ENVIRONMENTAL GEOSCIENCES

Prof. Prasoon Kumar Singh

Department of Environmental Science and Engineering

Indian Institute of Technology (Indian School of Mines), Dhanbad

Lecture-31

Groundwater Provinces of India

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are discussing the module 6. Already we have discussed in lecture 1 the distribution of water on earth. We will discuss the groundwater provinces of India in lecture 2. In this lecture the important concepts will be covered like groundwater provinces of India and the classification of groundwater provinces of India.

So In the first lecture, we have seen about the distribution of the groundwater resources on earth's surface. Now, we will see groundwater provinces of India. India is occupied by many rock types of different ages starting from Archaean to Recent ages and different modes of origin, mineral composition and tectonic features. They are characterized by some sort of similarity in the occurrence of groundwater.

Groundwater has been utilized extensively in India since before the beginning of the Christian era. Currently, groundwater is an important source of supply for domestic, municipal and industrial needs throughout the country and is widely used for irrigation in the Peninsular and Ganges Brahmaputra regions. Dug well, bored well, and drilled wells are the principal means by which groundwater is developed, although locally infiltration tunnels or improved springs are also used. Methods of lifting or pumping water from wells include the hand line and bucket, the hand lift pump, the counterpoised sweep, bullocks and mote, the water wheel, horizontal and vertical centrifugal pumps, and deep well turbine pumps. In modern India, there is increasing use of mechanical pumps.

With respect to the occurrence of groundwater, India can be divided into eight provinces lying in three major regions. The regions are the peninsular region, the first one, the Ganges Brahmaputra region, second, and third is the Himalayan region. Now, the peninsular region, it contains six groundwater provinces. Precambrian igneous, metamorphic and indurated sedimentary rocks and early tertiary volcanic rocks in three

of these provinces yield many small supplies of water, which generally is of good quality, but locally is brackish or salty. It is brackish or salty.

The Ganges Brahmaputra region, the second one, is a single groundwater province in which many tens of thousands of small water supplies and several thousand large supplies are obtained from water-bearing sands and gravels of late Tertiary and Quaternary alluvium. This province constitutes a vast groundwater reservoir which is most productive in India. The third one is the Himalayan region. Himalayan region also is considered as a single province in which groundwater occurs in a series of narrow valleys filled with moderately to highly permeable quaternary alluvium. So these are according to the occurrence of groundwater. Three different regions have been identified.

Peninsular, Ganges Brahmaputra and the Himalayan region. Now classification of groundwater provinces of India. We will see with respect to the mode of occurrence of groundwater. India can be divided into eight groundwater provinces lying in three major regions. What we have seen in the previous slides.

The Precambrian Crystalline, the first one. Then the Precambrian Sedimentary. Then the Gondwana Sedimentary. Then the Deccan Trap. Then Cenozoic sedimentary, Cenozoic fault basin, then Indo-gangetic alluvial, and the Himalayan highland.

So, these are the eight groundwater provinces in India. Now, in the map also, you can see here the different Precambrian crystalline, then Precambrian sedimentary, Gondwana sedimentary, Deccan trap, Cenozoic sedimentary, Cenozoic fault basin, Great Plains alluvial, and Himalayan. All the different. Your provinces have been marked here. You can see here. First one is the Precambrian crystalline. Second, the Precambrian Sedimentary.

Then the third is the Gondwana Sedimentary. Fourth is the Deccan Traps. Fifth is the Cenozoic Sedimentary. Sixth is Cenozoic Fault Basin. Seventh is the Great Plains Alluvial.

And eighth is the Himalayan region. So these are the different provinces in India as per the groundwater availability. Now first, Precambrian Crystalline Province. The Precambrian Crystalline Province occupying half the area of India and extends discontinuously, Kanyakumari in the south to the Delhi in the north. This province is underlain by igneous and metamorphic rocks of the Precambrian Age, chiefly granite, gneiss, schist, slate, quartzite and the marble or variants of these.

