Bhu-Jal NEWS

Quarterly Journal

Volume 25, No. 1&2
Jan.-June, 2010
ISSN 0970-5775

Silver Jubilee Publication

Special Issue on Transboundary Aquifer System

CENTRAL GROUND WATER BOARD
MINISTRY OF WATER RESOURCES

भू-जल न्यूज़

Quarterly Journal of Central Ground Water Board
Ministry of Water Resources
Government of India

The Statement and opinions expressed by authors in this Journal are not necessarily those of the Government.

Published by **Chairman**, Central Ground Water Board, Ministry of Water Resources, Bhu-Jal Bhawan, NH-IV, Faridabad-121 001 (Haryana).

All Editorial correspondence in future may be addressed to Editor, “Bhu-Jal News”, Central Ground Water Board, Bhujal Bhawan, NH-IV, Faridabad-121 001 (Haryana).

Bhujal News is registered journal with **ISSN No-0970-5775**
E-Mail : tsmsam-cgwb@nic.in

Quarterly Journal *Volume No.25 , Number 1&2, Jan- June 2010*

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Bhu-Jal News - Quarterly Journal of Central Ground Water Board with the objective to disseminate information and highlight various activities and latest technical advances in the field of Ground Water.

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Dr. S. C. Dhiman
Chairnman, CGWB

Profile

Dr Subash Chand Dhiman, has completed his Master degree in Geology from Punjab University, Chandigarh and Ph.D from University of Rajasthan, Jaipur. He has completed PG Diploma in environmental Studies from University of Rajasthan and Photogeology/ remote Sensing application from Indian Institute of Remote Sensing, Dehradun. He joined Central Ground Water Board in 1976 and served CGWB in various capacities. Dr Dhiman has worked in different Hydrogeological environment and served as Regional Director, CGWB in the states of Jammu & Kashmir and Himachal Pradesh before taking the charge of Member, Central Ground Water Board & Member Secretary, Central Ground Water Authority). After completing 34 years of service in various capacities he took over as Chairman, Central Ground Water Board in September 2010.

Dr Dhiman has been associated with various Universities/ Institutes for R&D studies related to Ground Water/ Water related issues including water quality. Dr Dhiman is visiting Professor of Punjab University, Chandigarh. Dr Dhiman is a pioneer worker in the field of ground water exploration and artificial recharge to ground water. His contributions for ground water development and management in Thar desert Rajasthan and Cold Desert of Ladakh Region are highly commended. His work towards scientific source finding for water supplies in Lahul & Spiti district of Himachal Pradesh and Parts of Kargil and Ladakh district of Jammu & Kashmir has been critically acclaimed. Dr Dhiman is widely travelled ground water scientist with versatile experience working in various facets of ground water management. He has attended various Conferences & workshops in India and abroad. He has number of National and International publication to his credit. Dr Dhiman has headed various inter-ministerial committees and member of national committees.

Editorial

Bhujal News has now completed 25 years of its scientific journey of dissemination of Ground water related information. It has now wide coverage of readers with the access through the Website also. To commemorate the silver-jubilee year of the journal we are publishing some of the special issues. First in the series on hand is on Transboundary aquifers systems.

International Association of Hydrogeologists (IAH) and UNESCO's International Hydrological Programme have established the Internationally Shared (transboundary) Aquifer Resource Management (ISARM) Programme to delineate and analyze transboundary aquifer systems and to encourage countries to work cooperatively toward mutually beneficial and sustainable aquifer development. Based on these objectives the present issue of Bhujal News has been compiled on Transboundary aquifer systems.

Seven papers have been compiled on the topic. Dr S.C.Dhiman & Dr Jain, have given through their paper, an overview of Ground Water issues of Transboundary aquifer System of Indian sub-continent. Shri S.Kunar, Shekhar & Mukherji have addressed Transboundary aquifer systems of the World. Shri Sushil Gupta and S.Marwaha have elaborated the issues of Transboundary aquifers in the state of Punjab, India. Dr R.C.Jain has discussed about Global significance of Transboundary aquifers. Shri Manoj Srivastava & O.P.Poonia through their paper,"Trasboundary Aquifers in Rajasthan,Issues & Management" attempted to illustrate ground water scenario around along Rajasthan(India)- Pakistan border areas. Shri Abhijit Ray addressed the Transboundary aquifers with special reference to Indo-Bangladesh Border. Shri G.C.Saha and S.S. Singh emphasised the importance of Transboundary Aquifers in North East India. Finally a special article on 25 Years of Bhujal News, compiled by Dr Shekhar has been included for an overview of journey of this journal.

All efforts have been made to make the present issue more informative. I hope that the findings of the papers in this issue will benefit our readers.

Dr S.K.Jain
Editor

S.C.Dhiman & S.K.Jain, Bhujal News, 25:1&2(2010), 1-6

An overview of Transboundary Aquifers of the Indian Sub-continent

S.C.Dhiman
Chairman, Central Ground Water Board, Faridabad
S.K.Jain
Scientist-D, Central Ground Water Board, Faridabad

INTRODUCTION

Transboundary aquifers are the internationally shared ground water resources across the countries in all parts of the world. India being the largest country of the Indian sub continent has large number of transboundary aquifers. India shares its ground water resources across its international border and at least eight aquifers have been identified as transboundary aquifers in the neighboring countries. The Indian sub-continent is one of the most populated Region and these transboundary aquifers are significant as the water and food securities issues are related to them. Management of transboundary aquifers, particularly extensive and continuous one is required urgently in reference to the retrieving Himalayan glaciers due to climate change.

TRANSBOUNDARY AQUIFERS OF INDIAN SUB-CONTINENT

Transboundary aquifers of the Indian sub-continent are generally shared between India with Nepal, Pakistan, Bangladesh, Bhutan, China & Myanmar (Sharma, 2009), which are as follows

1-Aeolian, Alluvial & Tertiary Sandstone Aquifers(India, Pakistan),
2- Upper Tertiary & Quaternary Alluvial aquifers Bhabhar Terai Aquifer (India, Nepal)
3-Alluvial/Deltaic aquifers(India, Bangladesh),
4-Tertairy Sandstone/Siltstone & Proterozoic (Granite, phyllite, quartzite) aquifers(India, China, Pakistan),
5- Tertiary (Tipam Sandstone)aquifers(India, Bangladesh),
6-Older Alluvium aquifer(India, Bhutan),
7-Sandstone & Siltstone aquifers(India, Myanmar),
8- Proterozoic (Granite-gneiss) aquifers(India, Bangladesh)

