

STUDY AREA AND DATA COLLECTION

Varanasi (Benares, Benaras) lies on a bend of Ganga (Ganges), one of the world's largest rivers. The area lies between longitude 82°56'0" E to 83°4'0" E and latitude 25°12'0" N to 25°24'0" of the survey of India topographical sheet nos. 63K and 63O on a scale of 1:253,440. The total area considered in the study is 292 km². The city derives its name from its physical location, as the rivers Varuna and Assi bound it from North and South, respectively. The location map of the city is shown in figure 3.1. It has grown over about a stretch of 10 km stretch of crescent-shaped left bank (concave side) at the meander of river Ganga. The area is the North Indian Territory of Uttar Pradesh

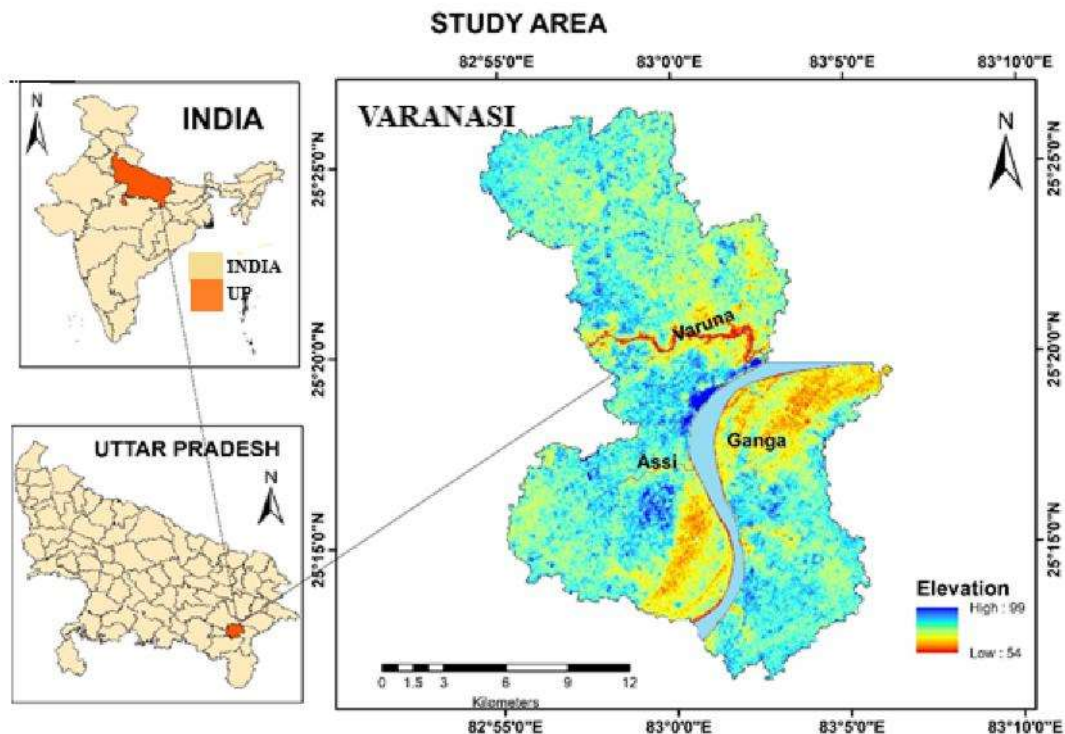


Figure 3.1 Location of study area

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3.1 Landforms

The study area is a part of the broad Gangetic plain having a few conspicuous topographical features. The general slope of the area is from west to east. The maximum elevation as revealed from the benchmarks on the quarter-inch sheet number 63 k and O is 88.68 m above mean sea level in the extreme North-Western part of the area near Surianwan (25°28': 82°25': 63K), and the minimum is 70 1.92 m North of Kaithi (25°30': 83°25': 63O). Several shallow local depressions of a small areal extent are scattered in the area, forming Swamps and lakes. Physiographically, the area could be divided into one-upland plains of older alluvium and second the lowland plains of newer alluvium. These physiographical descriptions and the patterns of cultivation therein are described below.

