	40
Clay, gray, sticky	10	50
Clay, yellowish-gray	10	60
Clay, yellow with sand	10	70
Clay, yellow, sticky	10	80
Sand, medium to fine	10	90
Sand, coarse to medium	10	100
Clay, yellow with sand	30	130
Clay, yellow with silt	30	160
Clay, yellow, plastic	10	170
Clay, yellow with fine sand	10	180
Clay, yellow with silt	31	211
Clay, yellow with gravel	15	226
Clay, yellow with gravel and medium to fine sand	19	245
Sand, medium to fine	5	250
Clay, yellow with sand	10	260
Sand, fine	10	270
Clay, yellow with sand & silt	10	280
Clay, gray with sand	40	320
Clay, gray, sticky	10	330
Clay, yellowish-gray and fine sand	10	340
Clay, gray, sticky	20	360
Clay, gray, sticky with gravel, well sorted	20	380
Clay, yellowish-gray with sand	20	400
Clay, gray, sticky	20	420
Clay, yellow, sticky	50	470
Clay, yellowish-gray with sand	10	480
Clay, yellow, sticky	30	510
Clay, yellow with medium to fine sand	10	520

Continued.........

Table 7 Well Logs

Test Hole No.: 6/1 (Cont.)

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellow, sticky with silt	50	570
Clay, yellow, sticky with gravel & silt	40	610
Clay, yellow, sticky	20	630
Clay, gray with sand	20	650
Clay, gray, plastic	10	660
Sand, v. coarse to medium	8	668
Sand, v. coarse to medium with some clay	22	690
Clay, gray, sticky	10	700
Clay, gray with sand	10	710
Clay, gray, sticky	50	760
Clay, gray, sticky with sand	10	770
Clay, yellowish-gray, sticky	10	780
Clay, yellowish-gray with medium to fine sand	15	795
Clay, yellowish-gray, plastic	25	820
Clay, yellowish-gray with sand	10	830
Clay, gray, sticky	10	840
Clay, yellow with sand	10	850
Clay, gray, plastic	20	870
Clay, gray, plastic with sand	15	885
Clay, yellowish-gray, plastic	65	950

Test hole-uncased.

Table 7 Well Logs

Test Hole No.: 6/2 Drilling Started 10/2/72

Location: Sombarsa Completed: 10/2/72

Drilled by: N.B. Tubewells Log by: G. P. Chaturvedi

Altitude of Land Surface: 293 ft. (89.3 m)

Static Water level (Head): ____________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, yellow with fine sand	10	12
Sand, fine	28	40
Clay, gray, plastic with silt	40	80
Clay, yellow	10	90
Clay, yellow with silt	30	120
Clay, gray, sticky	60	180
Clay, gray with fine sand	20	200
Clay, gray, plastic	80	280
Clay, yellow, sticky	50	330

Test hole - uncased - cemented off.

Table 7 Well Logs

Test Hole No.: 6/3

Location: Bogri

Drilled by: N.B. Tubewells

Altitude of Land Surface: 313 ft. (95.3 m)

Static Water level (Head): -9.9 ft. LSD

Drilling Started: 6/2/72

Completed: 9/2/72

Log by: G. P. Chaturvedi

92.38 m

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil, yellow sandy	8	8
Sand, fine to medium	5	13
Clay, gray, sticky	7	20
Clay, gray with silt	15	35
Clay, gray, sticky	5	40
Sand, fine to medium with mica	10	50
Clay, gray and yellow, sticky	30	80
Clay, yellow with gravel	16	96
Gravel, medium, sub-angular to rounded with coarse sand, water bearing	27	123
Clay, yellow, sticky	17	140
Clay, grayish-yellow with gravel & coarse sand	10	150
Clay, gray, sticky	15	165
Clay, gray with fine to medium sand	15	180
Clay, gray, sticky	12	192
Clay, yellow with thin sand layers	28	220
Clay, gray & yellow, sticky	20	240
Sand with gravel	10	250
Clay, grayish-yellow with fine sand	30	280
Clay, grayish-yellow sticky	10	290
Clay, gray with sand and gravel	30	320
Clay, yellowish-gray, sticky	60	380
Clay, gray with fine sand	20	400
Clay, yellowish-gray, sticky	20	420
Clay, gray with sand	25	445
Clay, grayish-yellow	10	455
Clay, yellow with gravel	5	460
Clay, gray, yellow, sticky	20	480
Clay, grayish-yellow with sandstone gravel	20	500
Clay, gray	10	510

Well completion data

Casing: 130 ft/3 in.

Screened Zone: 100 to 120 ft.

Yield: 15 GPM (Air lift)

Table 7 Well Logs

Test Hole No.: 6/4

Location: Bogri

Drilled by: N.B. Tubewells

Altitude of Land Surface: 313 ft. (95.3 m)

Static Water level (Head): -9.9 ft. LSD

Drilling Started 17/2/72

Completed 18/2/72

Log by: G. P. Chaturvedi

92.38 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	8	8
Sand, fine to medium	6	14
Clay, gray, sticky	6	20
Sand, gray, fine to medium	20	40
Gravel with coarse sand	12	52
Clay, dark gray, very sticky	46	98
Gravel, well sorted, water bearing	22	120
Clay, gray, sticky	5	125

Well completion data

Casing: 124 ft/ 8 in.
Screened Zone: 100 to 120 ft.
Yield: 50 GPM (pumped)
Drawdown: 7 ft.

Table 7 Well Logs

Test Hole No.: 6/5

Drilling Started: 21/1/72

Location: Nuwadiha

Completed: 24/1/72

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi

Altitude of Land Surface: 316 ft. (96.2 m)

Static Water level (Head): ____________ISD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	4	4
Sub-soil	6	10
Clay, gray, plastic	10	20
Clay, yellowish-gray with fine sand	10	30
Clay, gray, plastic	30	60
Clay, dark gray, plastic	10	70
Clay, yellowish-gray, very sticky	10	80
Clay, with sand and siltstone fragments	8	88
Clay with sand	12	100
Clay, gray with silt	40	140
Clay, gray with fine to medium sand	10	150
Clay, yellow with sand	10	160
Clay, gray, sticky	20	180
Clay, yellow, plastic with fine to coarse sand	30	210
Clay, yellow, plastic	70	280
Sand, coarse with gravel	10	290
Clay, yellowish-gray with sand & gravel	10	300
Clay, yellow, sticky with sand	70	370
Gravel with sand	10	380 —
Clay, gray with sand & gravel	20	400
Clay, gray, sticky	20	420
Clay, yellowish-gray with gravel	5	425
Gravel with sand	5	430 —
Clay, gray with gravel	10	440
Clay, gray, sticky	20	460
Clay, yellow with medium to fine sand	18	478
Clay, yellow, plastic	9	487
Clay, gray to yellow with sand	33	520
Clay, gray, plastic & very sticky	10	530
Clay, yellowish-gray, plastic with medium to fine sand	10	540
Clay, yellow with sand and gravel	16	556

Test hole-uncased.

Table 7 Well Logs

Test Hole No.: 6/6

Drilling Started: 14/11/71

Location: Semri

Completed: 2/12/71

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi, D. C. Parajuli

Altitude of Land Surface: 330 ft. (100.6 m)

Static Water level (Head): ____________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Clay	10	10
Clay with sand	14	24
Sand	6	30
Sand, very coarse with fine gravel	8	38
Gravel, fine to medium	3	41
Clay	10	51
Gravel with clay	23	74
Clay	36	110
Clay, gray with fine sand	20	130
Clay, gray, plastic & sticky	20	150
Gravel, well sorted, sub-angular & sub-rounded	12	162
Clay, gray, sticky with coarse, sand	8	170
Clay, gray, sticky with coarse sand	10	180
Clay, gray, sticky with some gravel	10	190
Gravel, well sorted with coarse sand	3	193
Sand, medium to coarse with clay, yellowish gray, sticky	7	200
Clay, gray, sticky with coarse sand	10	210
Clay, gray	5	215
Gravel, well sorted, angular to sub-angular with coarse sand	25	240
Gravel, well sorted	3	243
Clay, gray, plastic	37	280
Clay, yellow	70	350
Clay, gray, with gravel	20	370
Clay, gray	20	390
Gravel, rounded to sub-rounded	8	398
Clay, yellowish-gray	12	410
Clay, gray	20	430
Clay, gray with gravel & sand	10	440
Clay, light gray, sticky	5	445
Gravel, with coarse sand	10	455
Clay, yellowish-gray, plastic with gravel	10	465
Clay, gray, sticky	10	475
Clay, yellowish-gray with some gravel	35	510
Gravel, sub-angular	10	520
Clay with coarse sand	20	540
Clay, yellowish-gray	25	565
Clay, yellowish-gray with coarse sand	9	574
Clay, gray with kankar	6	580

Continued.........

Table 7 Well Logs

Test Hole No.: 6/61 (Cont.)

