GROUNDWATER BROCHURE OF RUDRAPRAYAG DISTRICT, UTTARAKHAND

1.0 INTRODUCTION

Rudraprayag district which was a part of district Chamoli and Pauri districts before 18 September 1997, was separately created by including Okhimath Tehsil, Jakholi Sub-Tehsil from Tehri district and Bacchansyon and Dhanpur patti of Srinagar Tehsil of Pauri district

Rudraprayag district covering an area of about 2439 sq. km lies between latitude $30^0$19'00" and $30^0$49' North and longitude $78^0$49' and $79^0$21'13" East, falling in surveys of India Toposheet Nos. 53J and 53N. The district is bounded by Uttarkashi in the north, Chamoli in the east, Tehri Garhwal in the west and Pauri Garhwal on the south.

The district with its head quarter at Rudraprayag town comprises of three tehsils viz. Okhimath, Rudraprayag and Jakholi and three development blocks viz. Okhimath, Augustmuni and Jakholi. It is approachable from Rishikesh and Dehradun through motorable metalled road. Rail links are not available in the district. The district has network of roads of 1372 kms which connects its major towns to its head quarter. The only national highway is from Rishikesh to Badrinath, which runs parallel to river Ganga and Alaknanda. The road bifurcates from Rudraprayag and goes up to Gauri Kund all along river Mandakini. Pathways, Katccha road and tracks play an important role in providing movement facility and communication in the difficult hilly terrain of rural area of the district. The administrative map showing drainage of District Rudraprayag is given in Fig. 1.

Agriculture is the main occupation of the people. The agricultural activities are restricted to river terraces, gentle hill slopes and intermontane valleys. The major crops are rice, wheat, maize, jhangora, mandua, potato, pulses, millets and seasonal vegetables etc. The net sown area, in the district, is 114.30 sq. km. and area sown more than once is 191.10 sq. km. The gross sown area is 305.40 sq. km.

The sources of irrigation are springs, gad, gadheras and rivers. The spring water, which, flows through the gads and gadheras, is diverted to small canals and guls by the minor irrigation department. In areas where sources, for minor irrigation, aren’t available

lift irrigation like hydrums are in practice. The total irrigated area, in the district, is 44.13 sq. km. The details of the blocks are given in Table 1.

Table 1. Details of the developmental blocks and tehsils, District Rudraprayag.

Sl. No.	Name Block	Reported Area (km^2)	Name of Tehsil	No. of Villages	No. of Towns
1	Okhimath	504.89	Okhimath	685	1
2	Augustmuni	1274.19	Augustmuni		1
3	Jakholi	575.11	Jakholi		1
Total		**2354.19**			
Forest		**1798.95**			

2.0 CLIMATE AND RAINFALL

The climate varies from Sub-tropical monsoon type (mild inter, hot summer) to tropical upland type (mild winter, dry winter, short warm summer). The northern, northwestern, northeastern and western part of the district is perennially under snow cover, here the climate is sub-arctic type as the area is represented by lofty Himalayan Range. Severe winter and comparatively higher rainfall are the characteristic features of the northern part. The year may be divided into four seasons viz. the cold winter season, (December to February), the hot weather season (March to May), southwest monsoon season (June to September) followed by post monsoon season (October to November).

Larger part of the district is situated on the southern slopes of the outer Himalayas, monsoon currents can penetrate through trenched valleys, the rainfall reaches its maximal in the monsoon season that spans betweens June to September. Rainfall, spatially, is highly variable depending upon the altitude. In the Lesser Himalayan Zone (1000-3000m amsl) maximum rainfall occurs about 70 to 80% in southern half. August is the rainiest month. Rainfall rapidly decreases after September and it is the least in November. About 55 to 65% rainfall occurs in the northern half in Central Himalayan Zone. About 17% of the annual precipitation occurs in winter season. The winter precipitation is in association with the passage of the western disturbances and is mostly in the form of snowfall, particularly at higher elevations. The precipitation during

the pre-monsoon month, which is about 7% of the annual total and the post-monsoon months, is frequently associated with thunderstorms. In the southern part of the district at Rudraprayag the average annual rainfall is around 1220.18mm while in the central part at Chandrapuri the average annual rainfall is 1750.9mm and the rainfall in the northern part at Okhimath is 1995mm.The overall average rainfall in the district is 1485mm.