Groundwater occurs in the weathered and jointed parts of these rocks, generally within 250 feet of the land surface. The granite, gneiss and schist are commonly weathered to the depths of as much as 100 feet under the tropical climate conditions prevailing in the central and southern parts of the peninsular regions and to the depths of 60 feet or more in the semi-arid northwestern part of the region. The weathered mantle of the de-integrated rock or grass is a large but not especially permeable groundwater reservoir. So this is about the Precambrian Crystalline Province. The yields of wells in the precambrian crystalline belt, depend on the well diameter, the depth of penetration in the saturated gruss, and the thickness and permeability of the saturated mantle.

In Central and Southern India, In Central and Southern India, thousands of dug wells tap water in the gruss at the depths of 25 to 100 feet below the land surface. Many of the wells used for irrigation are as much as 60 feet across and are capable of sustained yields of 1 lakh gallons a day or more. On the average, however, dug wells less than ten feet in diameter have sustained yields ranging from about 10000 to 15000 gallons per day. In northwestern India, most dug wells tapping water in gruss are less than 25 feet in diameter and are less than 80 feet deep and most have individual sustenance of 5000 to 15000 gallons per day. Generally, the water in the gruss mantle of central and southern India contains less than thousand parts per million of dissolved solids.

Locally, however, the water may be brackish or even slightly salty. On the other hand, water in the gruss of northwestern India commonly contains three thousand parts per million or more of dissolved solids. Now second province is the Precambrian sedimentary basin. This province comprises of Limestone, Shale, Sandstone and Quartzites and the local conglomerate belonging to middle or late Precambrian to early Paleozoic age. This province is found in Cuddapah Basin, Raipur Basin, Vindhyan Basin, Western Rajasthan Basin.

Owing to compaction and cementation after deposition, the primary openings in these sedimentary rocks have largely disappeared. Groundwater occurrence is largely limited to 150 meter. Yield characters ranges from 5 to 200 cubic meter per day for small drawdown. The shales are relatively impervious. Moreover, systems of solution passages do not appear to have developed to an important extent in the limestone of any of the Precambrian sedimentary basins. Thus, groundwater circulation through these rocks is apparently concentrated along the bedding planes and in joints or other secondary fractures, chiefly in limestones and sandstones and locally in the conglomerates.

Groundwater circulates to a depth of about 500 feet or more in the Precambrian sedimentary basin of western Rajasthan in northwestern India and to the depths of at least 300 feet in the Raipur basin of central India and the Kuddapah basin of southern India. Many hundreds of water supplies are obtained from dug wells, commonly 50 to 400 feet deep in the basin of Western Rajasthan, 10 to 100 feet deep in the Vindhyan basin of North Central India and 10 to 200 feet deep in the Raipur and Cuddapah basins. The individual yields of most wells in sandstone and limestones in these basins are about 1000 to 40000 gallons per day, averaging about 15000 gallons per day. In the basin of Western Rajasthan, the dissolved solids content of the water is generally more than 2000 parts per million and locally more than 5000 parts per million. In the other three basins, the water is hard but generally contains less than thousand parts per million of dissolved solids.

Next is the Gondwana sedimentary province. The Gondwana sedimentary province comprises more than a dozen of different asymmetrical fault troughs, grabens, structural basins, or folded belts. This province occurring as disconnected patches, mainly fluviatile or lacustrine sediments of sandstone, shale, and with little amount of limestone. The rocks all belong to the Gondwana system which ranges in age from the late Carboniferous to early Cretaceous and which is divided into a lower and upper unit by a stratigraphic break in the early Triassic. Water table generally lies within 30 meter. Dug wells in productive sandstone yielded maximum water.

Total thickness of the formations range from 6 to 7 kilometers. These rock formations are classified into lower and upper formations. The lower Gondwana rocks occur principally in fault troughs or grabens and structural basins in the central and east central parts of the peninsular region. Shales, which predominate in the Talchir series of lower Gondwana are generally compact and relatively impermeable. On the other hand, the sandstone members of the Damuda series are more permeable and constitute important aquifers where they are present.

For example, in the Jharia, Raniganj and Bokaro basins of East Central India, water-bearing sandstones of the Damuda series are interbedded with coal seams and necessitate extensive dewatering operations in many mines, several of which are reported to pump a million gallons of water a day or more. Elsewhere in these and other basins, many dug wells, generally less than 100 feet deep, yield individually as much as 1 lakh gallons a day from water-bearing sandstone and wells dried a few hundred feet deep so as to tap more than one saturated stratum of sandstone may yield individually 250000 gallons per

day or more. The water in the lower Gundwana sandstone is moderately hard but generally contains less than 1000 parts per million of total solids. Locally, the water contains considerable iron. Where coal seams are present, the water may contain hydrogen sulphide.