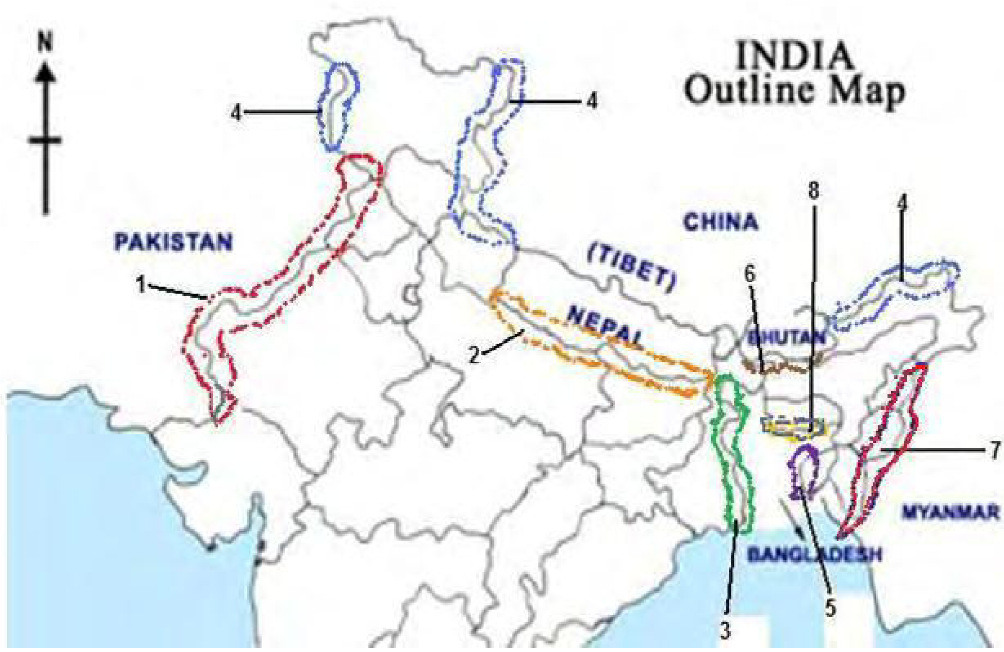

Fig 1 Showing the Transboundry aquifers of Indian subcontinent (after Sharma,2009)

ISSUES OF TRANSBOUNDARY AQUIFERS IN THE INDIAN SUBCONTINENT

There is a need of management plan for Transboundary aquifers in the Indian sub-continent to address various ground water and related issues of concern to the countries involved. Formulation of effective management plan for transboundary aquifer requires detailed information about these aquifers across the borders. The aquifers identified for Indian sub continent have varied geology, geomorphology, climate and groundwater utilization conditions. The common factor controlling these aquifers is the orogeny of the Himalayan Belt.

In the Ganga –Bramhaputra- Meghna and Indus river basin multi aquifer system has been laid down by the Himalayan orogeny. The sediments laid down in the fore deep of the Himalaya is as thick as 5000 meters in Ganga basin. Understanding these complex multi aquifer systems is a Herculian task. In India, so far aquifers have only been explored upto a depth of 750m by Central Ground Water Board (CGWB, 2001). However, aquifer geometry in 3D is yet to be established for aquifers at greater depth. Similarly the aquifer parameters viz transmissivity, hydraulic conductivity, storativity, groundwater flow ,abstraction, quality, vulnerability, pollution and recharge areas are yet to be established. Detailed aquifer mapping would therefore be needed to reveal vital scientific information. Some of the specific issues prevailing in various transboundary aquifers are discussed below:-

Transbounary aquifer of Indo-Pak Border

India shares its international border with Pakistan along the State boundary i.e Gujarat, Rajasthan, Punjab and J&K. Arid climate prevails in Gujarat-Rajasthan international border area which largely controls the hydrological conditions in this area. The alluvial and aeolian sediments constitute phreatic aquifer which is saline in general in this part. The annual Replenishable resource is small due to scanty recharge. The state wise details are as follows:

Gujarat:-. Gujarat State, located in western part of India has international boundary of around 500 km with Pakistan. The district along the Pakistan borders in Gujarat is Kutch. The eastern most 80 km part of the Cori Creek falls in estuarine zone of River Indus. The middle portion of nearly 300 km is part of the Thar Desert, covered by sandy plain in Pakistan and by marshy saline low land of typical salt encrusted Rann in Indian part. Last 120 km stretch, towards Pakistan is underlain by rocky upland with moderately rugged topography, underlain by Quaternary alluvium and Precambrian magmatic rocks; while on the Indian side it is extended parts of Rann in east, consisting of salty marshy land underlain by unconsolidated formations.

In Rann areas the soil is encrusted with salt at the top and there is no scope for fresh quality aquifer at shallow depth. In the adjoining Tharparkar region, (Pakistan) in north, the top soil are loose and porous aeolian sand, which absorbs rain water and percolates down to the ground water to form good quality aquifer at shallow depth. Granite basement are encountered at various depth and have poor to moderate yield prospect. Overall, quality is not good at higher depth. The southern side of the border areas in India has been explored by deep exploration down to 300 m bgl. However, their continuation across the border is remote, as the southern side in India is downthrown portion of Kachchh Tectonic Basin, filled up with argillaceous sediments, as confirmed from exploratory drilling(G.R.M.Rao etal, 1993). The continuation of aquifer system of Precambrian Granites / syenite of Nagarparkar region of Pakistan, across the border in east, below deep & multilayer Quaternary Alluvium is remote, as no basement are encountered in this region of India, upto explored depth of 350 m. Possibilities of ground water flow across the shallow aquifer system from western high land of Tharparkar into Rann of Kachchh is very remote and otherwise, difficult to confirm, as sediments in Indian side are predominated by silty clay formation, and saturated by highly brackish / saline ground water throughout the year.

Rajasthan: The districts along the Pakistan borders in Rajasthan are SriGanga Nagar, Bikaner, Jaisalmer, Barmer. The international boundary of Indo-Pak border along the Rajasthan State is largely occupied by Thar desert. The population of Thar desert is primarily living on limited agriculture products and raising cattle and live stocks, therefore ground water utilization is limited. In general ground water occurs in unconfined to semi-confined condition in alluvium. At places Ground Water occurrs in the Thar desert is in the form of perched water aquifer at the bottom of sand dune zone with fluctuating yield controlled by annual rainfall cycle(Zaigham, 2001). In general ground water in Thar desert is brackish to saline having electrical conductivity(EC) in the range of 5000-15000 microsemens/cm. Few patches of fresh groundwater below phreatic zone have been identified in Jaisalmer –Barmer-Ganganagar district having fossil water. The Indira Gandhi Nahar Pariyojna in Indian side and other canal system prevailing from pre independence in Sindh-Punjab province of Pakistan have brought water from inter basin transfer which has created patches of fresh water aquifer and also created water logging conditions in upper reaches of command area.

Punjab:-The transboundary aquifers of Punjab state, falls in the Indus basin. The districts along the Pakistan borders in Punjab are Pathankot, Gurudaspur, Amritsar, Taran Taran, Firojpur, Fazilka. The slope of the water table is towards west and south-west. The highlands of Punjab and J&K forms major recharge areas . The confined and semi-confined aquifers are having their slope towards west. As a first approximation, ground waters of Punjab are flowing across the international boundary towards Pakistan. There is a need to assess the quantity, quality and flow path of ground water. In the Punjab side of India, groundwater development is significantly high. Ground water resources of Punjab state have been computed as on 31.03.2004, and the Replenishable ground water resources of Punjab state have been assessed to be 23.78 BCM, and the net annual draft of the state has been estimated to be 31.16 BCM. Groundwater in the state contributes more than 70% of irrigation.