3.2 Upland plains

The upland plains or older alluvium occupying a significant part of the area do not get inundated, at present during the floods in the rivers. Practically all the plains of older alluvium are under cultivation. Generally, two crops are grown each year, one in the rainy season and the other in the winter.

3.3 Lowland plains (Newer alluvium)

The lowland Plains occur adjacent to the drainage courses of the river Ganga, Gomti, and Varuna and are subjected to flooding during the rainy season each year, when fresh silt and loam are deposited. After the floods, the soil contains so much moisture that the winter crop consisting of wheat, barley, gram, and oilseeds does not require irrigation.

3.4 Rivers

The Principal drainage system of the area is that of the Ganga River, which flows along the southern boundary of the area. The main tributaries of Ganga in the area are Varuna, Gomti, and Karamanasa rivers. The Ganga and the Gomti are perennial, but the Varuna and the Karamanasa are intermittent streams. The Varuna and Gomti meet the Ganga from the North and the Karmanasa rising from the Vindhayan hills joins the Ganga from south .The Varuna river flows through the middle of the district and joins the Ganga at the northern extremity of Varanasi city. Nadwadi, a distributary of the Gomti, flows from west to east in the Northern part of the district. The rivers Ganga, Varuna, and Gomti drain the unconfined groundwater occurring in upper part of the alluvium.

3.5 Lakes and Swamps

There are many depressions in the area in which water collects during the rainy season, but does not find any definite outlet and hence remains impounded throughout or during a part of the year. These natural depressions form lakes and swamps. The lakes could further be classified as perennial and ephemeral. The bottom of the perennial lakes extend to the zone of saturation and receive groundwater seepage after the rainy season.

3.6 Climate

The climate in the area is tropical. Its atmospheric condition is categorized as tropical and subtropical, characterized by blistering summer and extreme winter. Usually, the climatic condition of the area is dry. The year could be divided into three

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seasons: winter, summer, and rainy. Winter starts in the middle of October and continues until February. The temperature during the period is comparatively low, and there is little rainfall. The summer follows the winter and continues till the middle of June, making days hotter. The rainy season, which lasts from June until the middle of October, follows the summer. The warmest months are May and June. Residue wind and sweltering waves are regular in summers. The most extreme temperature in winter is 23.4⁰ Celsius, and the base is 9.5⁰Celsius. December and January are the most cooling months. The zone is under the grip of a cold wave by the cleaning cold Breeze of the northern Himalayas. In late spring, the ideal temperature is 44.50⁰Celsius, with a base of 22.60⁰ Celsius. The typical, extreme temperature has been seen as 41.5⁰ Celsius during June and at least 9.5⁰ during January. The virtual dampness vary for every month is extreme of 82% in August for the Southwest monsoon period and at least 28% during April. The average monthly relative moisture is 55.75%. The normal yearly precipitation is 1036.00 mm. Almost 90% of the rainfall happens from June to September. The Indian Meteorological Department (IMD) records the rainfall data. It is estimated that 95 percent of the yearly precipitation occurs during the five months between June and October. August is generally the wettest month of the year. The winter rains fall typically in December and January as mentioned in table 3.1. They are utmost importance for agriculture and lesser extent for groundwater recharge and surface storage.

Table 3.1: Details of monthly average rainfall and temperature of the study area

Sl. No.	Month (2011 to 2020)	Rainfall (mm)	Max Temp. (°C)	Min. Temp. (°C)
1	January	16.09	20.80	9.30
2	February	14.35	26.60	12.26
3	March	13.12	33.95	17.23
4	April	13.72	40.02	22.36
5	May	10.40	41.03	26.09
6	June	102.08	39.68	28.23
7	July	278.04	34.67	26.98
8	August	233.29	33.90	26.54
9	September	166.49	34.14	25.62
10	October	32.21	33.09	21.24
11	November	0.89	29.92	15.31
12	December	4.46	24.03	10.32

