A New Approach of Groundwater Resource Development in Indo Gangetic Plain

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Abstract: ***This research paper deals with the groundwater resource development of indo Gangetic plain and gives insight into the new approach of groundwater resource development.***

Keywords: Groundwater, Indogangetic plain, Resource development

1. Introduction

The Indo Gangetic Plain is the vast alluvial formation located at the south of the Himalayas. The State of Uttar Pradesh is located entirely on the Indo-Gangetic Plain. The Agriculture here is sustained by deep silty-loam soils and two desirable sources of fresh and good water: snow-fed rivers from the Himalayas and a huge resource of fresh groundwater. The state faces an increasing problem of rising groundwater levels in areas that are well-served by canals, and falling groundwater levels in the left over areas .Over the past century or more, an extensive irrigation canal system has been constructed, and since the late 1970s, there has been a sound increase in the installation of privately-owned shallow tubewells with diesel pumps, now numbering 3.5 million. There is general concurrence that equal use of surface and groundwater is required to increase the crop production and alleviate groundwater levels. The technology is available in abundance and is economically viable too, yet the implementation is not being supported by the governance arrangements.

The Scientific studies have proved that ample reserve of ground water is available in the areas underlain by Indo - Gangetic and Brahmaputra alluvial plains in the northern and north eastern parts of the country. And coincidently, the ground water developments in these areas are sub-optimal, in spite of the availability of resources, and offers considerable scope for ground water development in future. In addition to the sufficient availability of replenish able ground water resources in the Phreatic zone, there is a vast In-storage ground water resource in the deeper zones i.e. below the zone of ground water fluctuation. Surprisingly the three major States occupying the alluvial plains i.e. Uttar Pradesh, Bihar and West Bengal, has a share of the in storage ground water resources to the tune of 7652 bcm which is more than 70% of the total.

Availability of land in Fragments, lack of knowledge of modern technologies, lack of efficient work force, poor socio-economic status, poor infrastructure facilities, are the reasons for the under-utilization of ground water resources in these areas , in spite of the growing need for enhancing agricultural production. In this context there is an urgent need to explore various befitting options for optimal utilization of these resources.

2. The Study Area

Part of upper Yamuna basin i.e. Muzaffar Nagar between Yamuna and Krishni river. The alluvium that is found in study area consists of: Sand and clay and occasional inter beds of calc concentration (kankar).

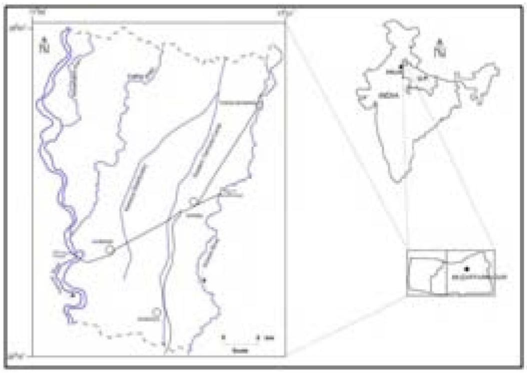

Figure 1: Location of study area

The study area forms a part of the Ganga basin. Morphologically, the Ganga plain is a shallow, asymmetrical depression with a gentle easterly slope. Along the piedmont zone, close to Himalaya, the altitude varies from 280 m in the west to 67 m in the east. Stratigraphically, it is built up of alternate layers of gravel, sand and clays of quaternary age. The Ganga plain exhibits asymmetrical sedimentary wedge, only few tens of meter thick towards peninsular craton and upto 5 km thick near Himalayan orogen (Singh, 2004).