Transboundary aquifers of Indo-Bangladesh border:

India and Bangladesh share the Bengal basin aquifer along the West Bengal part of India which is the largest international border with Bangladesh. In the bordering area of West Bengal (India) 96% of groundwater is being used for irrigation. However the main concern is about the large scale geogenic contamination of groundwater due to presence of Arsenic across the border. Since the shallow aquifer in Bengal basin is largely contaminated with Arsenic, therefore the drinking water augmentation is from the deeper confined aquifers. It is essential that the proper protection must be taken across the boundary to protect the deeper aquifer from contamination due to faulty design of well construction. The delta region of Bengal basin aquifer show saline groundwater at top. The Trans-boundary Bengal aquifer system may be broadly classified in to two parts, represented by two large river systems i.e Ganges & Brahmaputra river basins.

Ganges River Basin: The Ganges is the main river along with its tributaries which drains both India and Bangladesh, having its origin in the Himalayas. The districts covered by this basin in West Bengal adjoining to Bangladesh are Maldah, Murshidabad, Nadia, North and South 24 Parganas. In

Indian part, Quaternary aquifer system is represented by Recent alluvium at the top and Older alluvium at further depth except in Barind Tract in Malda and West Dinajpur districts along Old Malda- Gajol -Tapan -Balurghat -Gangarampur - Bansihari sector where older alluvium is exposed at top. In recent alluvium, groundwater occurs under unconfined condition in the near surface aquifer and under semi confined to confined condition in the deeper aquifers. The thickness of the clay bed increases towards south particularly in the coastal zones. In Nadia, Murshidabad (eastern part) districts, absence of significant clay beds down to the depth of 150 m makes entire aquifer system unconfined. However, towards west, as well as towards south fairly thick and regionally extensive clays are present. The depth to water table in the area varies from 2m to 10m bgl in pre-monsoon period and from less than 2m to 5m bgl in post-monsoon period with regional flow of groundwater towards east and southeast and ultimately enters Bangladesh.

The older alluvium consist of well-oxidized, massive argillaceous formation missed with calcareous and ferruginous concretions. Groundwater in Barrind tract occurs under unconfined condition in the near surface aquifer and under semi-confined to confined condition below a blanket of 15 to 20 m thick discontinuous clay bed in the depth span of 90 m to 110 m in most of the places. Water table is moderately deep with moderately high seasonal fluctuation. Depth to water level of the unconfined aquifer varies from 5 m to 10 m bgl in both pre- and post-monsoon period with flow towards southeast.

In adjoining parts of Bangladesh, older, 'Barind' tract of Pleistocene age separates Brahmaputra alluvium from Recent Gangetic alluvium. This recent alluvium of Ganga-Padma-Meghna system covers the rest of Bangladesh. General trend of groundwater flow is from north to south as well as towards the inland major rivers from their vicinity (Khandakar, 2010). The Teesta Fan in Bangladesh bordering India, reflects tectonic uplift, and a southward tilting of the apical fan segment, which developed southward longitudinal hydrologic divide between Tangon and Karatoya rivers system in the country. The average gradient of groundwater level in northern area is 0.65m/km (Khandakar, 2010).

Brahmaputra River Basin: In Indian part, Quaternery aquifer system is represented by the alluviums of 'Terai' which is made up of permeable sand, gravel and some pebbles interfringering with relatively impermeable silt and silty clay, unconformably lying over tertiary Shiwalik Group. Districts covered by this basin in West Bengal adjoining to Bangladesh are Coochbehar, Jalpaiguri, Uttar and Dakshin Dinajpur. The regional flow of groundwater is towards south. In adjoining parts of Bangladesh, major lithological units of the aquifer systems are unconsolidated piedmont alluvial sediments deposited by rivers draining from the foothills of the Himalayas (Khandakar, 2010).

Megahalaya & Tripura :-In the Meghalaya part of India-Bangladesh border, the East Khasi & Jaintiahill districts are having consolidated sedimentary aquifer across the border which have cavernous and fracture porosity and medium to good yield. The Indo-Bangladesh border area of Tripura is broadly occupied by semi-consolidated sedimentary formations .The valley area is having groundwater potential between 10-150 m^3/hr. The Artesian condition are found in pockets across the border and are largely developed.

Transbounary aquifer of Indo-Nepal border :

The Indo-Nepal border aquifer is laid down in the Gangetic plain alluvium running across the border of Uttarakhand, Uttar Pradesh and Bihar States of India. Groundwater development in Uttar Pradesh & Bihar is under safe category . It is largely recharged from the Bhabar zone of the Himalayan foot hills, which is partly in the Nepal. Bhabar zone is generally permeable and unconfined in nature. Coarse sand, gravel, pebble and cobble constitute the Bhabhar zone and consists mostly of reworked sediments from the Siwalik rocks. Terai zone is separated by spring line from Bhabar zone and consists of alternating layers of sand, silt, clay and gravel deposits of varying thickness (Khan & Tater, 2006). The Tarai belt along with Indo-Nepal border is known for its artesian condition especially for auto flowing wells, which forms extensive and prolific aquifers. The auto-flow discharge found along the Bihar-Nepal Border is upto 18 m^3/hr which is significant energy saving features for ground water resources development. It is construed that ground water development in Tarai zone in last few decade has lowered the peizometric head. Thus the Indo-Nepal transboundary aquifer management across the border is important for saving auto flowing condition. In general ground water flow is toward south moving towards India from Nepal border. The Upper Siwalik conglomerate is a potential aquifer unit intermittently found in Siwalik rocks across the border.

Transboundary Aquifers of Indo-China, Indo-Bhutan and Indo- Myanmar Border

Indo-China:The Indo-China international border is running through J&K, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh of India and is conspicuously separated by the Himalayan range. The terrain is extremely difficult and is characterised by high altitude land and valleys. The area is largely occupied by semi-consolidated to consolidated sedimentary and crystalline rocks. At many places, the area is covered with snow and glaciers, which is important for groundwater recharge. Groundwater draft is limited across the border due to scanty population, sloping topography and low yielding aquifers in the area.

Indo-Bhutan:- The Indo-Bhutan border area along Assam is largely covered by alluvial aquifer and is extension of the Bhabar –Tarai zone with moderate to high yield potentials (150-200 m^3/hr).

Indo-Myanmar:-The Indo-Myanmar border is predominantly covered by semi-consolidated Tertiary formations. The area is difficult to approach and is having low ground water yield potential for its development.