3.7 Geology

3.7.1 Sequence and general features of the rocks

The area is underlain by alluvial deposit of quaternary age. The older Alluvial of the Ganga Valley forms slightly elevated land surface of the area. This deposit, believed to be Middle to Upper Pleistocene in age, (Krishna, 1961) lies well above the highest flood level of the rivers in the area forests of the newer alluvium generally occupies the lower elevation and is restricted to the flood Plains of the present day rivers along their channels. The sequence lithology and water - bearing character of the rock unit of the Varanasi area are given in Table no.3.2 As far as surface geology is

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concerned, it could be viewed in the perspective of its utilisation in the assurance of the dissemination of groundwater possible extension of rocks of Vindhyan system

Table no 3.2 Generalised Stratigraphical sequence in Varanasi area

Group	System	Series	lithology	Water– bearing Properties
Quaternary	Recent	Newer Alluviums	Sands of the different grades, silt & clay	Coarse sedimentation yields moderate to abundant supplies of water to wells
	Pleistocene	Older Alluviums	Clay, clay with kankar, silt, medium & coarse – grained sands	Coarse sedimentation yields moderate to abundant supplies of water to wells
-----Un-conformity-----				
Possible extension of rocks of Vindhyan System				

3.7.2 Geological History of the area:

The latest phase of geological history of the Varanasi area begins with the formation of fore-deep concurrent with the uplift of Himalayan Mountain system. The fore-deep was gradually filled up in a very complicated geological environments, the details of which are not fully known. The sediments that underlie the Varanasi area to a depth of about 120 meter comprise clay, sands and clay with kankar. The Sands and clays are of alluvial origin. Kankar, however, has been formed by the precipitation of calcium carbonate from groundwater.

Climatic changes during the Pleistocene brought about the formation of ice on the higher elevation of land surface resulting in sea level fluctuation (Fisk 1944a, P68). The lowering of the sea level must have rejuvenated streams which brought about destruction of terraces by the channel scour. During the interglacial period when the glacial ice melted, it carried with it vast quantities of rock debris which were deposited in the Ganga valley. The deposition cycle was completed with the flattening of the river gradient due to rise in sea level resulting in back swamps and natural levee deposit of the Ganga and other tributaries. As established by (Oldham, 1904) four glacial and three interglacial periods existed in the Himalayas and this cycle of erosion and deposition continued during these changing climates.

The Sub-surface distribution of the alluvial deposits shows a thick sequence of sand deposition overlain by clay and at places clay with kankar. The lithological logs of the tube wells at places show that their borings have pierced through the sand and touched the clay bed underlying it. The thickness of the sand bed varies from 18 to 63 meters, the average thickness being 40 meters. The sand is fine to coarse-grained. The sand is encountered at different depths at different places. The depth varies from 6 to 109 meters below land surface. The top clay is thicker in the north than in the south of the Varanasi, the extensive thick deposition of the sand overlain by thick clay tends to indicate that there has been an abrupt change in the sedimentary history of the area after the deposition of the sands. A preliminary study of the sand system obtained from a tube well under construction at places indicate that the sand seems to be different in composition than those being deposited presently by the Ganga River suggesting thereby that they might have been derived from the Peninsular India.

3.7.3 Lower Palaeozoic to Upper Pre-Cambrian Vindhyan System:

The Rocks of Vindhyan system do not crop out within the area of specialization. Their outcrop, however are seen in the area beyond the southern limit of the area.

3.7.4 Quaternary Group

The older alluvium occurs at high land surface and has not been mapped separately from the newer alluvium, which is exposed in narrow belts along the river Ganga, Gomati and Varuna river courses. The back-swamp & the meander-belt deposits have been examined from Strata chart. Some lenticular sands which seem to have been formed by the split channels of the ancestral Ganga River are tapped by different tube wells. The meander belt deposits consist of medium to coarse-grained sand, thin lime cemented sand lenticles and minor amounts of clay sand silt. The back-Swamp deposits consist principally of unconsolidated, and poorly stratified clays. These also include thin lenticular lands of the fine-grained sand. From the geological cross- section, it is evident that there exist a thick clay and kankar bed overlying the water-bearings sand bed. The sand particles of the underlying sand bed that vary in grain size from fine to coarse. This bed contains nodules of kankar at places.