The upper Gondwana rocks occur in structural basins or folded belts, principally in the central, western and northwestern parts of the peninsular region. Friable sandstones in the uppermost part of the Gondwana system generally are moderately permeable. Such sandstones, when remain present in the zone of saturation, then these constitute the most productive aquifers in the Gondwana sedimentary province. For example, several wells 200 to 300 feet deep in sandstones of the Jabalpur series near Jabalpur in central India have individual sustained yields of 300 to 600 gallons per minute. In the state of Kutch in western India, water-bearing sandstones in the Bhuj series of uppermost Gunwana are tapped by 7000 dug or combination dug and bored irrigation wells.

These range from about 20 to 300 feet in depth and most of them are capable of sustained individual yields of 100 to 600 gallons per minute. The water from Bhuj sandstones in Kutch region generally is remaining very hard and commonly contains 500 to 2000 parts per million of dissolved solids. Locally, however, the water is brackish or salty. Next province is the Deccan Trap province. The Deccan Trap province comprises an area of more than two lakh square miles in Central and Western India.

This province is underlain by a series of basaltic lava flows that range in age from late Cretaceous to Eocene age and whose accumulated thickness is from a few tens of feet to a few thousand of feet. The flows are generally flat-lying or gently warped, but in places they are folded or faulted. Throughout the Deccan Trap province, water occurs in the weathered and jointed parts of the rock and in openings between the lava flows. However, in contrast to the plateau lavas in other parts of the world, deep circulation of groundwater does not appear to take place to any important extent in the flows of the Deccan Trap. A large number of borings have been put down to depths of 500 to 2000 feet in different parts of the province, and most of these have been encountered little or no water below the depths of about 150 feet.

The weathered basalt, locally called mooram, and joints and openings between the flows, all enlarged by weathering, collectively constitute the most important groundwater reservoir in the province. From this reservoir, many thousands of wells dug to the depths ranging from a few feet to hundred feet derive individual sustained yields of five

thousands to twenty five thousands gallons per day, averaging about fifteen thousand gallons per day. The water is generally hard, but otherwise of good quality. The content of dissolved solid is generally less than one thousand parts per million. Next province is the Cenozoic Sedimentary Province.

The Cenozoic Sedimentary Province comprises of three narrow coastal plains of Kerala and Tamilnadu coasts, a coastal fringes on the Saurashtra and Kutch Peninsulas, an extensive embayment in the western India and forth a belt of strongly folded rocks in eastern India. These areas are all underlain by semi-consolidated conglomerates, sandstones and shales ranging in age from late Cretaceous to late Tertiary. The shales throughout the province are generally impervious and yield little or no water to wells. On the other hand, the conglomerates and sandstones were well sorted, poorly cemented and relatively undisturbed by folding or faulting, are moderately or even highly permeable. Where such rocks are present in the zone of saturation, they form aquifers that sustain moderate to large withdrawals from wells.

In the plains of Kerala and Tamil Nadu coast, seaward-dipping Miocene and Pliocene strata contain several water-bearing sandstones and conglomerates at depths ranging from fifty to five hundred feet below the land surface. Drilled wells tapping these beds yield ten to five hundred gallons per minute. The individual yields depending on such factors as the well diameter, the screen length and the number and thickness of aquifers penetrated. The water is commonly remain in confined condition that is confined under artesian pressure. For example, on the Tamilnadu coast, there are one fifty or more wells that flow at the rates of fifty to five hundred gallons a minute.

The water is low in dissolved solids but contains considerable iron and hydrogen sulfide. Similarly, wells two hundred to four hundred deep on the barrier beaches of the Kerala coast commonly flow at the rates of ten to fifty gallons per minute. In the coastal fringes of Saurashtra and Kutch Peninsulas, where the Miocene and Pliocene sandstones and conglomerates are slightly cemented and poorly sorted, they form aquifers of relatively low productivity. Dug in these rocks to depths of twenty five to seventy five feet commonly have individual yields averaging about fifteen thousands gallons per day. The water is generally brackish or even salty, the dissolved solids contain ranging from two thousand to more than five thousand parts per million.