The flexing lithosphere below the Ganga plain shows many inhomogenities in the form of ridges and basement faults (Sastri et al.,1971, Rao, 1973) which are (i) Monghyr-Saharsa Ridge, (ii) East Uttar Pradesh shelf, (iii) Gandak Depression, (iv) Faizabad Ridge, (v) West Uttar Pradesh Shelf, (vi) Kasganj-Tanakpur Spur, (vi) Ram Ganga Depression and (vii) Delhi-Hardwar Ridge. These basement highs and faults have controlled the thickness of the alluvial fill (Bajpai, 1989, Singh, 1996) and have also affected the river channel on the surface. The study area is at the fringe of Delhi-Hardwar Ridge, which represents a north-north eastward extension of the

Delhi folded belt. The western limit of the Ganga basin is delimited by the Delhi-Hardwar Ridge and the oldest sedimentary sequence in the basin, namely, Upper Vindhyans, gradually thin out towards this ridge.

3. Geology of the Area

An extensive sub-surface data down to 450 m bgl have been generated under the Upper Yamuna projects of Central Ground Water Board (C.G.W.B.) with the objective of delineating the various aquifer system and their hydraulic parameters (Bhatnagar et al., 1982). On the basis of correlation of lithologs and electrical logs, four distinct groups of permeable granular zones (sand and gravel) were identified which are separated by three impermeable clay horizons. A map of the Ganga Plain 17 showing sub-surface basement high and thickness of the foreland sediment is published by Singh 2004. This map shows that the study area lies between the contour of 1.5 and 1.0 km (Fig.2). Therefore the probable thickness of alluvium in the area is approximately 1.3 km.

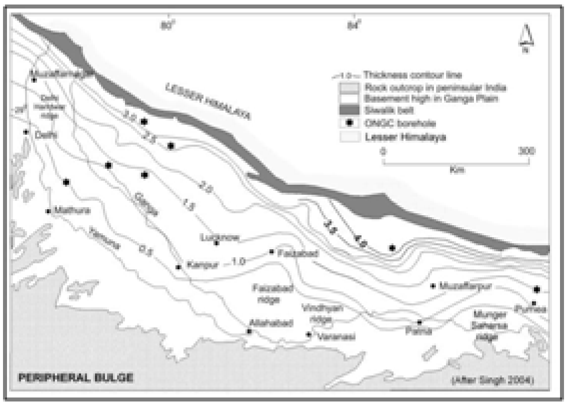

Figure 2: Study Area contour levels

Figure 2 Map of the Ganga Plain showing sub-surface basement high and thickness of the foreland sediment (in kilo meters) Compiled from various sources, namely Agarwal 1977, Karunakaran and RangaRao, 1979 and Singh 2004. Therefore the probable thickness of alluvium in the area is approximately 1.3 km.

The study area is a part of Central Ganga plain. Geologically, the area is underlain by alluvial deposits of Quaternary age, approximately 1000 m in thickness. The alluvium is underlain by Middle Proterozoic Delhi quartzites. The quartzites, in turn, are underlain by Bundelkhand Granitoid (3000 Ma). The alluvium in Krishni-Yamuna interfluve region consists of alternate beds of sand and clay with occasional interbeds of calc-concretion (Kankar).

4. The Aquifer study

Evaluation of Aquifer System is the new approach of groundwater resource development in indo Gangetic plain. The approach adopted for the study is as follows:

- Preparation of base map for field survey
- Collection of rainfall data.
- Preparation of land use and land cover map.
- Water level monitoring through wells.
- Pre and post monsoon water level monitoring.
- Preparation of, water level fluctuation maps.
- Study of water level data, of various water level stations, to determine long term water level trends.

Lithologs of deep tube wells were collected to prepare cross-sections and fence diagram.Sand sample collection and analysis.

The Indian landmass consists of three physiographic domains; the Himalayas, Indo-Gangetic Plain (I.G.P.), and Peninsular Shield. The Indo-Gangetic Plain is a 400800 Km wide, low relief, east west zone between the Himalaya in the north and the Peninsula in the south. It is a sinking basin that came into being about 50 Ma ago due to epiorogenic movements of Himalaya and was subsequently filled up by the sediments deposited by northerly and southerly drainage under the influence of climate changes, mainly from the Middle Miocene (Rowley 1996).