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellowish-gray	65	645
Clay, light gray with fine sand	30	675
Clay, light gray with coarse sand	30	705
Clay, light gray with fine to coarse sand	18	723
Sand, coarse to v. coarse with gravel & siltstone	10	733
Clay, light gray, plastic	8	741
Sand, coarse to v. coarse, with siltstone gravel	10	751
Clay, light gray, plastic	23	774
Gravel, sub-rounded to subangular with coarse sand and siltstone	12	786
Clay, gray, sticky	30	816
Clay, gray with gravel & coarse sand	4	820
Gravel with coarse sand	15	835
Clay, gray, sticky	9	844
Sand, very coarse with gravel	10	854
Clay, gray	30	884
Clay, gray with sand, gravel & siltstone	26	910
Clay, gray, sticky	11	921
Sand, coarse with gravel	7	928
Clay, gray with medium sand	42	970
Sand, medium to very coarse with fine gravel	10	980
Clay, gray with fine to coarse sand	60	1,040
Clay, gray, plastic	120	1,260
Clay, yellow, sticky	10	1,270
Clay, yellow with medium to very coarse sand	20	1,290
Sand, coarse to v. coarse with some gravel	13	1,303
Clay, gray with sand	37	1,340
Clay, grayish-yellow, sticky	60	1,400
Clay, gray, sticky	58	1,458
Sand, fine to medium	10	1,468
Sand, coarse to very coarse	19	1,487
Clay, dark gray	8	1,495
Sand, coarse to v. coarse	10	1,505
Clay, yellowish-gray, sticky	7	1,512

Well completion data

14" from 0 to 200 ft. - cemented
Test hole-uncased after 200 ft.

Table 7 Well Logs

Test Hole No.: 6/7

Location: Semri

Drilled by: N.B. Tubewells

Drilling Started 29/5/72

Completed 31/5/72

Log by: D.C. Parajuli

Altitude of Land Surface: 330 ft. (100.6 m)

Static Water level (Head): +43 ft. ISD

113.69 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, gray	4	4
Clay, grayish-yellow with sand	5	9
Clay, gray, sandy	16	25
Gravel, sub-rounded with sand	11	36
No sample	9	45
Clay, gray	15	60
Clay, yellow-gray	30	90
Gravel	4	94
Clay, yellow with siltstone gravel and coarse sand	13	107
Clay, yellow with siltstone particles	13	120
Clay, yellowish-gray	12	132
Gravel	2	134
Clay, gray	16	150
Gravel, sub-rounded	12	162
Clay, yellow	8	170
Clay, yellowish-gray, sticky	18	188
Clay, gray	9	197
Gravel	4	201
Clay, gray	10	211
Gravel, sub-rounded to sub-angular	29	240
Clay, gray	6	246
Clay, grayish-yellow	14	260
Clay, gray	20	280
Clay, grayish-yellow	10	290
Clay, yellow, sticky	5	295
Clay, yellow, sandy with gravel	9	304
Clay, yellow	19	323
Clay, grayish-yellow, sticky	28	351
Clay, yellow, sticky	5	356
Clay, yellow with gravel	13	369
Clay, yellowish-gray, plastic	22	391
Clay, yellow	10	401
Clay, grayish-yellow	10	411
Clay, gray	21	432
Clay, gray with siltstone particles	23	455

Continued........

Table 7 Well Logs

Test Hole No.: 6/7 (cont.)

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellow	17	472
Clay, yellow with siltstone particles	8	480
Clay, gray, sticky	13	493
Clay, grayish-yellow	10	503

Well completion data

Casing: 245 ft/ 4 in.
Screened Zone: 215-240 ft.
Yield: 80 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 6/8

Location: Chapia (Chilia)

Drilled by: N.B. Tubewells

Altitude of Land Surface: 375 ft. (114.4 m) 114.5 m

Static Water level (Head): +0.7 ft. LSD

Drilling Started: 9/12/71

Completed: 16/12/71

Log by: G. P. Chaturvedi

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, sandy	10	10
Sand, fine to coarse with some clay	20	30
Clay, gray with fine gravel	10	40
Clay, gray, plastic, sticky	30	70
Gravel, well sorted, sub-rounded to sub-angular, water bearing	10	80
Clay with fine sand	10	90
Gravel, well sorted, with some sand, water bearing	10	100
Clay, gray with sand	10	110
Clay, dark gray, sticky	25	135
Sand, fine to coarse with siltstone	7	142
Clay, yellowish gray, sticky with sand & gravel	8	150
Clay, yellow with gravel	17	167
Gravel with pebbles	18	185
Clay, gray	25	210
Gravel with coarse sand	20	230
Clay, gray with gravel and sand	7	237
Clay, gray with medium to coarse sand	3	240
Clay, gray, sticky	10	250
Clay, gray with sand	10	260
Sand, coarse with gravel	20	280
Clay, gray, sticky	30	310
Clay, gray with sand	50	360
Clay, gray, hard	10	370
Clay, gray with gravel	20	390
Clay, yellowish-gray with very fine sand	30	420
Clay, yellowish-gray	20	440
Clay, gray with fine sand	15	455
Clay with cobbles	3	458
Clay, gray, sticky	17	475
Gravel, fine with coarse sand	5	480
Clay, gray, sticky	3	483

Well completion data

Casing: 100 ft/ 8 in.

Screened Zone: 70-100 ft.

Yield: 3 GPM (flowing), 50 GPM (pumped)

Drawdown 4.3 ft. (pumped)

Table 7 Well Logs

Test Hole No.: 6/9

Location: Chapia (Chilia)

Drilled by: N.B. Tubewells

Drilling Started 26/12/71

Completed: 28/12/71

Log by: G. P. Chaturvedi

Altitude of Land Surface: 377 ft. (115.8 m)

115.82 m

Static Water level (Head): +3 ft. ISD

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil		
Clay, with fine sand	5	5
Clay, yellow with silt	8	13
Clay, yellow, hard	27	40
Clay, dark gray	14	54
Clay, yellowish-gray	6	60
Gravel, fine, with sand, water bearing	10	70
Clay, grayish-yellow	10	80
Gravel, sub-angular, water bearing	10	90
Clay, gray	10	100
	7	107

Well completion data

Casing: 104 ft/ 3 in.
Screened Zone: 70-100 ft.
Yield: 2 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 6/10

Location: Chapia (Baidauli)

Drilled by: N.B. Tubewells

Altitude of Land Surface: 380 ft. (114.8 m)

Static Water level (Head): +25 ft. LSD

123.44m

Drilling Started: 18/12/72

Completed: 21/12/72

Log by: G. P. Chaturvedi, D. C. Parajuli

Lithologic Description	Thickness (feet)	Depth (feet)
Soil with fine sand	5	5
Sand, fine to coarse with yellow clay	5	10
Clay, yellow with fine sand	13	23
Clay, gray with fine sand	10	33
Sand, coarse with fine gravel, and siltstone	9	42
Clay, gray, plastic	28	70
Gravel, well sorted	10	80
Clay, gray with fine sand	10	90
Gravel, well sorted	10	100
Clay, gray with sand	10	110
Clay, gray	20	130
Clay, grayish-yellow	20	150
Gravel	3	153
Clay, yellowish-gray	18	171
Gravel, sub-rounded to sub-angular, water bearing	16	187
Clay, yellowish-gray	17	194

Well completion data

Casing: 194 ft./ 8 in.
Screened Zone: 171-187 ft.
Yield: 450 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 6/11

Drilling Started: 23/12/71

Location: Chapia (Baidauli)

Completed: 25/12/71

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi, D.C. Parajuli

Altitude of Land Surface: 383 ft. (116.8 m)

127.36 m

Static Water level (Head): +25 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	5	5
Clay, yellow with coarse sand	7	12
Clay, yellowish-gray, sticky	8	20
Clay, gray, sticky with siltstone particles	10	30
Clay, gray, sticky	36	66
Gravel with coarse sand, water bearing	12	78
Clay, dark gray, sticky	12	90
Gravel, with coarse sand, water bearing	10	100
Clay, with gravel	5	105
Clay, yellow	10	115
Clay, gray	15	130
Gravel with gray clay	10	140
Clay, yellow with gravel	7	147
Gravel with coarse sand	4	151
Clay, gray & yellow, sticky	19	170
Gravel with coarse sand, water bearing	17	187
Clay, gray, plastic	7	194

Well completion data

Casing:	192 ft/ 3 in.
Screened Zone:	171-187 ft.
Yield:	50 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 6/12

Drilling Started: 28/12/71

Location: Bhujauli

Completed: 31/12/71

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi

Altitude of Land Surface: 393 ft. (119.7 m) 123.90 m

Static Water level (Head): +13.5 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	3	3
Sand, fine to coarse	4	7
Sand, medium to coarse with some gravel	23	30
Sand, medium to v. coarse	10	40
Gravel, angular & sub-angular	5	45
Clay, yellow, plastic	45	90
Clay, dark gray, sticky	10	100
Clay, gray, sticky	20	120
Clay, yellow, very sticky	8	128
Clay, yellow with sand	6	134
Clay, with sand & gravel	2	136
Gravel, fine, & v. coarse sand with clay	6	142
Clay, gray, sticky	5	147
Gravel, fine with coarse sand, water bearing	23	170
Gravel with clay	5	175
Clay, grayish-yellow	25	200
Clay, yellow, plastic with cobbles	34	234
Clay, yellow, sticky	8	242
Clay, with cobbles	38	280
Clay, yellow with gravel	45	325

Well completion data

Casing: 180 ft/ 3 in.
Screened Zone: 165-175 ft.
Yield: 22 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 6/13