SUM UP

Transboundary aquifers are significant for the food and drinking water security in coming future in the Indian sub continent. The broad recommendations for the management of Transboundary aquifers pertaining to the Indian Sub-continents are as follows:-

- The transboundary aquifer systems of Punjab and West Bengal are under stress due to overexploitation and contamination, which need prioritized attention.
- The retrieving glaciers due to the possible impact of climate change can be significant for change in recharge behavior of transboundary Indo-gangetic alluvial aquifers system, which need special emphasis.
- Indo-Pak transboundry aquifer of arid region contained fossil fresh groundwater need protection as precious drinking water resource.
- Proper identification of transboundary aquifer and its characterization has to be ensured.
- There is a need is to assess and quantify the flows as well as study the chemical quality of the water flowing across the countries

REFERENCES

- Khandakar M. A. T. (2010) Setting Stage of Cooperation Between Bangladesh and India for Transboundary Aquifers; Proc. of Transboundary Aquifers: Challenges and New Directions UNESCO-IAH-UNEP Conference, Paris, 6-8 December 2010.
- S.K.Sharma, 2009, Transboundary Aquifer System of Indian Sub-Continent, Technical Papers;Workshop on Transboundary Aquifer Systems by CGWB, MOWR, New Delhi , 23rd March 2009
- Siddhi Pratap Khan and Pratap Singh Tater, 2006, Hydrogeology and Groundwater Resources of Nepal. Workshop on the Role of Environmental Performance Verification for Safe Water in Nepal,(ICIMOD),Kathmandu, Nepal, 30th November and 1st December, 2006
- Nayyer Alam Zaigham, 2002: Strategic Sustainable Development Of Groundwater In Thar Desert Of Pakistan, Sciencevision,Vol.7,No3&4, P 61-74.
- CGWB, 2001, Hydrogeology And Deep Ground Water Exploration In Ganga Basin.
- G Ram Mohan Rao, Arun Kumar & P R Gupte (1993), Hydrogeology of a part of Great Rann of Kachchh, Gujarat, CGWB, WCR Report.

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Subrata.Kunar etal, Bhujal News, 25:1&2(2010), 7-12

International practices for Transboundary Aquifers Resource Management

Subrata Kunar
Member(SAM), Central Ground Water Board, Faridabad
S. Shekhar
Scientist - B, Central Ground Water Board, Faridabad
A. Mukherjee
Asstt. Hydrogeologist, Central Ground Water Board, Faridabad

INTRODUCTION

The recognition of Transboundary aquifers (TBA) as significant global water resource system in international water policy and legislation is gradually establishing. Significant international effort towards recognition of TBA as key factor in environmental and human development was initiated in year 2000, when IAH and UNESCO-IPH jointly adopted the ISARM (International Shared (Transboundary) Aquifer Resource Management) programme. The programme is designed to delineate and analyze TBA systems and to encourage riparian states to work cooperatively toward mutually beneficial and sustainable aquifer development. ISARM is providing aides to sharing nations in the management of their TBA through guidelines and recommendations prepared based on the case studies carried out internationally under the programme. (Puri & Aureli, 2005).

INTERNATIONAL EFFORTS

The first phase of the ISARM programme was dedicated to compiling global inventory of transboundary aquifers that has since been published by UNESCO-IHP. The UN General Assembly (UNGA) adopted the resolution (A/RES/63/124) on the 'Law of Tranboundary Aquifers in December, 2008. UNGA encourages the States concerned to make appropriate bilateral or regional arrangements for the proper management of their Tranboundary aquifers. Around the turn of the century the rapidly expanding exploitation of groundwater for portal, industrial and irrigation uses in both developed and developing countries and of the resulting critical over exploitation and pollution, problems were started showing its impact. Thus the Commission formulated set of 19th draft articles on the law of transboudary aquifers to encourage the States concerned to make appropriate bilateral or regional arrangements for proper management of their transboundary aquifers, taking into account the provisions of the draft articles.

The draft articles are based on the scientific evidence provided by experts and also on ample State practices as well as almost 400 relevant treaties-general regional and bilateral. The States have shown keen interest in the draft articles as aquifers exists in almost all States and the overwhelming majority of them posses transboundary aquifers with their neighboring States.

Draft articles would establish a legal framework for a proper management of transboundary aquifers in order to achieve the objectives of equitable and reasonable utilization of natural resources, protection of the environment and international cooperation .In order to promote studies on TBA under ISARM programme initiatives were taken internationally to identify five key areas for sound management of TBA. These are scientific aspects, Legal aspects, Socio-economic issues, Institutional considerations, and Environmental protection. Studies were initiated in Africa in 2002, American continent in 2003, Balkans in 2004. The scope aims and target group identified for the managing shared aquifers are -

Type of scope	**Aims**	**Target groups**
Scientific Hydrogeologial/ Technical/ Technological	To support the development of National and Regional Management policies and strategies	Regional scientific and research institutions, researchers, policy makers
Environmental	To prevent groundwater Pollution, environmental degradation and loss of biodiversity	Environment scientists, researchers, policy makers
Legal/ political	To ensure endorsement by Governments and international Partners and minimize/prevent conflicts	Government users and
Institutional and socioeconomic	To ensure endorsement , appropriate implementation and sustainability of actions	Policy makers, the public and international Partners

It has been estimated that in the year 2000 almost 40% of the world population, or about 2.3 billion people, were living in water basins with less than 1700m^3/yr/capita, i.e under water stress. This percentage is expected to have reached 50% by the year 2025 (Revenga et al.2000) Intentional shared river catchments effect 40% of the global population and cover about 45% of the total land on Earth and about 90% in South Eastern Europe (World Bank,1987) . Some countries receive almost all their surface water from outside their international borders (e.g. about 98% for Egypt).Transboundary groundwater aquifers resources are also very important in many regions such as North Africa, Middle East and South Eastern Europe.

As per UNESCO – IHP inventory, there are 273 known Transboundary Aquifers which include 68 in Americas, 38 in Africa, 155 in Europe,12 in Asia. The underground aquifers account for 70% water used in European Union. The Irrigation in many countries including India largely depends on ground water resources. UNESCO – IHP has brought out location map of shared aquifers as shown in the Figure-1. Some of the well known examples of Internationally Shared /Transboundary Aquifers are listed in the table-1

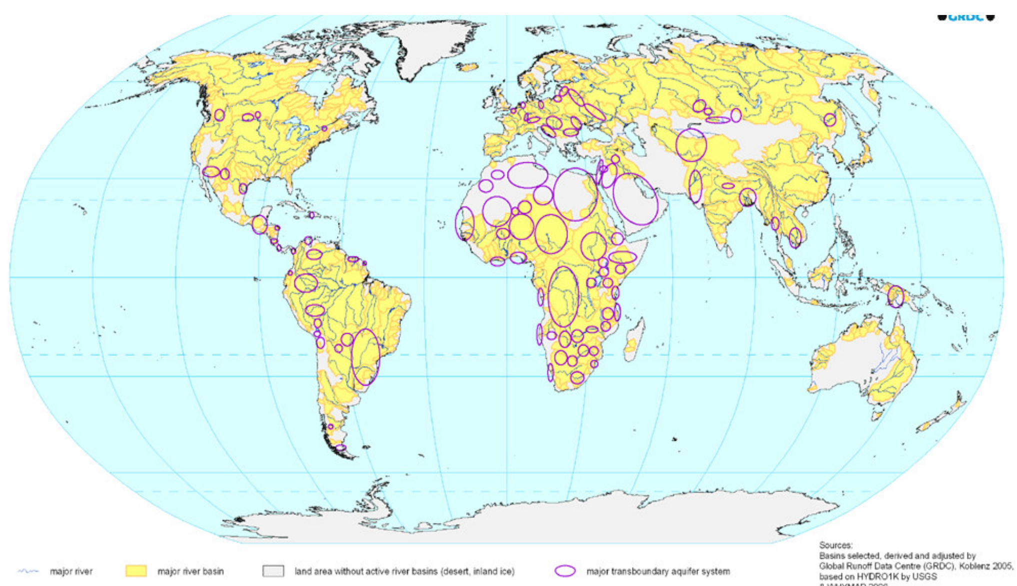

Fig-1. The River Basins and Transboundary Aquifer Systems in world

Name of Aquifers	Aquifer sharing Nations
GUARANI Aquifer	Largest aquifer in the world that extends over 1.2 million sq.km. and is shared by Brazil, Argentina, Paraguay & Urugua
NUBION Sandstone Aquifer	Jointly shared and managed by Chad, Egypt, Libya & Sudan
Kalahari/Karoo Multi-Layered Aquifers	Shared by Botswana, Namibia & South Africa
Mekong River Plain Aquifer	Shared between Thailand, Laos, Cambodia & Vietnam
Ili River Plain Aquifer	Shared between China & Kazakhstan
Himalayan Foot hill Aquifer	Nepal, India