3.7.5 Newer Alluvium

The newer alluvium, which occurs mainly in a narrow belt along the Ganga, Gomti, and Varuna rivers has not been mapped separately during this present study. This consist mainly of fine to medium-grained sand, silt, and a minor amount of clay. The thickness of the newer alluvium in the area is not precisely known but whenever it was examined, its thickness did not exceed 10 meters.

3.8 Properties of water bearing formations in study area

The older alluvium that contains groundwater varies in lithological characters at different depths. Two principal lithological types, i.e. (a) back-swamp clays and (b) meander belt sands, constitute the older alluvium in Varanasi area. These two types are considerably different in their capacity to absorb water at the land surface and to transmit water to the zone of saturation. The back-swamp clays are generally dense & impervious and cover the entire area. These clays are massive and contain Kankar and thin lenses of fine-grained sands because this material is generally too fine grained to transmit water readily, it prevents the downward percolation of water from the land surface and also confines water in the underlying meander-belt sand deposits. The meander belt deposit, consisting of medium to coarse-grained sands and underlying the back swamp clays, are moderately to highly permeable. These deposits constitute a ground water reservoir from which very large sample of water can be recovered perennially for the irrigation, Municipal and industrial purposes. The water yielding capability of the Meander-belt deposit varies greatly depending on the texture and thickness of the deposit. The deep bore well satisfies household and water supply needs because of the high yield of 750 to 3500 litres per minute at an average ground depth of 100 metres. The groundwater in the unconsolidated deposits of the older alluvium in the area comprises a shallow groundwater body which occur principally in clay and kankar, beds of back swamp deposits and a deep or main groundwater body which occurs in the thick end of the meander-belt deposits. These two water bodies are hydraulically separated, where the back swamp deposits are thick but are likely to be interconnected, where they are comparatively thin. The shallow water is generally unconfined. Its static level is a few metres below ground level, and it delivers water to

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a dug well used for household or irrigation purposes. The deep ground water body, considered to be hydraulically continuous is known to be confined locally. The piezometric surface of the deep body varies and is generally known to be deeper in comparison to the static water level in shallow water body. It supplies water to a large number of tube wells used for irrigation, industrial or public water supplies.

3.8.1 Form and depth to water table to shallow groundwater body.

The lowering of water table from north to south is largely due to the seepage of groundwater in the Ganga and Varuna rivers which maintain their flow below the water table during the dry part of the year .it is obvious that the river Ganga, Varuna and Gomti drain the unconfined groundwater occurring in the upper part of alluvium.

3.8.2 Fluctuations of water level in shallow groundwater body

There is no hydraulic interconnection between the groundwater occurring in the back-swamp deposits and that in the meander -belt deposits. On the other hand, tube wells tapping the water in the back swamp deposits when pumped results into a lowering of water level. To neighbouring dug wells. It is marked fact that the shallow water is generally unconfined. Whereas the deep ground water body is confined. Recharge of groundwater is controlled by lithology and climate of the area.

3.8.3 Fluctuation of piezometric surface in deep groundwater body

The deep groundwater body is tapped by the irrigation tube wells in the area. Depth to water level were measured by the author during the Inventory of these tube wells in 2015-2020.