Location: Chetri

Drilled by: N.B. Tubewells

Drilling Started: 5/1/72

Completed: 14/1/72

Log by: G. P. Chaturvedi

Altitude of Land Surface: 420 ft. (128.1 m) 129.23 m

Static Water level (Head): +4 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	3	3
Clay, yellow with fine sand	6	9
Clay, gray with fine sand	8	17
Clay, yellow with siltstone particles	8	25
Gravel with siltstone	7	32
Gravel, angular & sub-angular with fine to medium sand	8	40
Clay, yellow with gravel	20	60
Clay, yellowish-gray, plastic	18	78
Gravel with coarse sand	7	85
Clay, gray and yellow	36	121
Gravel, well sorted, angular to sub-angular with coarse sand	30	151
Gravel with pebbles and cobbles	24	175
Clay, yellow, sticky	7	182
Clay, yellow with gravel in thin 3" layers	15	197
Clay, yellow, sticky	13	210
Clay, yellow with fine sand	10	220
Clay, yellow	9	229
Gravel, angular, water bearing	11	240
Sand, coarse with gravel	5	245
Gravel with coarse sand	18	263
Clay, yellow with coarse sand	7	270
Clay, yellow, sticky	10	280
Clay, yellow with cobbles and pebbles	10	290
Cobbles & pebbles	12	302
Cobbles & pebbles with clay	25	327
Gravel, angular	5	332
Gravel, angular with clay	18	350
Sand, very coarse	5	355
Gravel with yellow clay	17	372
Clay, yellow with sand & gravel	15	387
Clay, yellow	15	402
Clay, yellow with sand	28	430
Clay, yellow	20	450

Continued......

Table 7 Well Logs

Test Hole No.: 6/13 (cont.)

Lithologic Description	Thickness (feet)	Depth (feet)
Boulders with clay	2	452
Boulders with clay	10	462
Clay, yellow	38	500
Clay, gray with sand	30	530
Clay, yellow	20	550
Clay, yellow with sand	20	570
Gravels	2	572

Well Completion data

Casing: 251 ft/ 3 in.
Screened Zone: 235-249 ft.
Yield: 8 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 7/1

Location: Mahajidia

Drilled by: N.B. Tubewells

Drilling Started: 20/2/72

Completed: 22/2/72

Log by: G. P. Chaturvedi

Altitude of Land Surface: 324 ft. (98.8 m)

Static Water level (Head): ______________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	8	8
Clay with fine sand	6	14
Sand, gray, fine	26	40
Clay, brown with v. fine sand	40	80
Gravel, fine with medium sand	13	93
Gravel, with clay	14	107
Gravel, well sorted	8	115
Gravel with clay	13	128
Gravel, well sorted	12	140
Clay with sand and gravel	20	160
Clay with gravel	60	220
Clay, gray, sticky	127	347
Gravel with coarse sand	18	365
Clay, gray, sticky	55	420
Clay, gray with medium to fine sand	40	460
Sand, medium to coarse with gravel	10	470
Clay, gray with sand	30	500

Table 7 Well Logs

Test Hole No.: 8/1

Location: Karidaha

Drilled by: Hydrology Department

Altitude of Land Surface: 310 ft. (94.5 m) 95.09 m

Static Water level (Head): + 2 ft. LSD

Drilling Started: 7/11/71

Completed: 17/11/71

Log by: S. M. Shrestha

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	3	3
Clay, gray	12	15
Sand, and siltstone fragments	15	30
Sand, fine	20	50
Clay, gray, loose	48	98
Clay with siltstone and sand	5	103
Clay, gray, loose	19	122
Clay, with sandstone fragments	13	135
Clay, yellow	100	235
Clay with siltstone fragments	15	250
Clay, yellow	45	295
Gravel, fine with coarse sand, water bearing	15	310
Clay, yellow	10	320
Gravel, with coarse sand	16	336
Clay, yellow	14	350
Gravel and sand	14	364
Clay, yellow	36	400
Gravel and sand	5	405
Clay, yellowish-gray	33	438
Clay, gray with fragments of siltstone	28	466
Sand	30	496
Clay	6	502

Well completion data

Casing: 330 ft/ 1½ in.
Screened Zone: 300-310 ft.
Yield: 3 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 8/2
Location: Mughla
Drilled by: Hydrology Department
Altitude of Land Surface: 337 ft. (102.7 m)
Static Water level (Head): +36 ft. LSD

113.69 m

Drilling Started: 1/12/71
Completed: 7/1/72
Log by: S. M. Shrestha

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, yellowish, sandy	4	6
Sand, yellowish-brown with siltstone fragments	18	24
Clay, yellowish-gray	16	40
Sand, siltstone	4	44
Clay, yellow with sand	23	67
Clay with sandstone particles	10	77
Sand with sandstone & siltstone particles	17	94
Gravel and clay	8	102
Clay, gray, sticky	38	140
Gravel	5	145
Clay, yellow	17	162
Gravel	3	165
Clay, yellow to gray with some layers of gravel	181	346
Gravel and coarse sand	19	365
Clay, yellow and gray	113	478
Clay with sand and siltstone particles	10	488
Gravel	4	492
Clay	6	498
Gravel, water bearing	18	516
Clay, yellow	14	530
Gravel	2	532
Clay and gravel	8	540
Clay, gray, sticky, becoming yellow, loose	41	581
Gravel and sand	24	605
Clay, yellowish-gray	18	623
Gravel and sand	7	630
Clay, yellow	30	660
Sand, gray and yellow	7	667
Clay, yellow	93	760
Gravel	5	765
Clay, yellow and gray	7	772
Gravel	3	775
Clay, gray and yellow, sticky, with layers of gravel	75	850
Gravel	5	855
Clay, yellow	132	987

Well completion data

Casing	528 ft/3 in.
Screened Zone:	505-512 ft.
Yield:	50 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 8/3

Location: Mughla

Drilled by: Hydrology Department

Altitude of Land Surface: 334 ft. (101.5 m)

Static Water level (Head): +39 ft. LSD

Drilling Started: 17/1/72

Completed: 26/1/72

Log by: S. M. Shrestha, S. B. Kansakar and B. D. Kharel

113.69 m

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil	2	2
Clay, sandy	5	7
Sand, fine	6	13
Clay, w/sand	7	20
Clay, yellowish-gray	15	35
Clay, greenish-yellow w/siltstone	8	43
Sand, coarse to fine w/gravel fragments	7	50
Clay, yellow	18	68
Gravel	10	78
Clay, yellowish-gray	13	91
Gravel, coarse w/sand	7	98
Clay, gray, sticky	39	137
Gravel	10	147
Clay, yellow	23	170
Clay, gray, loose	48	218
Gravel and siltstone fragments	2	220
Clay	17	237
Gravel and coarse sand	7	244
Clay	20	264
Gravel	4	268
Clay	25	293
Gravel w/sand	8	301
Clay	25	326
Gravel w/sand	7	333
Clay, sandy, hard	8	341
Gravel, w/fine to coarse sand	30	371
Clay, yellow	34	405
Gravel	6	411
Clay	50	461
Gravel w/sand	8	469

Continued.........

Table 7 Well Logs

Test Hole No.: 8/3 (cont.)

Lithologic Description	Thickness (feet)	Depth (feet)
Clay	17	486
Gravel	7	493
Clay	4	497
Gravel w/coarse sand	24	521
Clay	18	539

Well completion data

Casing: 530 ft/ 6 in.
Screened Zone: 500-520 ft.
Yield: 335 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 8/4

Location: Sarahawa

Drilled by: Hydrology Department

Altitude of Land Surface: 350 ft. (106.7 m)

Static Water level (Head): +11 ft. ISD

Drilling Started: 19/2/72

Completed: 25/2/72

Log by: B. D. Kharel

110.03 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, gray	2	2
Clay	13	15
Clay, gray, sandy	11	26
Clay, yellowish-gray w/silt	16	42
Clay, w/kankar and siltstone gravel	8	50
Clay, gray	12	62
Clay, w/siltstone gravel	13	75
Sand, fine to coarse	14	89
Clay, dark gray	11	100
Clay, w/silt	11	111
Gravel, w/sand	18	129
Clay, yellowish-gray, sticky	18	147
Gravel, w/sand	10	157
Clay, gray and yellow, sticky	36	193
Gravel	13	206
Clay, gray	30	236
Gravel, w/coarse sand	6	242
Clay, gray	14	256
Gravel and sand	4	260
Clay, gray	5	265
Gravel	4	269
Clay, gray	33	302
Gravel	8	310
Clay, gray	38	348
Gravel	10	358
Clay	20	378
Gravel and sand	26	404
Clay, gray	72	476
Gravel	3	479
Clay	10	489
Gravel	3	492
Clay	8	500

Well completion data

Casing: 140 ft/3 in.

Screened Zone: 120-130 ft.