3.0 GEOMORPHOLOGY AND SOIL TYPE

Geomorphologically Rudraprayag district may be divided into two major Units the high Denudational mountains and the river valleys. Separated from Siwaliks by the Krol thrust (Main Boundary Fault) is the Lesser Himalayas (1500 to 2500 m high). It has a comparatively wide and mature topography with gentle slops and deeply dissected valleys, which suggest that the rivers and streams are still furiously at work. The prominent peaks of this central belt of the Precambrian to Paleozoic sedimentaries and granite-injected metamorphics are Dudhatoli (3114 m east of Pauri) and Nagtibba (3022 m north of Mussoorie). The northern belt of Great Himalayas with its peak soaring 6500 to 7200m high is characterised by precipitous scarps, vertical walled gorgeous valleys and tumbling & foaming rivers. This belt of very youthful topography is tectonically still active and paradoxically is made up of oldest rocks of Himalayas i.e. Precambrian metamorphics and granitic gneisses. Parallel to Himalayan range lies the considerably denuded and rugged terrain of the inner Lesser Himalaya, characterised by many transverse spurs emanating from the Great Himalayan range. Besides, morainous plains, glacial valleys, river terraces, structural valleys, lineament, fault and thrusts are the other geomorphic units commonly observed in the entire Rudraprayag district. The Hydrogeomorphological map, based on interpretation of IRS-IA & Land Sat TM imagery with field check, prepared by Remote Sensing Application Centre, Lucknow is shown in Fig 2.. and the detail of geomorphic units and lithostratigraphy are given in Table -2.

The soils are natural, dynamic, heterogeneous, non-renewable resource, which support plant and animal life. The tract of Rudraprayag district consists of outward succession of ridges viz; Greater Himalaya and Lesser Himalaya of decreasing height. These hills

posses very little level land. The soils have developed from rocks like granite, schist, gneiss, phyllites, shales, slate etc. under cool and moist climate.

Very steep to steep hills and Glacio-fluvial valleys are dominantly occupied with very shallow to moderately shallow excessively drained, sandy-skeletal to loamy-skeletal, neutral to slightly acidic with low available water capacity soils. They have been classified as Lithic/Typic Cryorthents. These soils are in general under sparse vegetation.

The Lesser Himalayan range is mainly composed of highly compressed and altered rocks like granite, phyllites, quartzite etc. and a major part of it is under forest. Intermittent sparse patchy terraced cultivation is also practiced on fairly steep hill slopes whereas dry and wet cultivation are prevalent on the uplands and low-lying valleys respectively. The broader valley slopes dominantly have deep, well drained, fine-loamy, moderately acidic and slightly stony.

4.0 GROUNDWATER SCENARIO

4.1 Geology

Geologically, Rudraprayag district comprises of diverse rock types ranging in age from Palaeoproterozoic to Mesoproterozoic in age. The rock succession exposed in the district mainly falls in two groups namely,

1. The rock sequences exposed between Main Boundary Fault (MBF) and Main Central Thrust (MCT) – Constituting the Lesser Himalaya
2. The rock sequences exposed to the north of Main Central Thrust (MCT) – Constituting the Higher Himalaya

The rock sequences exposed between Main Boundary Fault (MBF) and Main Central Thrust (MCT) in Rudraprayag district are of Mesoproterozoic Period and are exposed at different structural levels and individually occupy very small areas. Regionally metamorphosed rocks, along with granitoids occur as Klippen, over the sedimentary sequence, towards south of Main Central Thrust (MCT) in the district.