3.8.4 Discharge of groundwater

Discharge of groundwater from the aquifer of the older alluvium takes place by evaporation and transpiration, effluents seepage and by withdrawals from the wells for irrigation, Industrial, public stock and domestic water supplies. Evaporation and transpiration losses occur principally in those area where the water table is less than 3 meters below land surface .In the Northern parts of the area there exists some patches where, such conditions prevail. A considerable volume of the groundwater is discharged by perennial seepage to the Ganga, Gomti and Varuna. A considerable part of water flowing in the Ganga is interpreted from the groundwater seepage. The river Gomti and Varuna are fed entirely by the groundwater seepage during 8 months dry season of the year. The discharge of water from wells is affected by withdrawal of water from dug wells and tube wells in the area. The dug well generally serve domestic and stock needs, though some are also used for irrigation purposes. As the demand of water for irrigation use has increased, the construction of tube wells was taken up. Some negative impact of groundwater conjunction may be cited as

1. Dehydration of well
2. Domination of water level in rivers and ponds
3. Worsening of water quality
4. Increase siphoning cost and land collapsing.

The tube wells extracting water from the meander-belt sand have yielded adequate supplies , while on the other hands the taking water from the left back swamp deposits are started to give trouble or have already failed.

3.9 Groundwater quality in Varanasi

The chemical quality is a very important factor for considering the economic utilisation of groundwater for irrigation, public water supply and industrial purpose. It is seen that the shallow groundwater body contains alkaline water whose pH ranges from 7.2 to 8.6. The water is hard, its total hardness range between 102 and 1702 ppm. The bicarbonate constituent appears to dominate among the acid radicals and ranges between 159 to 869 ppm. The chloride content in the groundwater is comparatively low and in a majority of cases varies between 5 to 95 ppm. It is observed that the well water having pH values above 8.2 contain carbonate ranging from 5 to 40 ppm. Based on the results of chemical analyses, it is concluded that the groundwater from dug Wells is suitable for irrigation and domestic water supply except locally. The water from well situated in the back swamp deposits consisting predominately of clay and kankar show distinctly higher concentration of dissolved solids which is reflected by the high specific conductance. In the same area, the tube wells which tap the lower sand strata of the 'meander-belt' of Ganga River shows very low specific conductance indicating thereby the groundwater of two distinct horizons. It is likely that the extensive clays have been deposited in the depression in Ramnagar tract under condition of desiccation, thereby increasing the concentration of mineral content in the back swamp deposits. The tube wells in the area generally tap water from the deep ground water body. It is seen that the deep groundwater is hard, low in chloride and alkaline in nature. It differs from shallow groundwater derived from the dug wells.

3.10 Corrosion and incrustation tendencies of groundwater.

The dissolved constituents in groundwater determine its corrosive or incrustation tendencies. The corrosion of the casing and screens of tube wells might be due to the concentration of the acidity or alkalinity of the groundwater. It has been found that the corrosion of steel casing and screens is most rapid in acid waters than in alkaline water. In fact the alkaline water is not so much harmful to casing and screens of tube well then acidic water. The incrustations are the result of the precipitation of dissolved or suspended solids in groundwater around the openings of a screen of tube wells. The precipitation is caused when dissolved gases escape from the water entering the well. The more common incrusting material present in solution are soluble silica and carbonates of calcium, magnesium and iron and those in suspensions are clays and silts.

The groundwater in Varanasi carries a considerable amount of soluble silica and calcium and magnesium bicarbonate in solution. The carbonate are released during the pumping of tube wells due to the reduction of the pressure head and release of carbon dioxide. The failure of tube wells in the Varanasi area might occur due to the development of the incrustation around the slot, closing thereby and slot opening and decreasing the yield of the tube wells. This tendency of incrustation is difficult to stop although it can be overcome to a great extent by reducing the pump rates, increasing the area of screen opening and decreasing the entrance velocity. Periodic acid treatment of the tube wells could also help in cleaning out the calcium carbonate incrustations. The water from the tube wells in Varanasi area is colourless and has no objectionable test. The quality of water suitable for drinking and domestic purposes, varies considerably and depends generally on the locality and individual users. The following

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water quality standard for domestic purpose has been recommended by United State Public Health Services (USPH) in table 3.3