Yield: 6 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 8/5

Location: Asnia

Drilled by: Hydrology Department

Altitude of Land Surface: 374 ft. (113.9 m)

Static Water level (Head): +37 ft. LSD

Drilling Started: 4/3/72

Completed: 9/3/72

Log by: B. D. Kharel

125.27 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, gray	5	5
Clay, yellow w/sand and gravel	5	10
Sand, coarse w/gravel	22	32
Clay, gray	158	190
Gravel and sand	15	205
Clay, gray and yellow	10	215
Gravel w/coarse sand, water bearing	22	237
Clay, gray	81	318
Gravel	4	322
Clay, yellow	26	348
Gravel and coarse sand	9	357
Clay, yellow, sticky	33	390
Gravel, w/cobbles and pebbles	13	403

Well completion data

Casing: 248 ft./3 in.
Screened Zone: 222-238 ft.
Yield: 115 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 8/6

Location: Sitlapur

Drilled by: Hydrology Department

Altitude of Land Surface: 429 ft. (130.7 m)

Static Water level (Head): ____________ ISD

Drilling Started: 16/3/72

Completed: 16/3/72

Log by: B. D. Kharel

Lithologic Description	Thickness (feet)	Depth (feet)
Sub-soil	2	2
Sand, gravel w/clay	2	4
Boulders	9	13

Hole abandoned.

Table 7 Well Logs

Test Hole No.: 9/1

Drilling Started: 27/2/72

Location: Chakacouda

Completed: 3/3/72

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi

Altitude of Land Surface: 313 ft. (95.3 m)

Static Water level (Head):__________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	5	5
Clay, yellow, plastic	15	20
Clay, yellow with sand	20	40
Clay, yellowish-gray, plastic	20	60
Clay, yellowish-gray with sand	40	100
Gravel with siltstone fragments	10	110
Clay, gray, plastic	30	140
Clay, gray with silt	10	150
Clay, gray, plastic	60	210
Sand, coarse with some gravel	10	220
Clay, gray, plastic with silt	80	300
Clay, yellow, sticky	20	320
Clay, yellow with some silt	10	330
Clay, yellowish-gray, sticky	50	380
Gravel	10	390
Gravel with yellow clay	10	400
Clay, yellow, sticky	30	430
Clay, yellow with gravel	20	450
Clay, grayish-yellow, plastic	10	460
Clay, gray, sticky with silt	130	590
Clay, gray with fine gravel	10	600
Clay, gray, plastic	60	660
Clay, yellow, plastic	10	670
Clay, gray, sticky	70	740
Clay, gray with fine sand	20	760
Clay, gray, sticky	20	780
Clay, yellow, plastic	80	860
Clay, yellow	30	890
Clay, gray, plastic	20	910
Clay, gray	40	950
Clay, yellow, plastic	35	985

Test hole - uncased.

Table 7 Well Logs

Test Hole No.: 9/2

Location: Dumraha

Drilled by: N.B. Tubewells

Altitude of Land Surface: 336 ft. (102.9 m) 103.02 m

Static Water level (Head): +2 ft. LSD

Drilling Started: 24/2/72

Completed: 26/2/72

Log by: G. P. Chaturvedi

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow	5	5
Clay, yellow, sticky	55	60
Clay, yellowish-gray, sticky	5	65
Gravel with siltstone and sand	10	75
Clay, yellowish-gray, sticky	45	120
Gravel with siltstone gravels and fine sand	10	130
Gravel, well sorted with fine to coarse sand	20	150
Clay, yellowish-gray, sticky	45	195
Gravel, well sorted, water bearing	15	210
Clay, yellow, sticky	10	220
Clay, yellow with siltstone gravel and some sand	60	280
Clay, yellow with siltstone gravel	40	320
Gravel, sub-angular and sub-rounded	10	330
Clay, yellowish-gray, sticky	30	360
Clay, gray, sticky	60	420
Clay, gray with some gravel and sand	10	430
Clay, yellowish-gray with fine sand	20	450
Clay, yellowish-gray	10	460
Clay, gray with gravel	20	480
Clay, gray, sticky	20	500
Clay, yellowish-gray with gravel	10	510
Clay, gray, sticky	30	540
Clay, yellowish-gray with gravel	10	550
Clay, yellowish-gray, sticky	10	560

Well construction data

Casing: 210 ft/3 in.
Screened Zone: 195 to 205 ft.
Yield: 2 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 9/3 — Drilling Started: 4/3/72

Location: Rehara — Completed: 6/3/72

Drilled by: N. B. Tubewells — Log by: G. P. Chaturvedi

Altitude of Land Surface: 355 ft. (108.2 m)

Static Water level (Head): ________________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	7	7
Clay, yellow with sand	6	13
Clay, yellow, sticky	27	40
Clay, yellowish-gray, sticky	30	70
Clay, yellow with gravel	10	80
Clay, gray, sticky	10	90
Sand, coarse to medium	10	100
Gravel, well sorted, sub-angular to sub-rounded	20	120
Clay, gray, sticky	20	140
Gravel, sub-angular to sub-rounded	20	160
Clay, gray, sticky	20	180
Clay, gray with coarse sand	10	190
Clay, yellowish-gray, sticky	50	240
Clay, yellowish-gray with gravel and sand	20	260
Clay, gray, plastic	20	280
Clay, yellow, plastic	10	290
Gravel with coarse sand	10	300
Clay, yellow with gravel	20	320
Clay, yellow	32	352
Gravel with coarse sand	8	360
Clay, yellowish-gray	60	420
Clay, yellow	60	480
Clay, yellow with gravels	20	500

Test hole - uncased

Table 7 Well Logs

Test Hole No.: 9/4

Drilling Started: 6/3/72

Location: Rehara

Completed: 7/3/72

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi

Altitude of Land Surface: 357 ft. (108.6 m) 107.59 m

Static Water level (Head): -4 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	7	7
Clay, yellow with sand	6	13
Clay, yellow, sticky	34	47
Clay, yellow with coarse sand	30	77
Clay, yellow	12	89
Clay, gray, sticky	4	93
Sand, gray, coarse	7	100
Gravel with coarse sand	20	120
Clay, yellowish-gray	7	127

Well completion data

Casing: 125 ft/3 in.
Screened Zone: 105 to 120 ft.

Table 7 Well Logs

Test Hole No.: 9/5

Location: Rehara

Drilled by: N.B. Tubewells

Drilling Started: 9/3/72

Completed: 10/3/72

Log by: G. P. Chaturvedi

Altitude of Land Surface: 358 ft. (109.1 m) 107.59 m

Static Water level (Head): -5 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, gray	5	5
Sub-soil with fine sand	3	8
Clay, yellow	5	13
Clay, yellow, sticky	22	35
Clay, yellow with fine sand	7	42
Clay, yellow, sticky	18	60
Clay, yellowish-gray	43	103
Clay, yellow, sticky	5	108
Gravel with coarse sand, water bearing	20	128
Clay	7	135

Well completion data

Casing: 126 ft/ 8 in.
Screened Zone: 111 to 121 ft.
Yield: 50 GPM (pumped)
Drawdown: 13 ft.

Table 7 Well Logs

Test Hole No.: 9/6

Drilling Started: 10/3/72

Location: Wadari

Completed: 13/3/72

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi

Altitude of Land Surface: 379 ft. (115.7 m)

Static Water level (Head):____________LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	5	5
Sand, medium to coarse with fine gravel	10	15
Gravel, well sorted with gray clay	27	42
Gravel, fine with coarse to v. coarse sand	18	60
Gravel, well sorted, sub-rounded with clay, yellowish-gray, plastic	46	106
Gravel well sorted, subrounded to sub-angular	5	111
Clay, gray, plastic	18	129
Gravel with gray clay	4	133
Clay, gray, sticky	15	148
Gravel, well sorted	10	158
Clay, gray, sticky	21	179
Clay, gray with gravel	14	193
Gravel, well sorted, sub-rounded to sub-angular	8	201
Clay, gray, sticky	19	220
Clay, gray with gravel	58	278
Gravel, with v. coarse sand	2	280
Gravel, with coarse sand	3	283
Clay, gray, plastic	13	296
Gravel	10	306
Clay, gray, plastic	34	340
Clay, yellowish-gray with gravel	16	356
Gravel, well sorted	8	364
Clay, gray with gravel	16	380
Clay, gray, plastic	40	420
Clay, gray, sticky	49	469
Gravel, with gray sticky clay	23	492
Clay	11	503

Test hole - uncased.

Table 7 Well Logs

Test Hole No.: 9/7

Drilling Started: 15/3/72

Location: Motipur

Completed: 20/3/72

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi

Altitude of Land Surface: 394 ft. (120.1 m)

128.93 m

Static Water level (Head): +29 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	4	4
Gravel	12	16
Sand, v. coarse to medium	5	21
Clay, gray with coarse sand	11	32
Gravel with cobbles and pebbles, sub-angular to sub-rounded, coarse sand	8	40
Clay, gray with sand	13	53
Clay, gray, plastic	21	74
Gravel, sub-angular to angular	6	80
Clay, gray, sticky	14	94
Gravel	7	101
Clay with gravel	4	105
Gravel with coarse sand and clay	5	110
Gravel, well sorted	12	122
Clay, yellowish-gray, plastic	9	131
Gravel, well sorted with pebbles	9	140
Gravel, well sorted, sub-angular to sub-rounded	22	162
Gravel, fine with coarse sand	5	167
Clay, gray with gravel and sand	23	190
Clay, gray, plastic	20	210
Clay, yellowish-gray with sand	30	240
Clay, gray with gravel	4	244
Clay, yellowish-gray	16	260
Clay, yellowish-gray with gravel and coarse sand	15	275
Clay, yellowish-gray with gravel	5	280
Clay and gravel in alternate layers	25	305
Clay, gray, plastic	15	320
Clay and gravel in alternate layer approx. 3" or 2" thick	17	337
Clay, yellowish-gray	13	350
Clay with gravel and fine sand	11	361
Gravel with coarse sand	8	369
Clay, gray, plastic	17	386
Gravel with clay	4	390

Continued........