The Central or Higher Himalayas in Rudraprayag district consists of metamorphosed rock sequences of Palaeoproterozoic age and are of green schist to amphibolite facies.

The rock sequences of Higher Himalaya and most of the Lesser Himalaya are mainly of **Proterozoic age**. Lithologically these sequences are regionally metamorphosed rocks emplaced by granitoids of various ages and weakly metamorphosed to unmetamorphosed sedimentaries comprising of quartzites with interbedded volcanics, carbonate rocks associated with slate, quartzite and shale. The ages of regionally metamorphosed sequence is not well known and has been inferred by the ages of intrusive granitoids. The generalized Stratigraphic succession of rocks exposed in Rudraprayag district is given in Table 3.

Rocks of Palaeoproterozoic (2500 – 1600 Ma) Period: The metamorphic rocks associated with granites, gneisses and migmatites have been referred as Central Crystallines in the Himalayan Region. Generally, these Crystallines occurs as thrust sheets over metasedimentaries of Lesser Himalaya in varied tectonic setting.

South of Main Central Thrust (MCT), the crystalline rocks occur in two settings – 1) bounded by the Main Central Thrust (MCT) on the north and thrust over the sedimentaries of Garhwal Group and 2) As a Klippe occurring over the rocks of Garhwal Group.

Rocks of Mesoproterozoic (1600 – 1000 Ma) Period: The Period is characterized by extensive development of quartzite with penecontemperaneous volcanic flows and carbonates. The section is well exposed in the inner part of the Lesser Himalayas – the belt bounded by North Almora Thrust in the south and Main Central Thrust in the north. The basal quartzite metavolcanic group is known as Rudraprayag Formation locally in Rudraprayag area and consists of Garhwal Group of Volcanics.

Granitoids of Mesoproterozoic Period: The granitoids of Rudraprayag district occur at different tectonic levels. Granitoids emplaced in the regionally metamorphosed rocks commonly known as Crystallines of Proterozoic age occur as Klippe in the Lesser Himalayan Zone locally known as Volcanics of Garhwal Group. Granitoids also occur associated with volcanic sedimentary sequences, emplaced in the rocks of Garhwal Group such as Chandrapuri Granite of age 1595 Ma (Pandey, 1981).

Table 3. The generalized Stratigraphic succession of rocks exposed in Rudraprayag district is given below.

Age	Formation		Lithology
Mesoproterozoic	GARHWAL GROUP	Basic Volcanics of Garhwal Group	Biotite granite
		Rautgara Formation	Quartzite interbedded with purple green mottled slate and calcareous phyllites
		Intrusive Granitoids of Chandrapuri (Plutonic Igneous Rocks)	Tourmaline biotite granite, microcline, plagioclase and quartz
	Agastmuni Formation		Schist, schistose quartzite and dolomite
Palaeoproterozoic	Bhilangana Formation		Quartzites, schists, granite gneisses, carbonaceous phyllites & metapeltic rocks.
----------MAIN CENTRAL THRUST----------			
Palaeoproterozoic	Central Crystallines		Metamorphosed rocks associated with granites, gneisses and migmatites

Central Crystallines: The Central Crystallines from the basement of Martoli Group and Tethyan Sediments. Central Crystallines probably represent the oldest rocks exposed in Higher Himalaya and thrust over the rocks of Lesser Himalaya along the Main Central Thrust (MCT). These are the metamorphic rocks associated with granites, gneisses and migmatites.

Bhilangana Formation: The Bhilangana Formation is bounded by Main Central Thrust on the north and consists of quartzite schists and granite gneisses. It is thrust over the rocks of Garhwal Group. This formation also includes quartzite, schist, carbonaceous phyllites, limestones and some metapeltic rocks.

Agastmuni Formation: It is the name given to schist, schistose quartzites and thin bands of dolomite exposed in the Mandakini valley. The metamorphosed sequence of orthoquartzite, slates with penecontemperaneous flows has been emplaced by the

Chandrapuri gneisses. Many workers consider the Agastmuni Formation as the base of Garhwal Group.