The Indus and Ganges river basins are among the world's largest and most productive ecosystems. Home to three quarters of a billion people; the combined basin area extends over 2.25 million km2 from the mouth of the Ganges to that of the Indus. The basin provides water for the economic base of agriculture, forestry, fisheries, and livestock, as well as the urban and industrial water requirements of about one billion people. More than 90% of total water use is for agriculture, followed by 8% for domestic use (IGB Brochure, 2003). The Indus Ganges plains form the largest consolidated area of irrigated food production on the globe with a net cropped area of 114 million ha. Groundwater development (i.e. the percentage of annual net draft to annual available groundwater resources), has been very rapid in the last two decades with development reaching 77.7% in the Indus and 33.5% in the Ganges part of the combined basin area (Sikka and Gichuki, 2006).

While agricultural technologies and the harnessing of water have proceeded apace, land and water degradation are taking an increasing toll on the basin economy. Future food security in this area, which is the key breadbasket for South Asia, is threatened by a combination of land and water degradation, stagnating productivity, reduced harvested area, and rapidly increasing populations and, concomitantly, food demand .Much of the groundwater use in the basin area is not sustainable.

While past development of tube well irrigation was an important factor in increasing food production and reducing poverty, the basin is now being confronted with major groundwater management challenges: overexploitation of groundwater and declining water tables in the drier Indus and western Ganges part of the basin, water logging and secondary salinization in high intensity irrigation command areas, and rapidly growing pollution of water resources.

The Indo Gangetic Basin, though blessed with a vast network of dams, canals, and strong irrigation bureaucracy, has lost its historical supremacy of the surface irrigation systems to the more informal, demand based and equitable groundwater irrigation.

Most canal commands in the region are shrinking with groundwater taking over the critical role of irrigation provisioning. In large parts of the Indo Gangetic Basin finding a farmer who either does not have his own pump or does not purchase water from his neighbouring pump owner may be a difficult task (Shah, 2006). The present size of the groundwater economy in the region is substantial, and it is groundwater irrigation that largely account for the variations in the value of agricultural output per hectare.

Groundwater irrigation is helping in catalyzing the spread of the green revolution into new areas that were not covered by surface irrigation in the 1970s. Despite this, the development, use, sharing and groundwater markets, and the agricultural production and large social benefits produced by the groundwater resource are not uniform and depend heavily upon the prevailing hydrology and socio ecology of the given region/state in the vast basin, albeit with very interesting twists. Understanding sustainable groundwater management in the developing world requires blending of three distinct perspectives: (a) the resource, (b) the user, and (c) the institutional.

The study area is being famous as an intensive agriculture tract of western Uttar Pradesh. Heavy withdrawal of groundwater has set a declining trend of water table over the decade. Few blocks of the basin is reported to be over exploited and some are in semi-critical to critical position. With rise in population and agricultural development, the withdrawal will go at higher scale, which needs especial study in order to ascertain the future behaviour of water table in time and space. The Indo-Gangetic Plains are formed by the periodic deposition of silt brought by rivers abounds in alluvial soil. The alluvial tracks of Ganga-Yamuna inter fluve have got very fertile soil. The study area is characterized by three types of soils viz. (i) Loam (ii) Clay Loam and (iii) Sandy Loam (Survey of India, 2003). The distribution of the three soil types is shown in figure 3.