Table 7 Well Logs

Test Hole No.: 9/7 (cont.)

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellowish-gray	4	394
Gravel with some clay	8	402
Clay, gray	15	417
Clay, gray with sand	3	420
Clay and gravel in alternate bands	32	452
Clay, gray, plastic	13	465
Gravel with clay	7	472
Clay and gravel in alternate bands	8	480
Gravel with sand	5	485
Clay, gray	17	502

Well completion data

Casing: 164 ft/4 in.
Screened Zone: 136 to 159 ft.
Yield: 60 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 9/8

Location: Motipur

Drilled by: N.B . Tubewells

Drilling Started 31/3/72

Completed: 2/4/72

Log by: D. C. Parajuli

Altitude of Land Surface: 394 ft. (120.1 m)

128.93 m

Static Water level (Head): +29 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, grayish-yellow	3	3
Sand, medium	6	9
Sand, coarse	4	13
Gravel, sub-angular	9	22
Clay, grayish-yellow with sand	10	32
Sand, coarse with gravel	8	40
Clay, gray, sticky	22	62
Clay, grayish-yellow with gravel & sand	11	73
Gravel, sub-angular to angular	9	82
Clay, gray, sticky	13	95
Gravel, angular to sub-angular with cobbles & coarse sand	25	120
Clay, yellow with gravel	11	131
Gravel, sub-angular to angular, water bearing	35	166
Clay, yellow	6	172

Well completion data

Casing: 172 ft/8 in.
Screened Zone: 136-163 ft.
Yield: 618 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 9/9

Drilling Started: 26/3/72

Location: Bhartapur

Completed: 27/3/72

Drilled by: N.B. Tubewells

Log by: G. P. Chaturvedi

Altitude of Land Surface: 437 ft. (133.3 m)

Static Water level (Head): ______________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	4	4
Gravel	23	27
Clay, yellow, sticky	5	32
Sand, coarse with gravel	5	37
Gravel, angular to sub-angular	6	43
Gravel with clay, yellow & gray	35	78
Gravel	4	82
Gravel with clay	25	107
Clay, yellow with coarse sand	13	120
Gravel & sand with yellow clay	11	131
Gravel, angular to sub-angular	14	145
Clay, yellow with gravel and coarse sand	9	154
Clay, redish	6	160
Boulders	5	165

Hole abandoned.

Table 7 Well Logs

Test Hole No.: 10/1

Drilling Started: 23/5/72

Location: B akapur

Completed: 25/5/72

Drilled by: Hydrology Dept.

Log by: B. D. Kharel

Altitude of Land Surface: 330 ft. (100.3 m)

Static Water level (Head):________________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, yellow	8	8
Clay, yellow and gray, sticky	4	12
Clay, w/sandstone gravel	3	15
Sand, fine	13	28
Sand, coarse & gravel w/clay	7	35
Clay, black and yellow w/coarse sand	52	87
Sand, coarse w/clay	25	112
Clay, yellow	3	115
Gravel, sandstone	9	124
Clay, gray, yellow	64	188
Gravel, sandstone	16	204
Clay, yellow	21	225
Gravel, sandstone	5	230
Clay	15	245
Clay, w/sandstone gravel	34	279
Gravel, w/clay	12	291
Clay	3	294
Gravel, w/sandstone particles	15	309
Clay	5	314
Gravel, sandstone	6	320
Clay, w/gravel	15	335
Gravel, w/sandstone particles	49	384
Clay, yellow, sandy	9	393
Gravel, interbedded w/clay	11	404
Clay, yellow and gray, sticky	36	440
Gravel interbedded w/clay	20	460
Gravel w/sand	20	480
Gravel	14	494
Clay	11	505

Test hole - uncased

Table 7 Well Logs

Test Hole No.: 10/2

Location: Taulihawa

Drilled by: Hydrology Department

Altitude of Land Surface: 340 ft. (103.5 m) 106.07 m

Static Water level (Head): + 8 ft.

Drilling Started: 25/4/72

Completed: 3/5/72

Log by: B. D. Kharel

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, gray to dark gray, yellow, sticky	23	25
Clay, gray and yellow, sticky	44	69
Sand, w/gravel and siltstone particles	14	83
Clay, yellow	14	97
Sand w/siltstone gravel	18	115
Clay, gray	16	131
Sand, w/fine gravel	11	142
Clay, yellow	5	147
Sand, w/gravel	10	157
Clay, yellow	9	166
Gravel, w/sand	11	177
Clay, yellow	77	254
Gravel	2	256
Clay, yellow	67	323
Silt, compact	2	325
Clay	15	340
Gravel	19	359
Clay, yellow	14	373
Gravel, interbedded with clay	8	381
Clay	11	392
Gravel	6	398
Clay	102	500
Gravel, w/siltstone particles, water bearing	36	536
Clay, dark gray and yellow	19	555
Gravel	16	571
Clay	17	588
Gravel, w/siltstone particles	4	592
Clay, gray	17	609
Clay, w/gravel	19	618
Clay, gray and yellow	53	671
Gravel	3	674
Clay	26	700

Well completion data

Casing: 522 ft/3 in.

Screened Zone: 501-512 ft.

Yield: 20 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 10/3

Drilling Started: 8/5/72

Location: Taulihawa

Completed: 16/5/72

Drilled by: Hydrology Department

Log by: B. D. Kharel

Altitude of Land Surface: 340 ft. (103.5 m) 106.07 m

Static Water level (Head): +8 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, gray and yellow, sticky	53	55
Sand, w/gravel	28	83
Clay, yellow and gray	3	86
Gravel, sandstone with sand	69	155
Clay, yellow	9	164
Gravel, sandstone	12	176
Clay, gray and yellow	30	206
Gravel, w/siltstone particles	2	208
Clay, yellow	28	236
Gravel, siltstone	7	243
Clay, yellow	10	253
Gravel	2	255
Clay, yellow w/thin layers of silt	24	279
Clay, yellow	81	360
Gravel, interbedded w/clay	8	368
Clay, yellow	28	396
Gravel	4	400
Clay	25	425
Gravel	1	426
Clay, yellow, hard	69	495
Gravel, w /sandstone particles	19	514
Clay	12	526

Well completion data

Casing: 10" casing to 98 ft./6" from 98 to 520 ft.
Screened Zone: 500-514 ft.
Yield: 36 GPM (pumped)

Table 7 Well Logs

Test Hole No.: 10/4

Drilling Started: 15/4/72

Location: Janakpur

Completed: 18/4/72

Drilled by: Hydrology Department

Log by: B. D. Kharel

Altitude of Land Surface: 353 ft. (107.5 m)

Static Water level (Head):________________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, sandy	11	11
Clay, yellow	14	25
Clay, yellow w/siltstone gravel	35	60
Sand, fine to coarse	14	74
Clay	8	82
Sand, fine w/siltstone particles	10	92
Clay, gray, sticky	69	161
Gravel	4	165
Clay, yellow	5	170
Gravel	3	173
Clay, gray and yellow	55	228
Gravel w/siltstone particles	6	234
Clay	34	268
Gravel, w/siltstone and sandstone particles	8	276
Clay, gray	34	310
Gravel, mixed with clay	9	319
Clay	16	335
Clay w/gravel	22	357
Gravel	17	374
Clay, gray, sticky	68	442
Gravel	8	450
Clay	52	502

Test hole - uncased.

Table 7 Well Logs

Test Hole No.: 10/5

Location: Gorsinghi

Drilled by: Hydrology Department

Drilling Started: 6/4/72

Completed: 10/4/72

Log by: B. D. Kharel

Altitude of Land Surface: 398 ft. (121.4 m)

Static Water level (Head): +5 ft. LSD

122.83 m

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, gray	10	10
Clay, yellow, hard, sticky, w/siltstone gravel	28	38
Sand, coarse to fine w/clay	9	47
Clay, yellow and gray	33	80
Clay, w/siltstone fragments	5	85
Clay, gray	16	101
Gravel, w/coarse sand & siltstone particles	29	130
Clay, yellow and gray	61	191
Gravel w/coarse sand	12	203
Clay	97	300
Gravel	4	304
Clay, gray and yellow	81	385
Gravel, w/sand	18	403
Clay, yellow	9	412
Gravel, w/sand	7	419
Clay, gray	14	433
Gravel, w/sand	14	447
Clay	55	502

Well completion data

Casing: 218 ft/ 3 in.
Screened Zone: 196-208 ft.
Yield: 5 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 10/6

Drilling Started: 23/3/72

Location: Bhelai

Completed: 27/3/72

Drilled by: Hydrology Department

Log by: B. D. Kharel

Altitude of Land Surface: 438 ft. (133.4 m)