Rautgara Formation: The Rautgara Formation is well exposed along the Srinagar – Rudraprayag section in the Alaknanda valley. Its the name given to a sequence of massive cream coloured, purplish and brownish fine grained quartzite interbedded with purple green mottled slate and calcareous phyllites exposed in Saryu valley of Pithoragarh district by Valdiya (1962). The Rautgara Formation is best developed and mapped by Gopendra Kumar and Agarwal (1975) in the Alaknanda valley.

Granitoids of Chandrapuri: These intrusive granitoids of plutonic origin are best exposed in Chandrapuri area of Rudraprayag district. The granitoid is mainly of tourmaline biotite granite and is made up of hypidiomorphic granular aggregate of feldspars (microcline and plagioclase) and quartz with subordinate greenish biotite.

Volcanics of Garhwal Group: The granitic intrusive in the Grahwal Group is of Biotite granite type and intrudes the Rautgara Formation towards west of Tilwara. The volcanics are composed of very coarse grained, non-foliated, rich in biotite and generally porphyrytic. They are also exposed in Pokhri area of Rudraprayag district.

4.2 Hydrogeology

Ground water is the prime source of water supply in the district for drinking purpose. Ground water in the major part of the district occurs in localized, disconnected bodies under favourable geological conditions. Thus there is no homogenous aquifer system having wide aerial extent. Ground Water occurs along the thrust plains, strike slip fault/ normal fault plains, tensile joints, synclinal folds, tensile fractures and at the contact of two different rock formations etc. Further it also occurs in solution cavities, channels etc. in the carbonate rocks. In alluvial formation it occurs in the valley fill deposits, terraces, river terraces and glacial valleys, weathered rock cover and in moraines and glacial deposits. On the hill slope ground water mostly occurs in the form of seepages, springs and gadheras under gravity and favourable geological structures intercepting the topography. The occurrence of springs and seepages is controlled by geological structures and physiography of the area. Most of the springs are originating

from higher reaches of the mountains. Two-three springs jointly makes a high discharge gadhera also originating and meeting at higher reaches and flows through contacts of mountains / rocks under gravity. A location map of identified springs and hand pumps is given in fig 3. The discharge and temperature of the springs fluctuate throughout the year depending upon its recharge and discharge factor. During the rains the favourable geological structures get recharged and resulting in higher discharge of spring and gadheras after the monsoons. During the post-monsoon period their discharge reduces gradually with time and it is minimum in pre-monsoon period.

The ground water discharge and its temperature of spring/gadheras located in various litho tectonic zones significantly vary. The maximum discharge in the area through spring is observed in Central Crystalline lithotectonic zone in the rock formations of gneisses and schists of high-grade metamorphic facies. In this lithotectonic zone the discharge varies from 1 to 50 lpm in springs and approximately 30 to 1200 lpm in gadheras / gads. The temperature of ground water generally varies from 17 to 22.5^{0}C in springs. The Tapt Kund spring which is a hot water (46^0 C) sulphur springs located at Gaurikund shows that the water in the spring is coming through deep-seated fractures. Mostly the springs in the area are of gravitational type except the hot spring, which is deep seated and non-gravitational type. The major part of the district is occupied by Central Crystalline lithotectonic unit. In Garhwal lithotectonic unit, the discharge of the springs vary 1 lpm to 18 lpm with temperature ranging between 18^{0}C and 24^{0}C. The springs of this zone are of gravitational type and are of VII to V order of magnitude (after Meinzers Class). In this zone ground water occurs mainly in the secondary structures.

Generally all the cold springs distributed in the different lithotectonic zones are not as deep seated as in the case of hot springs found in the Himalayas. The cold springs are gravitational spring originating from higher altitudes. The meteoric and surface water directly recharge the favourable geological structures controlling the springs. Direct rainfall and snow melt infiltrates through the joints, fissures, fault plains and weathered zones of the rocks and the thin veneer of soil cover. The perennial Rivers and streams also recharge the springs located on the valley side and near streambeds. The potential recharge areas in the hilly terrain are flat ridges, hills,

saddles, spurs, flood plains developed on terraces of major rivers, fault plains, sheared zones along the riverbed etc. The discharge takes places through springs/ gadheras on the hill slops where the structurally weak and saturated zones intercepts the topography. The ground water budgeting in the hilly terrain is not possible due to hilly, rugged topography and hydrogeological discontinuity.