Table 1 - Some of the Internationally Shared/ Transboundary Aquifers

The guideline suggested for development of case studies under ISARM (Puri and Aurile,2005) is as fig2

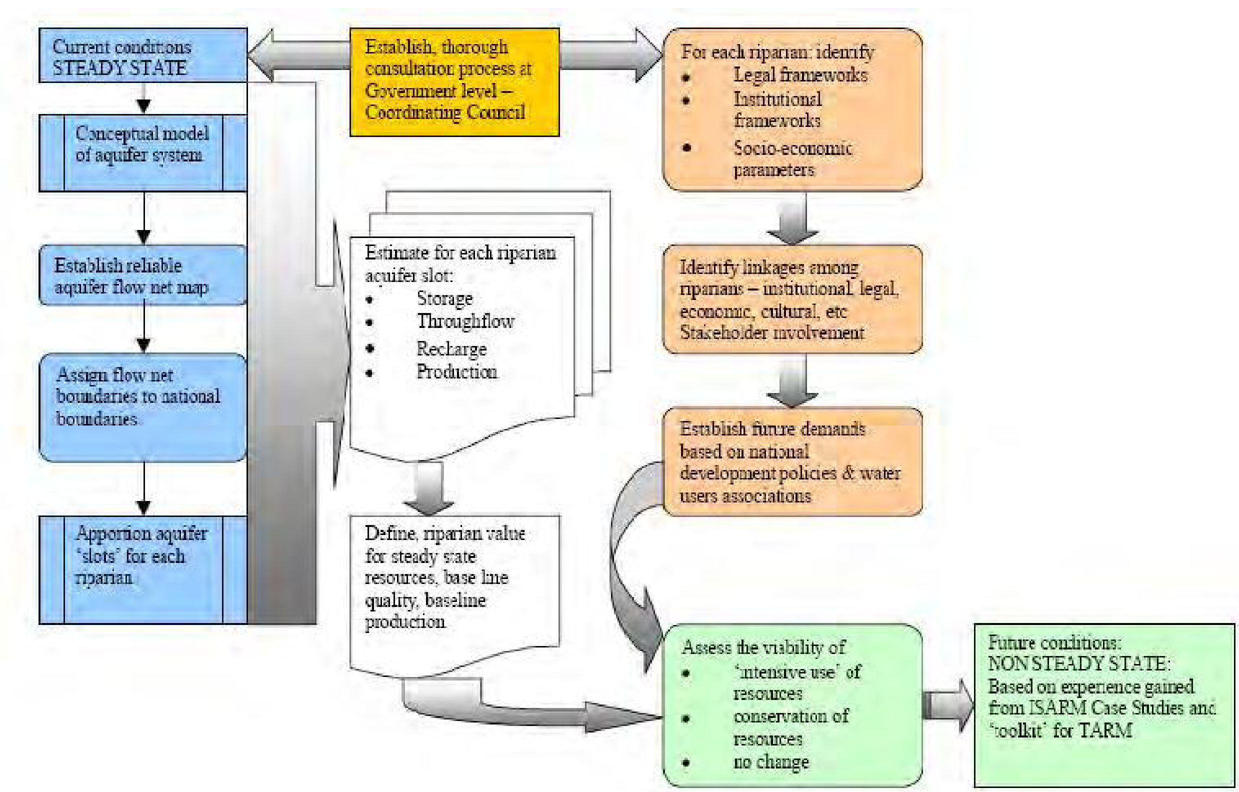

Fig 2 Suggested toolkit for development of case studies under ISARM

INTERNATIONAL CASE STUDIES UNDER ISARM

Under ISRAM the Economic and Social Commission for Western Asia (ESCWA) working for Arabian Plate, comprehensively 'map' shared groundwater system and surface water basins in Western Asia. They have identified about 25 major water basins shared between at least two riparian countries creating hydrological, social and economic interdependencies. ISARM activities in Central & Eastern Asia is a regional initiative aimed at promoting the sustainable use of transboundary aquifers (TBA) in Asia by promoting awareness of transboundary aquifers as vital natural resources, especially among the policymakers. It also enhances international collaboration when it comes to sustainable management of these shared aquifers. Twelve Transboundary Aquifers were identified in Central South and East-Asia.

Eight additional Transboundary Aquifers were identified, which are shared between China and its neighboring countries. Of the identified aquifers, data was collected and demarcations were made. A pilot study was performed for the Transboundary Aquifers shared between China and Russia, in the Middle Heilongjiang-Amur River Basin 65 Transboundary Aquifers (TBA) were identified in the South Eastern European (SEE) region in the inventory (Fig 3). Two main types of TBA were distinguished (1) Karst aquifers ranging from a few tens to hundred of square kilometers, which generate major karstic springs, and (2) Alluvial aquifers with greater areal extent, up to some thousands of square kilometers in Dinaric region (e.g. along the river Danube). Karstic aquifers are highly vulnerable to pollution from different pressure factors like- agriculture, industry, mining, sewage waste disposal and tourism. Effective cooperation mechanism between countries to reduce groundwater and ecosystem vulnerabilities and contribute to the sustainable management of transboundary Karst groundwater resources (Dinaric Karst Transboundary Aquifers System) was formulated, specifically for the Dinaric area. Karstic aquifers with their lack of soil cover and rapid flow paths leaving little time for attenuation are almost invariably classified as highly vulnerable by mobile and persistent pollutants. Alluvial aquifers are likely to be vulnerable, unless they contain a high proportion of clay rich material to reduce their permeability or overlain by a protective confining layer of clay or the water table is relatively deep. Agricultural activities put major pressure on freshwater in terms of both quantity and quality.