Static Water level (Head): +2 ft. LSD

12.4 " m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, gray	2	2
Sand, fine w/clay	6	8
Clay, yellow, sandy	7	15
Sand, fine to coarse w/fine gravel	15	30
Clay, gray and yellow, sticky	26	56
Sand, coarse w/gravel	8	64
Clay, gray, hard, sticky	53	117
Gravel, and sand, water bearing	15	132
Clay, gray	9	141
Clay, yellow	33	174
Clay, gray and yellow	44	218
Gravel and sand	3	221
Clay, w/gravel	4	225
Gravel and sand	12	237
Clay, gray and yellow	63	300
Gravel	2	302
Clay, yellow	65	367
Gravel	2	369
Clay, gray	10	379
Gravel and sand	6	385
Clay,	17	402
Gravel	8	410
Clay, gray	93	503

Well completion data

Casing: 145 ft/ 3 in.
Screened Zone: 121-133 ft.
Yield: 2 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 11/1

Drilling Started: 27/4/72

Location: Paraspur

Completed: 29/4/72

Drilled by: N.B. Tubewells

Log by: D. C. Parajuli

Altitude of Land Surface: 323 ft. (98.4 m)

Static Water level (Head):______________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow	5	5
Clay, yellow with kankar	5	10
Clay, yellow, sandy	15	25
Clay, yellow with sand & siltstone particles	10	35
Sand, fine to medium	16	51
Clay, yellow, sticky	19	70
Clay, yellow, hard with kankar and siltstone particles	30	100
Clay, gray with kankar & siltstone particles	20	120
Clay, yellowish-gray with siltstone particles from 130 ft.	22	142
Clay, yellow with some siltstone particles	38	180
Clay, yellowish-gray with siltstone particles	30	210
Clay, yellow, sandy	11	221
Clay, yellow	19	240
Clay, yellow, sandy	18	258
Clay, yellowish-gray	14	272
Clay, grayish-yellow with sand & sandstone particles	10	282
Clay, yellow with siltstone particles from 290 ft.	18	300
Clay, gray, sticky, hard	30	330
Clay, yellow with siltstone particles from 350 ft.	30	360
Clay, yellowish-gray, sandy	22	382
Clay, yellow, sandy with siltstone particles	13	395
Clay, yellow, sandy	23	418
Clay, yellow, sticky with siltstone particles	26	444
Clay, yellow, plastic	11	455
Clay, yellow, sticky with siltstone particles	8	463
Clay, yellow, sticky	7	470
Clay, yellow with siltstone particles	22	492
Clay, yellow with sand and siltstone particles	10	502

Test hole - uncased.

Table 7 Well Logs

Test Hole No.: 11/2

Location: Gaidahawa

Drilled by: N.B. Tubewells

Drilling Started: 20/4/72

Completed: 24/4/72

Log by: D. C. Parajuli

Altitude of Land Surface: 335 ft. (102.1 m)

Static Water level (Head): -5 ft. LSD

100.58 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, sandy	4	4
Clay, yellow, sandy	5	9
Clay, gray & yellow, sticky	22	31
Siltstone	5	36
Clay, gray to yellowish-gray, sticky	34	70
Clay, gray to yellow with siltstone particles	90	160
Clay, yellowish-gray, sticky	5	165
Gravel, siltstone & sandstone	18	183
Clay, gray and yellow, sticky	14	197
Clay, yellowish-gray, with siltstone particles	8	205
Gravel, sandstone, siltstone	15	220
Clay, yellow, sandy	16	236
Clay, yellow with siltstone particles	44	280
Clay, grayish-yellow, sandy	10	290
Clay, yellow, sandy	27	317
Clay, yellowish-gray, sandy	10	327
Clay, gray with siltstone and sand	7	334
Clay, yellow, sticky	56	390
Clay, yellowish-gray with siltstone and sand	22	412
Clay, gray and yellow	28	440
Clay, yellow, sticky with siltstone particles to 452 ft.	42	482
Clay, yellow, sandy	11	493
Clay, yellowish gray, sticky	9	502

Well completion data

Casing: 190 ft/3 in.
Screened Zone: 165-180 ft.
Yield: 50 GPM (Air lift)

Table 7 Well Logs

Test Hole No.: 11/3

Drilling Started: 19/4/72

Location: Bankatti

Completed: 22/4/72

Drilled by: N.B. Tubewells

Log by: D.C. Parajuli

Altitude of Land Surface: 345 ft. (105.1 m)

Static Water level (Head):________________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow	5	5
Clay, gray & yellow	15	20
Clay, gray, sticky	11	31
Clay, gray with siltstone particles	10	41
Clay, yellow & gray, sticky	19	60
Clay, yellowish-gray, sticky	20	80
Clay, sandy with siltstone particles	17	97
Clay, yellowish-gray, sandy	23	120
Clay, yellowish-gray with sand and siltstone particles	16	136
Siltstone	6	142
Clay, yellowish-gray, sandy	7	149
Clay, yellow	11	160
Clay, gray	33	193
Clay, yellow with sandstone particles	10	203
Clay, yellow, sticky	25	228
Clay, yellow with sandstone & siltstone particles	24	252
Clay, yellow, sticky	13	265
Clay, yellow, plastic	5	270
Clay, yellow with siltstone and sandstone particles	10	280
Clay, yellow, plastic	8	288
Clay, yellow with sandstone & siltstone particles	3	291
Clay, yellow, plastic	19	310
Clay, yellow with sandstone particles	10	320
Gravel, rounded	11	331
Clay, yellow, plastic	11	342
Clay with siltstone particles	10	352
Clay, yellow, plastic	8	360
Clay, grayish-yellow with siltstone particles	20	380
Clay, gray with siltstone particles	20	400
Clay, grayish-yellow with siltstone particles	10	410
Clay, gray, plastic	12	422
Clay, yellow, plastic	18	440
Clay, gray & yellow with siltstone particles	32	472
Clay, yellow, plastic	8	480
Clay, yellowish-gray, sticky	22	502

Test hole - uncased

Table 7 Well Logs

Test Hole No.: 11/4

Location: Bhaktapur

Drilled by: N.B. Tubewells

Altitude of Land Surface: 430 ft. (131.0 m)

Static Water level (Head):____________ LSD

Drilling Started: 13/4/72

Completed: 17/4/72

Log by: D. C. Parajuli

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow	4	4
Clay, yellow, plastic	16	20
Gravel, rounded to sub-rounded with coarse sand	17	37
Clay, gray, sticky	15	52
Clay, yellow, sandy with gravel, subangular to rounded	8	60
Gravel with coarse sand	5	65
Clay, gray	5	70
Clay, yellow with coarse sand	19	89
Gravel, sub-angular to rounded	11	100
Clay, yellow with gravel & coarse sand	9	109
Clay, yellow, sandy	13	122
Gravel, with clay	8	130
Clay, yellow, plastic	24	154
Gravel, rounded to sub-angular	11	165
Clay, yellow with gravel	10	175
Clay, yellow, sticky	25	200
Clay, yellow, sandy with gravel	12	212
Gravel, rounded	10	222
Clay, yellowish-gray, plastic	7	229
Clay, yellow with gravel	6	235
Clay, grayish-yellow, plastic	35	270
Clay, grayish-yellow, with gravel	10	280
Clay, yellowish-gray	13	293
Clay, yellow, sandy	7	300
Clay, gray, plastic with gravel	14	314
Gravel with sand	46	360
Sand, coarse with gray clay	11	371
Clay, yellowish-gray, plastic	19	390
Clay, yellow, sandy	10	400
Clay, yellow, sticky	9	409
Clay, yellowish-gray, plastic with sandstone particles	31	440
Clay, yellow with gravel	49	489
Clay, gray, plastic	38	527
Clay, gray, sandy	38	565
Gravel with clay and sand	5	570
Clay, gray with gravel	10	580
Clay, grayish-yellow, plastic	126	706
Clay, yellowish-gray, sandy	10	716
Clay, gray with sand	10	726
Clay, grayish-yellow, sandy	19	745
Clay, gray, plastic	40	785

Test hole - uncased.