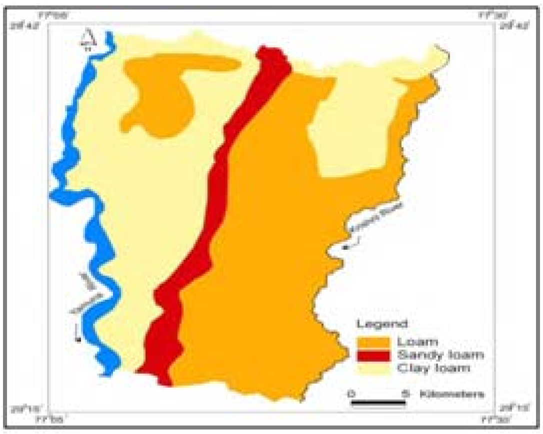

Figure 3: Soil types in study are

5. Aquifer Geometry

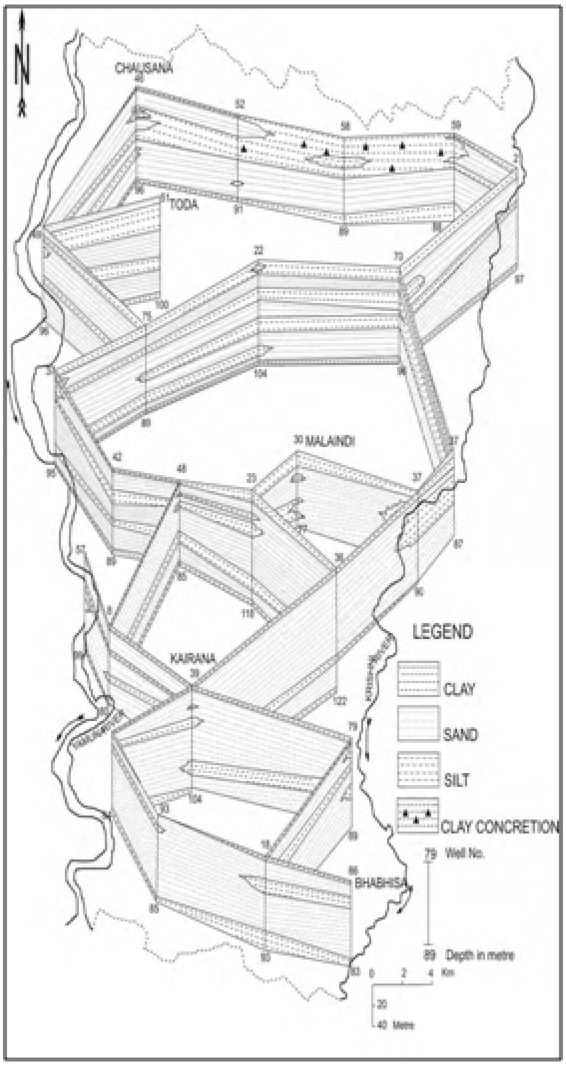

Figure 5: Fence Diagram

A Fence diagram based on lithological logs of borehole (Fig.5) drilled by State Tubewell Department has been prepared. The fence diagram (Fig.5) reveals the vertical and lateral disposition of aquifers, aquiclude and aquitard in the study area down to depth of 122 m bgl. Nature of alluvial sediments is generally complex and there is quick alteration of pervious and impervious layer. The top clay layer is persistent throughout the area varying in thickness from 3 to 20 m bgl. The top clay bed is underlain by granular zone, which extends downward to different depths varying up to 122 m bgl. The granular material is composed of fine, medium to coarse sand. The granular zone is subdivided at places into two to three sub-groups by occurrence of sub-regional clay beds,local clay lenses are also common throughout the area. By and large the aquifer down to 122 m appears to merge with each other and behaves as single bodied aquifer. Granular zone composed of medium to coarse sand and gravel form about 80-90 % of total formation encountered, particularly in south eastern and southern part of the basin.

This area being a down faulted area due to NE-SW Muzaffarnagar fault possibly became a dominant recipient of sand than the area north of the fault. Muzaffarnagar fault is an active transverse E-W running fault, with through to the south side and passing through the Muzaffarnagar city (Bhosle et al., 2007).

In addition to fence diagram three hydrogeological cross section A-B, C-D and E-F (Fig.4) are distributed across the entire area in which two sections run from west to east and the section E-F from North West to south east.