The entire district is having predominantly rural population. The villages are scattered over the hill slopes and valleys. The rural population depends upon the springs, perennial streams and rivers for their domestic and irrigational requirements. The water supply in the villages are inadequate and at several places the sources are far from the inhabitation, which causes great hardship to villagers. However, some efforts are being made by state agencies, local bodies such as Jal Nigam, Swajal Yojna, Gram Sabha to facilitate the water supply by constructing bore wells (shallow tube wells) and installing hand pumps in the district and tapping the source of spring at higher reaches and supply the water in the different villages through gravitational method. In the area where low discharge springs/seepage occur, the water collection tanks are constructed at the higher altitudes and after collecting the water in storage tank it is supplied to the villages at lower altitudes. Many such type of schemes have been made by the state agencies in the district. Based on geology and geomorphology, the hydrogeological map has been prepared and shown in fig. 4. Apart from the springs now Uttarakhand Jal Nigam, Pey Jal Nigam and Jal Sansthan etc. have also started installing hand pumps for fulfilling the need of drinking requirement of rural populace. The discharge of these hand pumps varies from 12 to 18 lpm. The majority of these hand pumps are located along the roadside. Since, most of the rural people are living on hill slopes in scattered manner they are not benefited by these hand pumps. The hand pumps cannot be installed nearer to their hamlets because of the non-approachability of rig machine. Therefore, the ultimate source for water supply is spring in these areas. In the urban area as well as in densely populated villages water is being supplied by lift schemes. In this scheme water is lifted from rivers at lower reaches and pumped to town or villages located at higher altitude directly or through overhead tanks. The drinking water supply is made in rural as well as in urban area of Rudraprayag

district through tapping 275 springs /gadheras and 67 Nos. of hand pumps made by Uttaranchal Jal Sansthan and Uttaranchal Pey Jal Nigam

4.3 Ground Water Resources

Ground water assessment has not been carried out as the ground water abstraction is done mainly through handpumps with almost negligible discharges.

4.4 Ground Water Quality

27 numbers of water samples collected from handpumps and springs and were analyzed complete chemical constituents. The variations of different chemical parameter, in District Rudraprayag, are as given in Table 9.

Table 4. Range of different chemical parameters, District Rudraprayag

Parameter	Hand pumps/ Springs
Electrical Conductivity	60-680 µmohos
pH	7.80 - 8.10
Calcium	8-48 mg/l
Magnesium	2-34 mg/l
Sodium	-
Potassium	-
Bicarbonate	12-195 mg/l
Chloride	7-85 mg/l
Nitrate	Nil-14 mg/l
Fluoride	Nil-1.60 mg/l
Total hardness as $CaCO_3$	30-260 mg/l

Barring few local contaminations the water in the area is suitable for domestic and irrigation requirements. The Fluoride concentration at Usyan gaon is above permissible limit (1.6 mg/l).

4.5 Status of Ground Water Development (Block wise)

Ground water abstraction is mainly done through handpumps with very negligible discharges. There is no large-scale ground water development in Rudraprayag district.

5.0 GROUNDWATER MANAGEMENT STRATEGY

5.1 Ground Water Development

The district Rudraprayag is mainly occupied by Himalayan Mountain ranges. Around 50% of the area is perennially covered under snow. Hence there is no scope of ground water development in this area. However, at lower reaches, there is scope of ground water development through hand pumps. For this, hydrogeological investigation is required at micro level so as to decipher the water bearing rock formations, which has sufficient secondary porosity like joints, fractures, lineaments etc. These discontinuous aquifers along with favourable physiographical set-up can help to develop ground water by hand pumps.