Table 7 Well Logs

Test Hole No.: 11/5

Location: Champapur

Drilled by: N.B. Tubewells

Altitude of Land Surface: 379 ft. (115.5 m)

Static Water level (Head): +13 ft. LSD

Drilling Started: 10/4/72

Completed: 12/4/72

Log by: D. C. Parajuli

119.48 m

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow, sandy	5	5
Clay, yellow with fine sand and silt	15	20
Sand, yellowish-gray, medium	13	33
Clay, grayish-yellow, plastic with siltstone fragments	58	91
Clay, yellow	25	116
Clay, yellowish-gray with siltstone fragments	5	121
Clay, yellow	17	138
Clay, grayish-yellow with siltstone fragments	7	145
Clay, grayish-yellow, plastic	20	165
Clay, gray, sandy	10	175
Gravel, rounded to sub-rounded with siltstone	17	192
Clay, gray, sticky	18	210
Clay, gray with gravel	10	220
Clay, gray, plastic	10	230
Clay, yellow	8	238
Clay, yellowish-gray with gravel	15	253
Clay, yellow, plastic	10	263
Clay, yellowish-gray with gravel	8	271
Clay, yellow, plastic	11	282
Clay, yellow, sandy	18	300
Clay, gray with sandstone, siltstone, particles	10	310
Clay, yellow with sandstone particles	15	325
Clay, yellowish with gravel	20	345
Clay, yellow, plastic with sandstone particles	10	355
Clay, yellow, plastic	6	361
Clay, grayish-yellow, sandy with sandstone particles	20	381
Clay, gray with gravel	10	391
Clay, yellowish, sandy with gravel	29	420
Clay, yellowish-gray with gravel	15	435
Clay, yellow, plastic with gravel	19	454
Clay, gray with coarse sand	21	475
Clay, gray, sticky with sandstone & siltstone particles	20	495
Clay, gray, plastic	5	500

Well completion data

Casing: 192 ft/3 in.
Screened Zone: 177-187 ft.
Yield: 13 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 12/1

Drilling Started: 30/4/72

Location: Ajigara

Completed: 4/5/72

Drilled by: N.B. Tubewells

Log by: D. C. Parajuli

Altitude of Land Surface: 342 ft. (104.2 m)

Static Water level (Head): ________ ________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow	5	5
Clay, yellow, sandy	40	45
Clay, gray, sticky	10	55
Clay, gray, sticky with siltstone particles	25	80
Clay, gray & yellow, sandy with siltstone particles	40	120
Clay, gray with siltstone particles	19	139
Gravel, sandstone and siltstone with clay	12	151
Clay, yellow, loose	29	180
Clay, yellowish-gray, plastic	14	194
Clay, grayish-yellow, sticky with silt	11	205
Clay, grayish-yellow, sandy with siltstone particles	45	250
Clay, yellow with siltstone particles	50	300
Clay, grayish-yellow, sandy with siltstone particles	37	337
Clay, yellow & gray, loose, sticky	105	442
Clay, yellowish-gray with siltstone particles	20	462
Clay, yellow with siltstone particles	30	492
Clay, yellow & gray, sticky	90	582
Clay, yellow, loose with coarse sand	11	593
Clay, yellowish-gray with siltstone particles	30	623
Clay, grayish-yellow	33	656
Clay, grayish-yellow, sticky with siltstone particles	12	668
Clay, grayish-yellow, sticky	19	687
Clay, gray, sticky with siltstone particles	60	747
Clay, gray, sticky	40	787
Clay, gray with siltstone and sandstone particles	8	795
Clay, gray, loose sticky	73	868
Clay, gray with some siltstone particles	18	886
Clay, yellow & gray, sticky	47	933

Test hole - uncased.

Table 7 Well Logs

Test Hole No.: 12/2

Drilling Started: 29/5/72

Location: Bahadurganj

Completed: 31/5/72

Drilled by: Hydrology Department

Log by: B. D. Kharel

Altitude of Land Surface: 352 ft. (107.2 m) 100.28 m

Static Water level (Head): -23 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Sand, yellow and black, fine	35	35
Clay, yellow, gray sticky	35	70
Clay, gray with sand	20	90
Clay, yellow, sticky with coarse sand	15	115
Gravel with siltstone fragments	16	131
Clay, yellow and gray	20	151
Gravel with siltstone fragments	3	154
Clay, yellow	7	161
Gravel	2	163
Clay, yellow, soft	5	168
Gravel, water bearing	13	181
Clay, yellow	29	210
Gravel	5	215
Clay	11	226
Gravel, interbedded with clay	22	248

<u>Well completion data</u>

Casing: 10" casing to 98 ft./6" from 98 to 181 ft.
Screened Zone: 171-181 ft.
Yield: Slight

Table 7 Well Logs

Test Hole No.: 12/3

Drilling Started: 5/5/72

Location: Ganeshpur

Completed: 6/5/72

Drilled by: N.B. Tubewells

Log by: D. C. Parajuli

Altitude of Land Surface: 371 ft. (113.0 m)

Static Water level (Head):________________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow	6	6
Sand, medium to fine	7	13
Clay, sandy	13	26
Sand, medium to fine	13	39
Clay, grayish-yellow, sandy	41	80
Clay, gray with siltstone fragments	93	173
Clay, yellow, sticky	8	181
Clay, yellow, loose, sandy with silt	49	230
Clay, gray, sticky	19	249
Clay, grayish-yellow with silt	95	344
Clay, grayish-yellow, sticky	29	373
Sand & gravel, coarse with gray clay	7	380
Clay, gray with siltstone gravel	30	410
Clay, sandy with siltstone fragments	31	441
Clay, grayish-yellow	21	462
Clay, yellow, loose	40	502

Test hole - uncased.

Table 7 Well Logs

Test Hole No.: 12/4

Drilling Started: 7/5/72

Location: Dharamnagar

Completed: 8/5/72

Drilled by: N.B. Tubewells

Log by: D. C. Parajuli

Altitude of Land Surface: 406 ft. (123.7 m) 128.62 m

Static Water level (Head): +16 ft. ISD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	2	2
Sand, medium to fine	57	59
Sand, coarse with gravel, rounded to sub-rounded	9	68
Gravel, rounded to sub-rounded	5	73
Clay, yellow, sticky	8	81
Gravel, rounded to sub-rounded	9	90
Clay, sandy with siltstones particles	78	168
Clay, sandy with siltstone gravel	12	180
Gravel with siltstone fragments	20	200
Clay, gray & yellow, sandy	40	240
Clay, yellow, sticky with kankar	13	253
Clay, yellow & gray, sticky	29	282
Clay, yellow with sandstone and siltstone particles	86	368
Clay, yellow	12	380
Clay, yellowish-gray, sticky with coarse sand	20	400
Clay, yellow, sticky with sand & siltstone particles	27	427
Clay, yellowish-gray, sticky	13	440
Clay, yellow & gray with kankar	44	484
Clay, gray	18	502

Well completion data

Casing: 214 ft/ 3 in.
Screened Zone: 192-209 ft.
Yield: 27 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 12/5

Drilling Started: 10/5/72

Location: Dharamnagar

Completed: 11/5/72

Drilled by: N.B. Tubewells

Log by: D. C. Parajuli & B. P. Bhattarai

Altitude of Land Surface: 406 ft. (123.7 m) 128.37 m

Static Water level (Head): +15 ft. ISD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellow, sandy	3	3
Sand, yellowish-gray, fine to medium	39	42
Sand, coarse with gray clay	21	63
Sand, gray, coarse	7	70
Clay, grayish-yellow with sand	30	100
Clay, yellowish-gray	17	117
Clay, yellowish-gray with siltstone particles	45	162
Clay, yellow	7	169
Clay, yellow with sandstone & siltstone fragments	21	190
Gravel, rounded to sub-rounded with coarse sand from 202 ft.	20	210
Clay, yellow, sticky	10	220

Well completion data

Casing: 215 ft/ 6 in.
Screened Zone: 192-209 ft.
Yield: 26 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 12/6

Location: Rahatkol

Drilled by: N.B. Tubewells

Drilling Started: 12/5/72

Completed: 13/5/72

Log by: D. C. Parajuli & Bhattarai

Altitude of Land Surface: 430 ft. (131.0 m)

Static Water level (H ead): ____________________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	7	7
Clay, yellow with medium sand	11	18
Sand, fine to medium	10	28
Clay, yellow with siltstone fragments	72	100
Clay, grayish-yellow, sticky	17	117
Sand, coarse with siltstone fragments	8	125
Clay, sandy with siltstone fragments	21	146
Clay, grayish-yellow, sticky with silt	46	192
Clay, yellowish-gray, loose, sticky	36	228
Clay, grayish-yellow, sandy with siltstone fragments	32	260
Clay, yellow, sticky	10	270
Clay, grayish-yellow with coarse sand	21	291
Clay, grayish-yellow, plastic	19	310
Clay, yellow with medium to coarse sand	30	340
Clay, yellow, sticky	35	375
Clay, grayish-yellow, plastic with gravel	8	383
Clay, grayish-yellow, plastic	37	420
Clay, grayish-yellow with siltstone and sandstone fragments	8	428
Clay, gray, plastic	22	450
Clay, grayish-yellow with gravel	10	460
Clay, yellow with sand	11	471
Clay, yellow, plastic	31	502

Test hole - uncased.

Table 7 Well Logs

Test Hole No.: 13/1

Drilling Started: 25/5/72

Location: Krishnagar

Completed: 27/5/72

Drilled by: N.B. Tubewells

Log by: Keshab K.C.

Altitude of Land Surface: 334 ft. (101.8 m) 97.23 m

Static Water level (Head): -15 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Clay, sandy	8	8
Clay, dark gray	6	14
Clay, gray	9	23
Clay, yellow with fine silt	17	40
Clay, yellowish-gray with siltstone particles	28	68
Clay, yellowish-gray, sticky with siltstone particles	20	88
Clay, grayish-yellow with siltstone particles	22	110
Clay, grayish-yellow	10	120
Clay, gray	34	154
Clay, grayish-yellow with sandstone & siltstone fragments	8	162
Gravel with coarse sand, water bearing	10	172
Sand, coarse to medium with some gravel	8	180
Clay, yellow, sticky	30	210
Clay, yellow with some sandstone fragments	10	220
Clay, yellow, plastic	10	230
Clay, yellow	7	237
Clay, yellow with siltstone and sandstone fragments	13	250
Clay, yellow with siltstone particles	10	260
Clay, yellow with sandstone & siltstone fragments	10	270
Clay, yellow, loose with gravel and coarse sand	10	280

Well completion data

Casing: 10 in. to 90 ft/ 6 in. to 177 ft.
Screened Zone: 162-172 ft.
Yield: 42 GPM (pumped)
Drawdown: 27 ft.