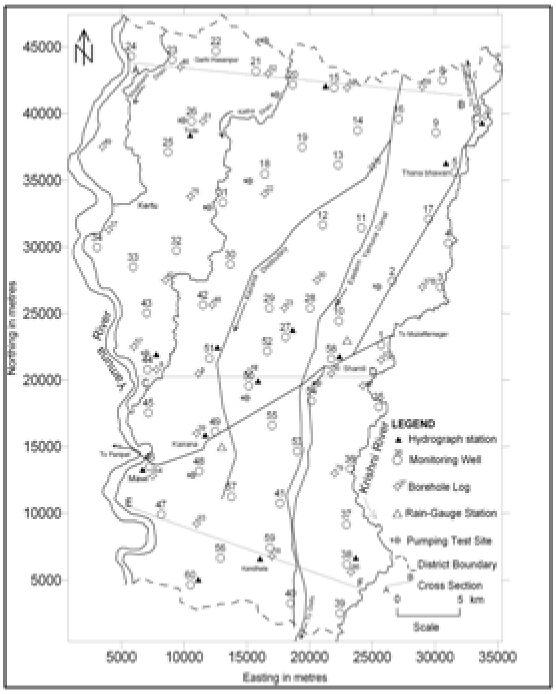

Figure 4: Base map of Yamuna-Krishni sub basin.

6. Sand Percent Map Grain Size Related Aspects

The granular zones encountered down to 100 m have been utilized in preparing the sand percent map (Fig.6, Plate 5). The sand percent map has been prepared on the basis of cumulative thickness of granular zones encountered in the boreholes. The area has been divided in to five sand percent zones viz. (i) <50 (ii) 50-60 (iii) 60-70 (iv) 70-80 (v) >80 percent. The sand percent map reveals that granular zone attain maximum thickness in southern part between Shamli and Kandhala village. The percentage of granular material decreases in the northern part of the area. The fence diagram also shows the same fact. It can also be infer that the variation in sand percent map is more along the course of river Krishni as compared to the river Yamuna. This may be explained by dominance of clay horizons along river Krishni which is also reflected by its highly meandering character.

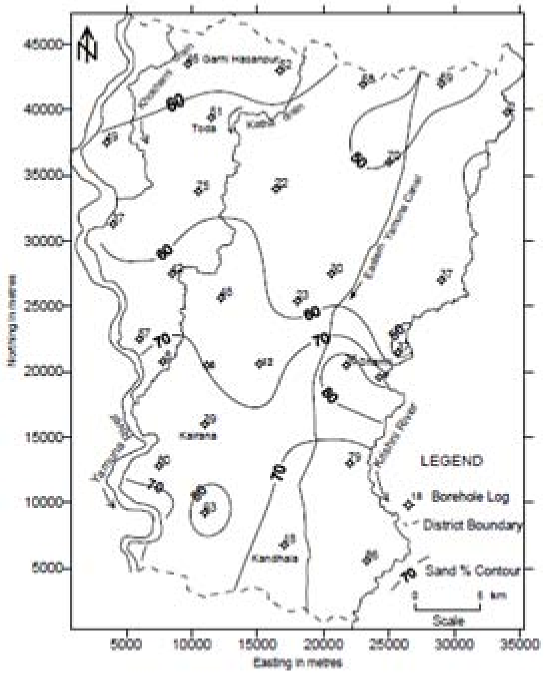

Figure 6: Sand percent map of the study area

7. Grain Size Analysis

The grain size analysis is carried out of aquifer material collected from available drilling sites and calculated the parameters like effective grain size and uniformity coefficient.

Sand sample No.	Location	Depth (m)	Effective grain size (d_{10})	Uniformity coefficient (Cu)	Typical sand type
1	Bhoora	25	0.19	1.36	Fine sand
2	Bhoora	45	0.14	1.78	Fine sand
3	Dulawa	25	0.15	1.66	Fine sand
4	Mundait	30	0.064	2.96	Silt
5	Kandhala	35	0.13	1.84	Fine sand
6	Issapurteel	30	0.15	1.66	Fine sand
7	Sikka	45	0.16	1.56	Fine sand

Figure 7: Grain size Analysis

8. Groundwater level and its variations

Shallowest level in the month of November
Minimum level in June.
Water level monitoring done during this period.
Fluctuation is mostly observed in unconfined aquifer.
Fluctuation depends on:
Pumping influence in the nearby area
River stage
Groundwater movements.