Table 3.3 Desirable limit of water as recommended by USPH

Constituent	Upper limit (ppm)
Lead (Pb)	0.1
Fluoride (F)	1.5
Arsenic (As)	0.05
Selenium (Se)	0.05
Hexavalent Chromium	0.05
Copper (Cu)	3.0
Iron (Fe)& Manganese (Mn) together	0.3
Magnesium	1.25
Zinc	15
Chloride (Cl)	250
Sulphate (SO ₄)	250
Phenol	0.001
Total Solid -Permissible	500
Total Solid -Desirable	1000

The upper limit listed above for the first five constituent are mandatory and other are recommended. The dug well waters are generally used for drinking purposes it is often used for supply of the drinking water to the neighbouring villages. The chemical quality of water generally meets the drinking water standards. It is, however considered advisable to check the bacterial content of drinking water from time to time. The hardness of water is another factor to be considered while using the water for domestic and industrial purposes. The hard water, due to soap consuming capacity and formation of scales in boilers, water heaters, radiators and pipes are generally considered undesirable for such purposes. The water from dug wells in the area as well

as tube wells are considered excessively hard and need to be softened if used for industrial purposes. The domestic use accepts locally where it exceeds the desirable concentration of common chemical constituents.

3.11 Physical character of ground water.

The characteristics determined in standard physical analysis of the water include taste, odour, turbidity, colour and temperature. It is seen that the temperature of water from dug wells and tube wells was recorded. The water from dug wells are generally cooler and it ranges in temperature from 21 degree Celsius to 26 degree Celsius. The water from the tube wells are comparatively warmer ranging in temperature from 26.7 degree Celsius to 28.9 degree Celsius.

The water from the wells in the area is, in general, colourless, odours are generally absent and the test is non objectionable. The tube wells generally yield clean water. A few tube wells which pump very fine-grained sand at the start yield turbid water. The water in such tube wells remains turbid for the same time till the sand settles.

3.12 Age of groundwater in the study area

The Tata Institute of Fundamental Research (TIFR), Mumbai has conducted groundwater dating in Varanasi (in Pathak, 1977). The radioisotopes tritium carbon-14 and silica-32 are used in age estimation procedures. The following is the end result shown in table 3.3.

Table 3.4 Age of Groundwater

Location of Wells	Depth of Well	S-32 age in Year	C-14 age in Year
Banaras	100	2000	-----

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The radiocarbon analysis of the sample of well water from the Shankarpura has given a result of 2500 ± 150 , years. It may be pointed out Varanasi groundwater is existing for 2000 years. It may be further mentioned hence that no bomb produced tritium signal was found in the groundwater of this area. Also, there is no direct recharge of groundwater in this area. Apparently the age of groundwater reflect the time taken to movement by the groundwater from the area of recharge to discharge.

3.13 Dependency on Groundwater in the Area

The city of Varanasi is short of water and present water supply system is not enough to cater to around 50 lac peoples in the city. There is a considerable gap between the recommended norm and the actual water supply. The city obtains a total of 2 70 million liters water from the river Ganga and groundwater source. Yet, every fifth citizen lacks drinking water. The problem is bound to turn worse with the proposed plan to set a new population in a new township nearby. So there is an urgent need to search ground water-bearing horizon. The water intake points from river Ganga are at two levels to suck water from the river and when the water level goes down below, there are two suction points, which quite often happens, the intake system fails to draw more water from the river. This is the reason why there is a dependence on groundwater.

Further the existing intake and supply system being very old and laid out with smaller diameter pipes for a population of approximately 10 lac wherever, the present population about 50 lacs which obstructs the limit for the intake of water. Most of the city surface below which the pipelines are laid comes under built-up area and hence there is no scope to dig up to replace the old pipes. Hence, it is difficult to laid new pipeline in the same built up area, a problem to understand, since it effects the whole

water resource management. Surface pipelines cannot withstand the onslaught of indisciplined public, especially in the part of India, this is the reason why there is no other alternative but to go for ground water supply to compensate the scarcity of drinking water in the area of study.