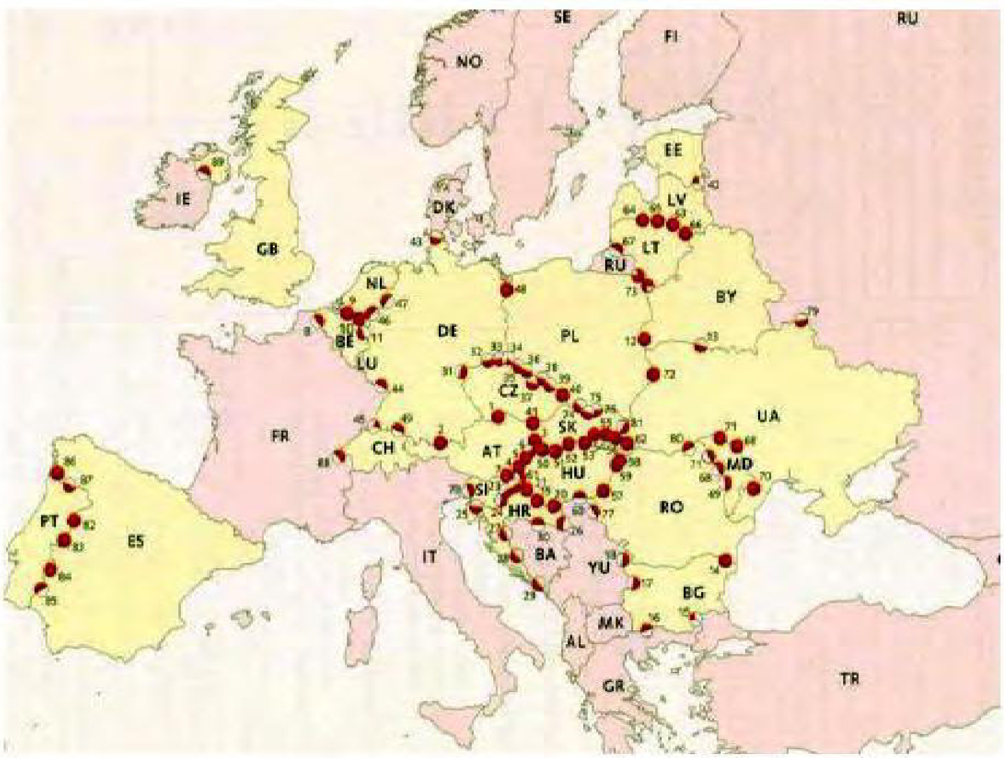

Fig.3 Tranboundary aquifers in Europe

Southern Africa is one of the focal regions receiving support from ISARM in West Southern Africa. Groundwater is likely to be the key resource to improve the water supply coverage of many areas. This is important for the industrial, agricultural and societal development of the region. Groundwater is also an important conditioning factor in regional environmental processes.

Boundaries of individual aquifers are mainly based on surficial extent of geological formations (lithological transitions) and surface water divides.(Fig 4)

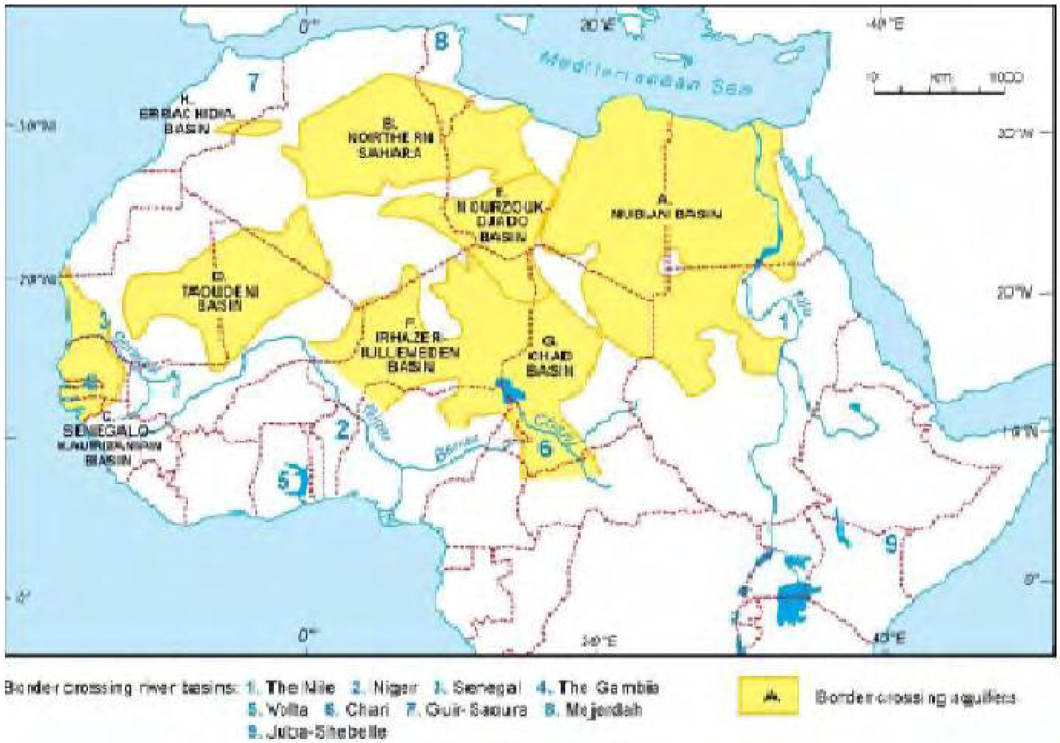

Fig.4 Transboundary aquifers in Africa

Transboundary Aquifers in Asia: There are several transboundary aquifers in Asia, involving two or more countries . UNESCO, HP has demarcated 12 transboundary aquifers which are significant and depicted in fig-5 and Table-2