In the parts of tertiary embayment of western India where the sandstones and conglomerates are unconsolidated and fairly well sorted, they form productive aquifers in

the zone of saturation. For example, in Gujarat, there are two or more soft sandstone aquifers at depths between 200 to 700 feet below the land surface that are intercalated with the clay sills. Several tens of these wells in the western Gujarat have artesian heads of 5 to about 25 feet above the land surface and flow at the rates of 50 to 250 gallons per minute. Most of the other wells, which do not flow, yield 200 to 500 gallons per minute when pumped. The water has a dissolved solids content of about 1000 to 2500 parts per million. In the northern part of embayment near Bikaner, soft sandstones and conglomerates of probable eocene age are trapped by dug and bored wells at the depth of about 325 to 450 feet below the land surface.

The individual sustained drafts from these wells, ranged from about 25 to 250 gallons per minute, the dissolved solids content of the water is generally 1000 to 2000 parts per million. The folded sandstone of tertiary age in eastern India generally are poorly sorted and have lost much of their original permeability by the cementation. They are not extensively developed by wells for water supplies, but they give rise to numerous springs of moderate flow in the hilly tracts of the Indo-Burmese frontier. The water is generally of good quality. Next province is the Cenozoic Fault Basin.

This province comprises three discrete fault basins. First one is the Narmada, second the Purana and the third is the Tapti Valleys, each of which contains an extensive fill of unconsolidated quaternary alluvium. The Narmada alluvial fill apparently lies in a rift valley or graben, but the Purana and Tapti fills occur in asymmetric basins formed by simple tilted fault blocks. In each of these valleys, water occurs primarily in lenses of sand and gravel intercalated with silt and clay of the alluvium. Recent exploratory drilling in the Narmada Valley has shown that the alluvium ranges in thickness from a few tens of feet to as much as 500 feet and that it is highly variable from place to place in texture and sorting. Relatively impermeable clay and silt constitutes considerably more than half the bulk of the alluvium in large parts of the valley.

However, in a number of areas, lenses of well-sorted water bearing sand and gravel, a few feet to few scores of feet thick, are intercalated with clay and silt. These sand and gravel lenses from aquifers, which can yield 300 to 600 gallons per minute to individual wells. The dissolved solid-content of the water generally ranges from about 100 to 500 parts per million. The evidence of the existing shallow wells and the geology of the Purana Valley indicate that the alluvium ranges from a feather edge on the south side of the valley to a probable maximum thickness of 500 feet or more near the north side. The alluvium is predominantly fine-textured sand, silt, and clay in the central and southern

parts of the valley, but in the northern parts of these materials are interlocked with the lenses of coarse sand and gravel, which are generally saturated and form moderately productive aquifers. The groundwater in the central and southern parts of the Purana Valley is commonly salty and unfit for many purposes, but in the northern part of the water is of good quality and generally contains less than 500 parts per million of total solids.

The alluvial fill of Tapti Valley is less than 250 feet thick at most places and is deeply dissected by Tapti River and its tributaries along the southern side of the valley. These are, however, several score irrigation wells of combined dug and bored construction that tap water-bearing sands and gravels intercalated with silts and clays in the Tapti alluvium. These wells generally range in depth from hundred to 200 feet and yield 100 to 250 gallons per minute. The water generally contains less than 500 parts per million of dissolved solids in this region. Next province is the Ganga-Brahmaputra alluvial province.

The Ganga's Brahmaputra alluvial province comprises the Ganga plains, the contiguous Brahmaputra valley and the deltaic plains of the Ganga's and Brahmaputra rivers. Most of this lowland is in the great crustal downbuckle or foredeep, between the Himalayan orojen and the Peninsular shield. The foredeep is filled with late tertiary and quaternary alluvium which in places attains a thickness of 2000 feet or more. This alluvial field constitutes a vast groundwater reservoir which is or potentially is the most productive in India. Many tens of thousands of small water supplies of our domestic stock and village use and small-scale irrigation and several thousand large supplies for irrigation projects, for public water supplies and for industrial use are obtained from water-bearing sands and gravels of the Ganges, Brahmaputra, Alluvium.