3.14 Current status of water supply

State government department “Jal Sansthan” is engaged in the supply of drinking water to the people residing in the city of Varanasi. “Jal Sansthan” draws raw water from two sources i.e., river Ganga and groundwater. “Bhadaini Intake works” is pumping a total of $1.25 \times 10^5 \text{ m}^3 \text{ d}^{-1}$ raw water of the river through its six pumps, four each with a capacity of $40 \text{ m}^3 / \text{minute}$ and two each with $30 \text{ m}^3 / \text{minute}$. The pumped raw water is sent to Bhelupur water works situated at about 1.5 km away from the water drawing point, for its chlorination and purification. The treated water is supplied to the inhabitants of the city through a network of pipelines, the total length of which is about 575 km. This water supply system was laid out way back in 1892 by James Princep. Sometimes because of failure of electricity supply the “Bhadaini Intake works” fail to pump water from the river to its full capacity and because of which the problem becomes acute. At a few places, quite often public of the city raise a hue and cry about mix up of water with sewage because of leakage in the pipes. The gastro-enteric diseases and other health hazards support this type of claim.

Along with the river water a total of $1.4 \text{ m}^3 \text{ d}^{-1}$ of groundwater is extracted from 118 deep bore tube wells installed in different location of the city to cater to the growing demand of potable water. ‘Jal Sansthan’ has divided the city area into six Zones. Eleven Zones within the city spread between Ganga and Varuna and five zones in the trans-

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Varuna area (located to the other side of the river Varuna, as a western extension of the city) for the management and distribution of water Supply. The trans-Varuna is dependent entirely on the ground water. With all types of water supply put together, 'Jal Sansthan' provided a total of $2.70 \times 10^5 \text{ m}^3 \text{d}^{-1}$ water with such a capacity of water-supply, each person in the city get 169 L d^{-1} water .That means, about one fifth the population of the city is not supplied with the potable water. The river Ganga is an important source of drinking water in the city, but the level of water is depleting/going down for various reason, Below the intake point 'Jal Sansthan' finds, it very difficult to draw $1.25 \times 10^5 \text{ m}^3 \text{d}^{-1}$ water not only during spring, winter but also during some period of rainy season. What, more there is a problem of pollution concentration. It may be stated that the recharge of ground water is controlled by lithology and climatic condition.

3.15 Field Data

To develop any groundwater numerical model, a large amount accurate data sets are required. Moore (1979) outlined the information needed to conceptualise a groundwater flow model, which is summarised here

- Aquifer Characteristics
- River Network and boundary condition
- Land check
- Topography of area
- Geological formation knowledge and vertical stratification of the aquifer system
- Hydrological parameters of the groundwater aquifer.
- Groundwater table map for the study area.

- The number of layers in the aquifer and their thickness, along with description such as which one is confined and which one is not.
- Hydraulic conductivity (Horizontal as well as vertical) data for the study area.
- Detailed information about the well extraction in the study area.
- Rate of evapotranspiration (E_T) in the study area.
- Recharge and discharge information for the groundwater.

This data collecting needs a thorough understanding of the research topic. To perform this task in a systematic manner, required data has been categorized into two parts. First part is Physical Framework under which topography, geology of the area, aquifer characteristics etc. are included. Second category is the Hydrological Framework which covers, water-related information such as groundwater table elevation, rate of recharge and discharge from the area etc. All the details has been provided in table no 3.5 which will be used in the methodology and for successful implementation of the work. Table 3.6 shows the borehole data record used in the study area to construct fence diagram (Chapter-5, fig: 5.4) which has a use in conceptualisation of model.