Depth to water level along river Yamuna:

The area is divided in eight water level zones:(i)6-8mbgl(ii)8-10mbgl(iii)10-12m bgl(iv)12-14 m bgl(v)14-16 m bgl(vi)16-18 m bgl(vii)18-20 m bgl(viii)20 m bgl

Average depth of water level

Pre monsoon
Year 2008:5.76-21.96, Year 2009:5.67-21.01, Year 2010:4.62-21.14

Post monsoon
Year 2008:5.16-21.96, Year 2009:5.18-21.02, Year 2010:4.90-21.53

Water table fluctuation

The study area experiences two types of fluctuations:

Positive fluctuation it shows rise in water level during post monsoon. Negative fluctuation shows further decline in post monsoon. Positive and negative groundwater fluctuation would pertain to the conditions where groundwater recharge components exceeds the groundwater discharge and vice versa.

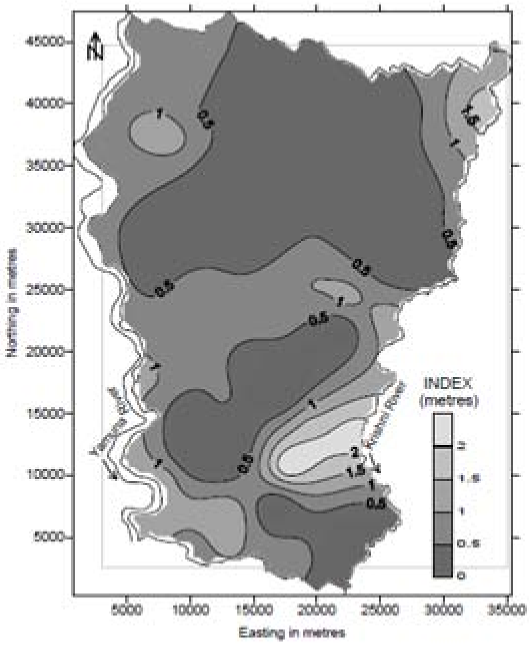

Figure 8: Water level fluctuation Map

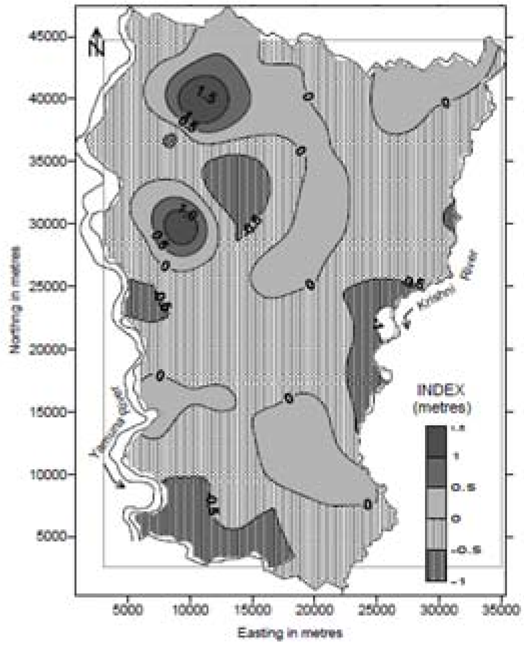

Figure 9: Water table fluctuation map

Water Table Contour Map and Groundwater Movement

Water level data of wells collected were analysed and altitude of water level with reference to the mean sea level were worked out. The reduced level of water with reference to mean sea level was plotted and water table contour map was prepared, with contour interval of one metre.