The groundwater occurs in three distinct physiographic and hydrologic belts, the Bhabbar, the Terai and the Axial. The bhabbar comprises the higher parts of the compound alluvial fans of streams issuing from the Himalayan highland and forms a belt some 6 to 8 miles wide along the foot slopes of the Himalayan front. The alluvium of the bhabhar is composed largely of boulderly to pebbly gravel and coarse sand. Groundwater in these deposits is generally unconfined. Along the mountain margin of the bhabhar, the water table is commonly as much as 100 feet or more below the land surface.

But downslope the depth to water progressively decreases to a line of springs where the water table intersects the land surface. This spring line marks the mountainward limit of the Terai. The Terai is a belt some 5 to 10 miles wide parallel to the Bhabbar and

comprises and comprises the lower parts of the alluvial fans. The alluvium of Terai belt is made up of tongues of permeable water-bearing gravel and sand intercalated with relatively impermeable silt and silty clay. Water in strata at depths of less than 100 feet in the Terai is generally unconfined and the water table is ordinarily within ten feet of the land surface.

However, water in the aquifers deeper than 100 feet is generally confined and wells that tap them at depths greater than 200 feet commonly flow at the land surface. The lower slopes of the terai merge imperceptibly with the axial belt which comprises the bulk of the alluvium laid by the larger streams of the Ganges and Brahmaputra systems. The alluvium of the axial belt is composed of intercalated lenses of relatively impervious silt and clay and pervious well-sorted medium to fine-grained sand and some fine gravel. The lenses of sand and gravel in the axial alluvium are water-bearing at depths ranging from near the land surface down to a depth of fifteen hundred feet at Lucknow. Groundwater in the shallow aquifers is unconfined and the water table is commonly 15 to 40 feet below the land surface.

Water in the deeper aquifers is confined or partially confined, but the hydrostatic head is not greatly different in altitude from the water table. The water in the Ganges Brahmaputra alluvium is commonly hard, but generally contains less than 500 parts per million of dissolved solids. In some localities, however, particularly near the margins of the peninsular plateau, the groundwater is brackish or even salty. Most of the wells are screened in water bearing sands between 150 and 500 feet below the land surface. The draft from individual wells is generally from about 300 to 800 gallons per minute.

Next province is the Himalayan Highland province. The Himalayan Highland comprises complex rocks, largely sedimentary, ranging in age from Paleozoic to Cenozoic. These rocks include limestones, sandstones, shale or their metamorphic equivalents, and some intrusives, which are chiefly granite. Most of these rocks have been greatly deformed by thrust faulting and folding in the orogeny of the himalayas. The highland is traversed by deep gorges and narrow valleys some of which are partly filled with the quaternary alluvium.

The consolidated rocks give rise to numerous small but perennial springs which are the chief source of domestic, stock and village water supplies in the region. However, in the lower reaches of the larger valleys, many dug wells used for domestic and stock purposes, for irrigation, and for public supplies tap beds of coarse-grained gravel and sand in the

alluvium at depths generally less than 100 feet. The alluvial fills of the Himalayan valleys also constitute important underflow conduits, which transmit large quantities of water to the groundwater reservoir of the Ganges-Brahmaputra, alluvial province. In most places, the groundwater of the Himalayan province is soft and contains less than 500 parts per million of dissolved solids. So the summary of this lecture is, first we have discussed the groundwater provinces of India.

We have seen that the India is occupied by rock types of different ages, starting from archaean to recent, and the different modes of origin, mineral composition and tectonic features were remaining present. They are characterized by some sort of similarity in the occurrence of groundwater. These areas may be contiguous or may not be grouped into common group of similarity of occurrence and can be called as groundwater provinces where minor difference in the hydrologic and hydraulic properties of the formation is ignored. Secondly, we have discussed the classification of groundwater provinces of India. In which we have seen total 8 different groundwater provinces, the Precambrian Crystalline, the Precambrian Sedimentary, Gondwana Sedimentary, Deccan Trap, Cenozoic Sedimentary, Cenozoic Fault Basin, Indo-Gangetic alluvial and the Himalayan Highland.

And thirdly, we have seen the map also in which the different eight groundwater provinces have been mapped. Thank you very much to all.