Besides, there are number of natural springs which can be utilized to cater the need for drinking and irrigation. There are numerous springs with sufficient discharge, the water of these springs can be channelized for irrigation. During non-monsoon period, the discharge of springs gets reduced. To augment the discharge and sustainability of these springs, small surface water reservoir can be developed at suitable locations on higher level. The reservoir can be developed by constructing gully plugs, check dams, gabion structures etc. at suitable places. These reservoirs will not only provide surface water availability but will also help in recharging the aquifers.

Ground water may be develop in valleys areas by constructing large diameter dug wells and shallow tube wells. The large diameter dug wells and shallow tube wells will able to sustain the discharges between 250 to 1000lpm.

5.2 Water Conservation and Artificial Recharge

Groundwater, in the area, is mainly developed through handpumps. The area replenishing the handpumps should be identified precisely. Suitable groundwater recharge structures like gullying plugs, checking dams, gabion structures etc. can be constructed so that the yield of the handpump is sustained round the year.

Further, ground water is also developed naturally through springs. It oozes out in the under gravity and favorable geological structures intercepting the topography. Basically *spring* is a localized natural discharge of ground water issuing on the land surface through outlets. The discharge of spring may vary from a trickle to as big as a stream.

Rain water harvesting structures like gully plugs, check dams, gabion structures etc. may be constructed in the nearby vicinity of the springs and nalas having negligible to low discharges.

6.0 GROUNDWATER RELATED ISSUES AND PROBLEMS

The poor availability of Ground Water is the main issue in Rudraprayag district.

7.0 AWARENESS AND TRAINING ACTIVITY

7.1 Water Management Training Programme (WMTP) by CGWB

A Water Management Training Programme on conservation of ground water, Rainwater Harvesting and Artificial Recharge to ground water was organized by CGWB, UR, Dehradun at Chandrapuri, district Rudraprayag. Shri U. D. Chaubey, District Magistrate, Rudraprayag was the Chief Guest on the occassion. The special emphasis was given to the Farmers, engineers, NGO's and local populace working in the area to save ground water from various sources of pollution. The Gram Pradhan and Village Development Officers were especially invited so that they can increase the awareness among villagers on important issues like sustainable development of the depleting spring discharges by adopting methods on conservation of ground water. In order to create impact on (WMTP), an exhibition on different techniques of rainwater harvesting in rural and urban areas was also displayed. During Water Management Training Programme, Smt. Anita Gupta, Regional Director (I/C) addressed on general ground water scenario and management. Dr. R. P. Singh, Sc-D, delivered lecture on various techniques of rainwater harvesting in rural and urban areas and discussed about the significance of such activities, particularly in context of Uttarakhand State. Sh. Pushpraj Singh, STA (Geophysics), elaborated on the techniques of geophysical applications to ground water.

8.0 AREAS NOTIFIED BY CGWA/SGWA

No area has been notified in Rudraprayag district by CGWA. Uttarakhand State does not have State Ground Water Authority.

9.0 RECOMMENDATIONS

On the basis of hydrogeological, geomorphological and geophysical studies, following recommendations are made:

(1) The Rudraprayag district is occupied by Himalayan ranges, therefore large-scale development of ground water is not possible.

(2) Ground water can be developed through Hand pumps and springs in the area occupied by Lesser Himalaya.

(3) Small-scale ground water development can be made in the valleys area having considerable valley fill deposits like Augustmuni, by constructing shallow tube wells and large diameter dug wells.

(4) Small surface water reservoir may be developed at suitable locations so as to increase the recharge of the aquifer and surface water availability

(5) The water of the high discharge springs may be channelized for irrigation at lower altitude.

(6) Due to sufficient rainfall and more number of rainy days, roof top rainwater harvesting in urban as well as rural areas may be promoted to cater the domestic requirement.

Organizing Mass Awareness Programme is required to aware the public regarding harvesting of Rainwater.