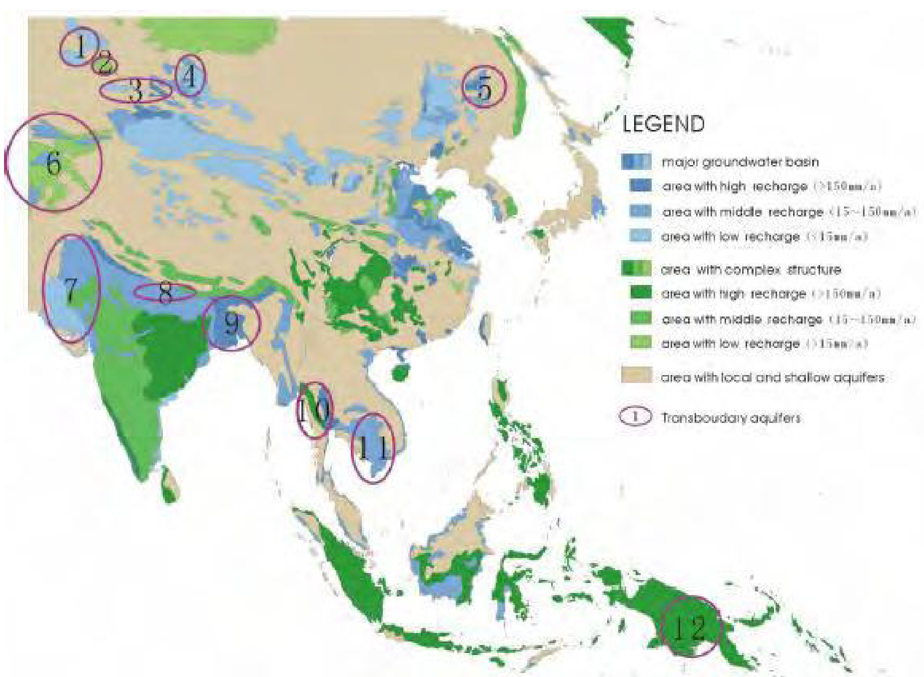

Fig-5. The occurrence of Transboundary Aquifers in Asia

Table 2 Transboundary Aquifers in Asia

No	Name of Transboundary Aquifer System	Countries sharing this aquifer system	Type of aquifer system	Extension [km²]
1	Ertix River Plain	Russia, Kazakhstan	1	120000
2	West Altai	Russia, Kazakhstan	1,2	40000
3	Ili River plain	China, Kazakhstan	1	53000
4	Yenisei upstream	Russia, Mongolia	1,2	60000
5	Heilongjiang River plain	China, Russia	1	100000
6	Central Asia	Kazakhstan,Kyrgyzstan,Uzbekistan, Tajikistan,Turkmenistan,Afghanistan	1,2	660000
7	India River plain	India, Pakistan	1	560000
8	Southern of Himalayas	Nepal, India	1	65000
9	Ganges River plain	Bangladesh, India	1	300000
10	South Burma	Burma, Thailand	2	53000
11	Mekong River plain	Thailand, Laos, Cambodia, Vietnam	1	220000
12	New Guinea Island	Indonesia, Papua New Guinea	2	870000

Type of aquifer system: 1 - porous, 2 - fissured/fractured, 3 - karst

Transboundary aquifers of Indian subcontinent: Transboundary aquifers of Indian subcontinent are shared between India and neighbouring countries. There are 8 such sharing aquifers. Such Regional aquifers and their flow path crossing national boundaries some times extend over large areas. Some of the aquifers are very high yielding and can provide sustainable water supply for human need in different parts of world, including India. These aquifers are very important in view of food security in India and neighboring countries.

REFERENCE

- Revenga C, Brunner J, Henniger N, Kassem K, Payne R(2000) Pilot analysis of Global Ecosystems: Freshwater Systems. Washington, DC: World Resources Institute.
- UNESCO/ISARM (2001) A framework document. Paris, UNISCO, non serial document on Hydrology.
- WORLD Bank (1987) Water Resources Management in South Eastern Europe, Volume-I, Issues and Directions.
- Puri S and Aureli A (2005) Transboundry aquifers: A global programme to assess, evaluate and develop policy. Groundwater, v 43(5), p.661-668

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Sushil Gupta & Sanjay Marwaha, Bhujal News, 25:1&2(2010), 13-20

Trans-boundary aquifers in the State of Punjab, India, along Pakistan Border

Sushil Gupta
Member(SM&L), Central Ground Water Board, New Delhi
Sanjay Marwaha
Suptd Hydrogeologist, Central Ground Water Board, Lucknow

Abstract

Insatiable demand for water resources has increased manifold with growth of civilizations. The huge stress on water resources is due to increasing demands and declining water levels, growing vulnerability from floods and droughts, and eco-hydrological problems. Water resources management need comprehensive strategies for providing water of adequate quantity and protecting mankind from adverse impacts. Sustainable solutions for trans-boundary water aquifer systems are therefore of high priority since nature does not draw its boundaries to coincide with the political boundaries.

Punjab state is one of the most prosperous states of India with an agricultural based economy. The total water requirement of the state is 61.675 BCM. Against this, the water availability is only 17.54 BCM of surface water and 23.78 BCM of replenishable ground water resources. Punjab has a very long international boundary and the ground water aquifers are contiguous across the border too. Whereas the majority of the recharge areas lie in the hills of J&K and Punjab, the discharge areas extend to Pakistan too.

It is thus felt that now is the time to study the trans-boundary aquifers of Punjab state in totality and on the basis of proper assessment of ground water contained down to a certain depth (say 1000 meters), decide the allocation of ground water usage by the neighboring countries. The present paper outlines the above along with the hydrogeological set up of Punjab state with special emphasis on Upper Bari Doab area covering the districts of Amritsar, Gurdaspur and Taran Taran.

INTRODUCTION

For any country water is at the core of human interdependence, a shared resource that serves agriculture, industry, households and the environment. Water governance is about striking a balance among these competing users. But water, especially ground water is also the ultimate fugitive resource. Countries may legislate for water as a national asset, but the resource itself crosses political boundaries without a passport in the form of rivers, lakes and aquifers. Trans-boundary waters extend hydrological interdependence across national frontiers, linking users in different countries within a shared system. Managing that interdependence is one of the great human development challenges facing the international community.

As water becomes scarce relative to demand, trans-boundary competition for shared surface and ground water resources will grow. Cross-border waters almost always create some tension between the societies they bind. Because ground water is a flowing resource rather than a static entity, its use in any one place is affected by its use in other places, including other countries.

TRANSBOUNDARY AQUIFER

The key features of trans-boundary aquifers include a natural subsurface path of ground water flow, intersected by an international boundary, such that water transfers from one side of the boundary to the other. In many cases, the aquifer might receive the majority of its recharge on one side, and the majority of discharge would occur in another side. The subsurface flow system at the international boundary itself can be visualized to include regional, as well as the local movement of water. Generally, international boundaries do not follow natural physical features, and water resources can cross them unhindered.

TRANS-BOUNDARY AQUIFER SYSTEM IN PUNJAB

Punjab having geographical area of 50,362 Sq.Km. is predominantly an agrarian State. Nearly 83% of the State's geographical area is under cultivation with an average cropping intensity of 188% and about 80% of water resources available are used for agriculture sector. Out of the total irrigated area (97% of the net area sown is irrigated), 73% of the area is now irrigated by groundwater through tubewells and the remaining 27% by mostly canals & their distributaries as against 55% and 45% respectively three decades ago. The water needs of the state for various activities, i.e. domestic, industrial, Agriculture, Thermal Power, etc. have been estimated to be 61.675 BCM by Government of Punjab, out of which about 51.81 BCM is for agriculture sector alone. Punjab has been allocated 17.54 BCM of water from its three perennial rivers. Even this water availability has shown a declining trend due to decrease in river inflows during the last three decades. Dwindling surface water resources in Punjab has resulted in over dependence on ground water. The tubewells in the state have grown from 26 thousand in the year 1965-66 to 12.32 lakh in the year 2006-07 and the ground water withdrawal is now 31.16 BCM against total Replenishable ground water resources of 23.78 BCM. There is thus an overdraft of 7.38 BCM of ground water. Despite this, Punjab state is short of 12.98 BCM of its total water requirement.

Hydrogeological Set Up

The State forms a vast tract of alluvial plain formed by mighty rivers, the Ravi, the Beas and the Satluj. Ground water exploration has revealed existence of thick fresh water aquifers throughout the State(Fig-1). These aquifers are laterally and vertically extensive and persistent in nature . However, in south western part the thickness of fresh water aquifer is much less as compared to the other parts because area is underlain by brackish / saline water. The area having prolific aquifers adjoining Pakistan is Upper Bari-Doab, the aquifer disposition of which is depicted through a fence diagram (Fig-2).