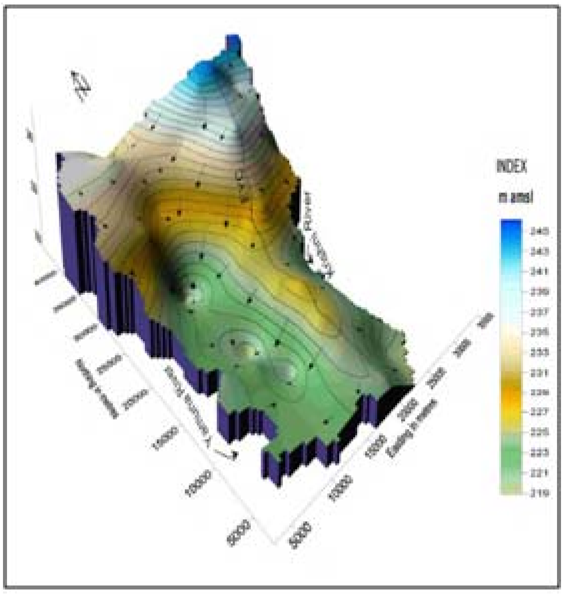

Figure 10: 3-D Water table contour Map

Form and Slope of water level

Contour map shows flow direction NNE –SSW.
Local flow directions were also observed due to local factors.
Eastern Yamuna Canal acts like a groundwater divide almost throughout the area.The hydraulic gradient of canal is 1.25/km.
The track between river Yamuna and EYC occupies greater area

Recharging due to this is not very pronounced restricted only to close proximity of EYC.

Long term behaviour of water level

Biannually water level monitoring was done. The water levels in unconfined aquifers are affected by direct recharge from: Precipitation, Evapo-transpiration, withdrawals from the wells, discharge to streams, sometimes changes in atmospheric pressure. Thus we conclude that the water level has a rising and declining trend with respect to time and a function which causes such rises in water levels i.e. availability of rainfall.

9. Groundwater Availability

Groundwater resources can be classified as static and dynamic. The static resource is the amount of groundwater available in the permeable portion of the aquifer below the zone of water level fluctuation. The dynamic resource is the amount of groundwater available in the zone of water level fluctuation. Sustainable groundwater development requires that only the dynamic resources are tapped. Exploitation of static groundwater resources could be considered during extreme conditions, but only for essential purposes. The static fresh groundwater resource of the Indus and Ganga basin are listed below.

River basin Alluvium/Unconsolidated rocks Hard rock's Total

Indus 1,334.9 3.3 1,338.2 Ganga 7,769.1 65 7,834.1Groundwater resources in the Ganga basin are nearly six times that of the Indus basin.

The Ganga basin falls under 'safe' category on (G.W. development <70%) compared to the Indus basin (overexploited category) based their status of groundwater development. This implies that annual groundwater consumption is more than the annual groundwater available in the Indus basin.

The best yielding aquifers of northern India are the Quaternary alluvial deposits of the Gangetic plain. These constitute a major source of water supply. Good groundwater yields are also found in many of the Tertiary sediments. Groundwater storage in crystalline basement rocks is restricted to the fractures and groundwater yields are determined by fracture density. This can be significant in some areas: groundwater yields of around 10–50 m3/day were reported from dug wells in fractured basement rocks of the Gambhir River Basin of Rajasthan for example (Umar and Absar, 2003).

In the arid regions of northern India, groundwater is often the only source of available drinking water. Overexploitation of aquifers in some areas has resulted in falling water levels. Singh and Singh (2002) reported decreases in groundwater levels of 1–2 m/year in some boreholes. At the same time as a result of irrigation, some canal levels have been rising at a rate of 1 m/year. Experiments in some areas are being conducted to assess the feasibility of aquifer storage and recovery to alleviate the water shortage problem. Ground water exploration in Indo Gangetic plains has shown existence of potential aquifers down to 1000 m. or more. Annual replenishable ground water resources of this region are ~200 BCM which is more than 45% of the country. Besides, it also has vast in storage ground water resources down to the depth of 450 m. Deeper confined aquifers get their recharge from distant recharge zone and have ground water of varying ages. In some of the areas, the deeper aquifers are under auto flow conditions. The quality of ground water in these aquifers is also good. These aquifers can support large scale development through both shallow and deep tubewells. In the states of Punjab and Haryana, the stage of ground water development is very high ranges from 103 to 145 %. The eastern and north eastern parts of the country mainly in the states of Assam, Bihar, West Bengal and UP have huge ground water resources both in unconfined and confined aquifers. The annual replenish able resources of 165 BCM have been assessed in these states. The ground water draft is ~77 BCM and stage of ground water development is ~47 %.