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Table 3.5. Details of data collection used in the study area

Data	Location	Period of Record	Organization	Primary Use
Meteorological Data	Varanasi and its adjoining area	1996 to 2020	IMD Pune	Model Input
Satellite Imagery Landsat 5 and 8	Longitude 82°56'0" E to 83°4'0" E and Latitude 25°12'0" N to 25°24'0" N.	June 2004 and November 2015	USGS	For creating LULC map required Model Input
DEM	longitude 82°56'0" E to 83°4'0" E and latitude 25°12'0" N to 25°24'0" N.	Unknown	USGS	Watershed Delineation, Slope
Soil Borehole Data	Uttar Pradesh	Unknown	From Literature Dubey P et. al (2014) Omar et.al (2019)	For defining the Hydrogeology of study area
Pre-monsoon and Post Monsoon Well Data	Varanasi and its adjoining area	1996 to 2014	Water Resources Information System, India - WRIS - Varanasi District Central Ground Water Board (Varanasi)	Model Input
Pre-monsoon and Post Monsoon Well Data	Varanasi and its adjoining area	2015 to 2020	Field Survey	Calibration and Validation
Population of Study Area	Varanasi and its adjoining area	2011	Census of India	Groundwater Abstraction rate
Hydraulic Conductivity	Varanasi and its adjoining area	2015-2020	From Literature Dubey P et. al (2014) Omar et.al (2019)	Model Input

Table 3.6 Aquifer characteristics and their lateral extent for 4 borehole locations.

CENTRAL JAIL		ASSI		MANDUADIH		RAMNAGAR	
Depth (m)	Type	Depth (m)	Type	Depth (m)	Type	Depth (m)	Type
6	surface clay	6	surface clay	6	surface clay	6	surface clay
16	clay	30	kankar clay	15	sandy clay	18	clay
116	kankar clay	45	fine sand	48	clay kankar	54	kankar clay
122	fine sand	63	kankar clay	54	fine sand	73	fine sand
127	fine to med sand	90	fine sand	69	med sand	82	kankar with sand
160	med coarse sand	136	fine to med sand	81	med coarse sand	108	sandy clay
175	fine sand	160	fine sand	110	coarse sand	141	med sand
		166	very fine sand	120	med coarse sand	160	med to fine sand
		172	sandy clay	133	fine sand		
				150	sandy clay		
				153	clay kankar		

The top layer of the study area contains surface clay which varies from 3 m to 6 m in depth. The second layer comprises of fine sands and varies spatially in nature. Pictures were taken during the field survey which is shown in figure 3.2 to figure 3.7 for the years 2015 to 2020. The total no of wells studied was 110, but most of the wells are now either dumped or not being used.

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Figure 3.2 Location of the well in the study area (Dafi Site)



Figure 3.3 Location of the well in the study area (Cant Site)



Figure 3.4 Soil infiltration test in the study area



Figure 3.5 Location of the well in the study area (Vyass Chakki)

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Figure 3.6 Location of the well in the study area (near Varuna)



Figure 3.7 Location of the well in the study area at different locations

3.16 Software's Used

Different software packages were used for obtaining various objectives. The Soil & Water Assessment Tool (SWAT) 10.5 version was used for the sediment yield modelling of the basin also with the help of ArcSWAT 10.5. Ground water modelling software GMS-MODFLOW 10.5 has been used for groundwater modelling and MATLAB (version 2020b) has been used for optimization technique.

3.17 Summary

The Varanasi and adjoining areas have been selected for the modeling of the groundwater and to know the current situation of water level, water budget etc. scenario in the area. The study area consists of five rivers, which enclose it from almost all sides. River Ganga is the major river of the area which converge all the rivers into themselves. To know the actual present condition of the aquifer and groundwater level in the area, field data has been collected for all over the area and earlier period data has been collected from various government offices. However, for the measurement of water level field survey has been done with the help advance technology such as DGPS (Differential Global Positioning System). Detailed analysis has been done for the meteorological data, collected from the IMD, Pune. To know the topographic characteristics of the study area, DEM data have been used, which is downloaded from the USGS website. Analysis of the DEM has been done in the GIS environment using ArcGIS 10.1 software. Ground surface profile, extracted from the DEM, suggested that the general slope of the area is west to east.