Table 7 Well Logs

Test Hole No.: 13/2

Drilling Started: 21/5/72

Location: Shivanagar

Completed: 22/5/72

Drilled by: N.B. Tubewells

Log by: Keshab K. C.

Altitude of Land Surface: 337 ft. (102.8 m) 97.84

Static Water level (Head): -16 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	6	6
Clay, yellow, sandy	26	32
Clay, sandy with siltstone particles	4	36
Clay, gray	16	52
Clay, gray with siltstone particles	8	60
Clay, gray, sticky	40	100
Clay, with siltstone fragments	17	117
Clay, gray & yellow with siltstone fragments	19	136
Clay, yellow with siltstone particles	24	160
Clay, yellowish-gray, sandy	32	192
Clay, yellow with siltstone	8	200
Clay, yellow with siltstone particles	10	210
Siltstone gravel, water bearing	17	227
Clay, yellow with siltstone fragments	15	242
Clay, yellowish-gray	18	260
Clay, gray with siltstone bands	48	308
Sand, coarse with siltstone fragments	12	320
Clay, gray	20	340
Clay, gray with siltstone fragments	40	380
Clay, gray, sandy, with siltstone particles	22	402
Clay, sandy, with alternating layers of clay and sandstone	20	422
Clay, sandy, with hard sand layers	11	433
Clay, gray, sticky	26	459
Clay, yellow, with sandstone particles	20	479
Clay, gray, sticky	21	500

Well completion data

Casing:	8 in. to 90 ft/ 6 in. to 229 ft.
Screened Zone:	208-222 ft.
Yield:	42 GPM (pumped)
Drawdown:	20 ft.

Table 7 Well Logs

Test Hole No.: 13/4

Drilling Started: 17/5/72

Location: Pipri

Completed: 18/5/72

Drilled by: N.B. Tubewells

Log by: D. C. Parajuli

Altitude of Land Surface: 375 ft. (114.3 m) 114.60 m

Static Water level (Head): +1 ft. LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil, yellowish-gray	5	5
Sand, medium	6	11
Clay, gray, sandy	3	14
Clay, gray, sticky	11	25
Clay, grayish-yellow, sandy	5	30
Clay, grayish-yellow	6	36
Clay, yellow with siltstone fragments	5	41
Clay, yellowish-gray, sticky	10	51
Clay, yellowish-gray with siltstone particles	10	61
Clay, yellow, sandy	9	70
Clay, sandy with kankar	10	80
Clay, yellow with siltstone particles	32	112
Gravel, siltstone & sandstone	8	120
Clay, yellow with siltstone fragments	12	132
Clay, gray, loose	8	140
Clay, yellow, loose with siltstone and sandstone particles	24	164
Gravel with coarse sand, water bearing	18	182
Clay, yellow, sandy	38	220
Clay, yellow, plastic	25	245
Gravel with sandstone particles and coarse sand	16	261
Clay, yellow, sandy with some gravel	20	281
Clay, grayish-yellow, sandy	19	300
Clay, grayish-yellow	20	320
Clay, yellow, loose	62	382
Clay, yellow, sandy with sandstone & siltstone particles	78	460
Clay, yellow, loose	42	502

Well completion data

Casing: 181 ft/ 3 in.
Screened Zone: 168-176 ft.
Yield: 1 GPM (flowing)

Table 7 Well Logs

Test Hole No.: 13/5

Drilling Started: 14/5/72

Location: Lohraula

Completed: 16/5/72

Drilled by: N.B. Tubewells

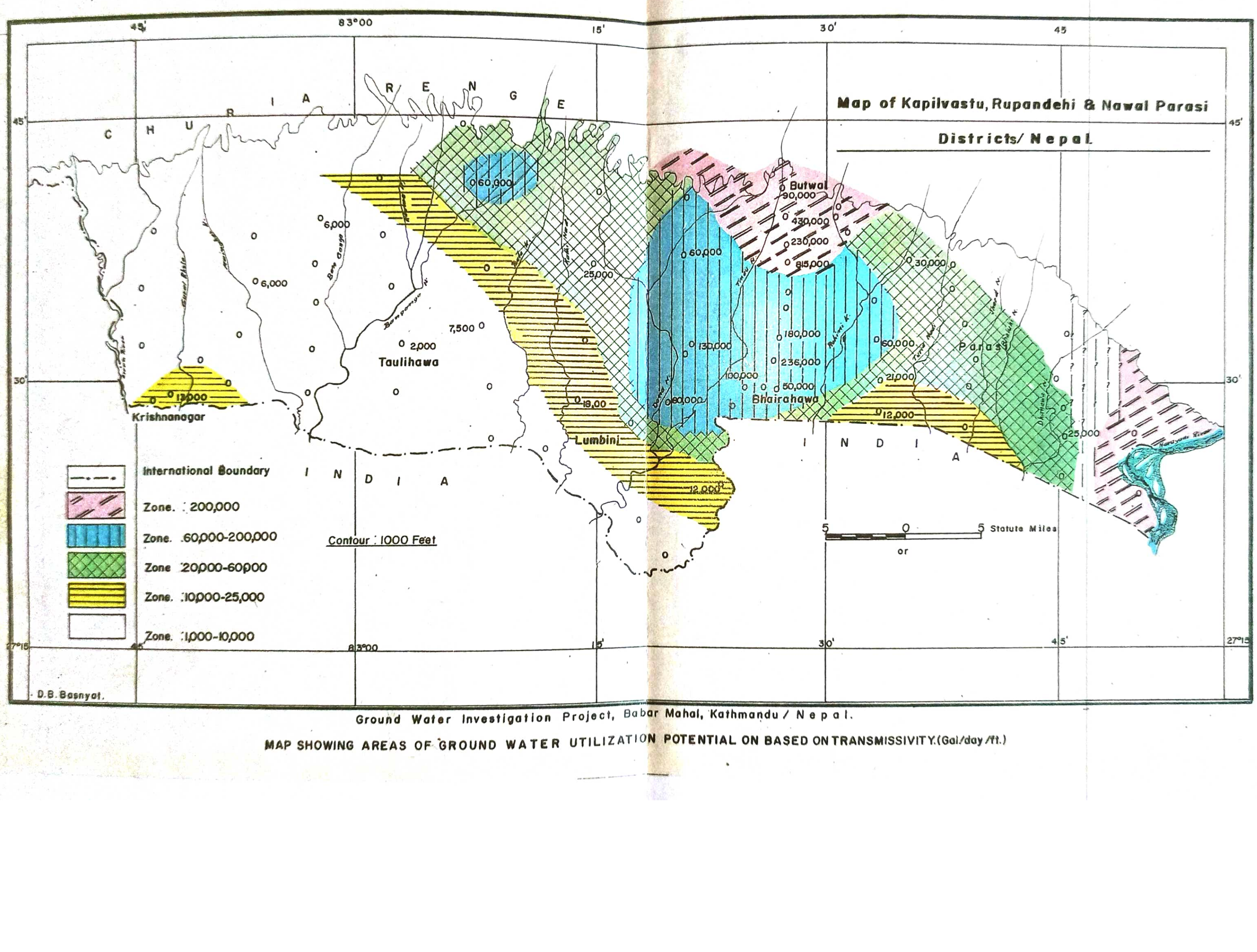
Log by: D. C. Parajuli

Altitude of Land Surface: 428 ft. (130.5 m)

Static Water level (Head):________________ LSD

Lithologic Description	Thickness (feet)	Depth (feet)
Soil	8	8
Sand, medium	12	20
Sand, fine	25	45
Sand, fine to medium	16	61
Clay, gray with siltstone	15	76
Clay, gray with siltstone particles	9	85
Clay, grayish-yellow, sticky with siltstone fragments	43	128
Gravel, rounded to sub-rounded	12	140
Clay, yellow, sandy	33	173
Gravel, sandstone & siltstone particles with clay	7	180
Clay, yellow, sandy, loose	22	202
Clay, yellow, sandy with siltstone particles	8	210
Clay, yellow, sandy	20	230
Clay, yellow and gray	38	268
Clay, yellow with siltstone fragments	12	280
Clay, yellow, sticky	10	290
Clay, yellow, sticky with siltstone particles	10	300
Clay, yellowish-gray with sand	13	313
Clay, yellow with siltstone particles	55	368
Clay, yellowish-gray, sticky	32	400
Clay, yellowish-gray, sticky with siltstone particles	10	410
Clay, yellow, sticky with sand	12	422
Clay, yellow with coarse sand	13	435
Clay, yellow, sticky	25	460
Clay, gray with sandstone particles	23	483
Clay, gray with coarse sand and sandstone particles	9	492
Clay, grayish-yellow, sandy	11	503

Test hole - uncased.



Ground Water Investigation Project, Babar Mahal, Kathmandu / Nepal.

MAP SHOWING AREAS OF GROUND WATER UTILIZATION POTENTIAL ON BASED ON TRANSMISSIVITY.(Gal/day/ft.)