A lithological section along AA' (NE-SW) drawn parallel to the left bank of Ravi river, reveals the presence of 5 to 6 thick permeable granular zones down to a depth of 300-420 m below ground level(Fig-3) The thickness of clay layers varies from 2.0 to 20.00 m and all these clay beds pinch out towards south–western direction except the clay layers occurring between 42.0-63.5 m, 130-140m, 165-170, 212-230m and 282-294m which are persistent. The first aquifer which forms the water table aquifer occurs up to 40-50m bgl and consists of sand with minor amount of gravels and kankar. In the SW part of the section, covering Gujjarpur and Kohala, the phreatic aquifer occurs up to 32-36m bgl. and consist of fine to medium sand. In the NE part, in the water table aquifer gradation from sand to pebbles had been observed. Aquifer material is coarser between 30-50m. The second and third aquifers consist of sand, gravel and pebbles, but and fine to medium sand at places. The aquifer occurring below 230m bgl consists of fine sand and silt at Taragarh and Thathi.

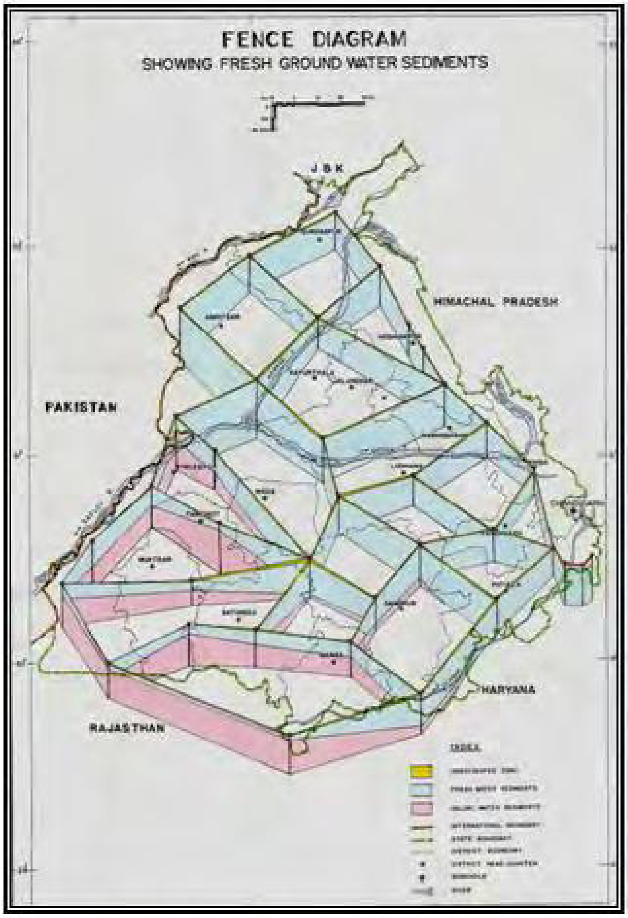

Fig1. Fresh ground water aquifer of Punjab

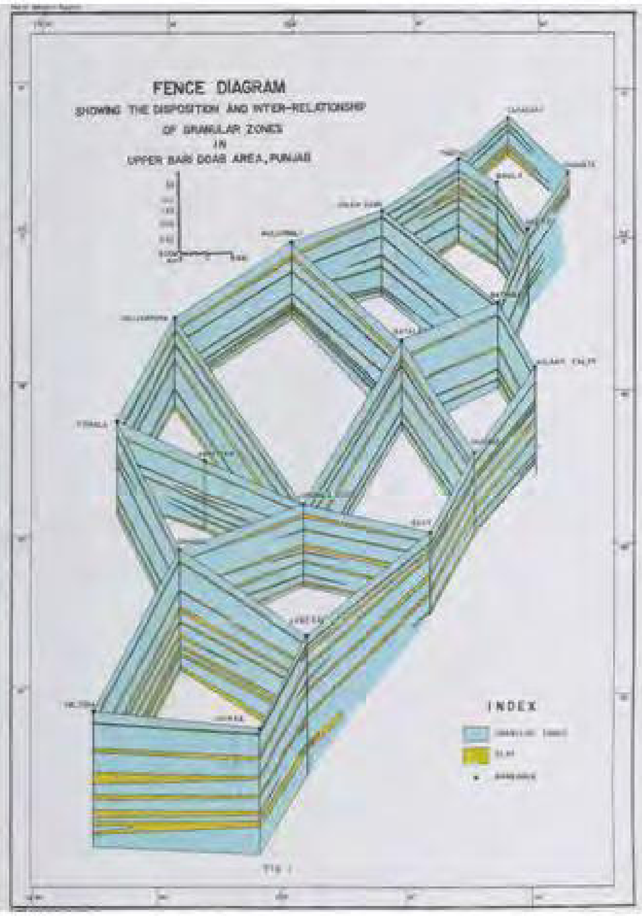

Fig2. Fence diagram showing granular zones

Ground Water flow

Water table elevation map of Punjab state depicts that a water divide runs in NE-SW direction roughly passing through Sirhind, Kotkapura, Muktsar and Abohar. Water table contours are closely spaced in the extreme NE part indicating that ground water movement is fast, in other parts these are widely spaced which show that ground water movement is slow.

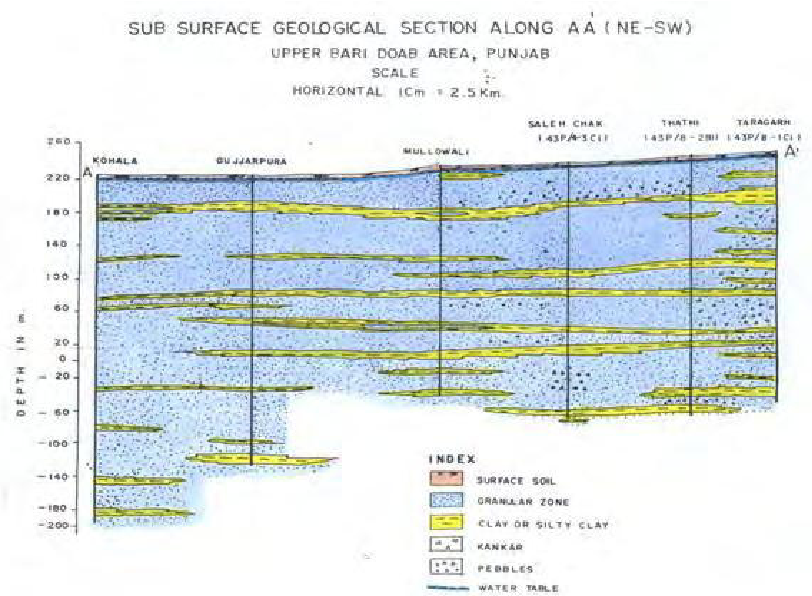

Fig3. Geological cross section showing granular zones

The maximum value of water table elevation above M.S.L. is in the NE part having value more than 330 m above Mean Sea Level and the lowest is 165 m above MSL in the extreme SW part

(Fig-4). Both the rivers i.e. Sutlej and Ghaggar are effluent in nature. It is also evident from the map that ground water, in general, is flowing towards west and south-west and ultimately crossing over to the neighboring country.

Long Term Water Level Fluctuation

The long term water level fluctuation map of the State, a map (Fig-5) reveals that ground water levels have registered fall varying between 4 and 16 meters in Nawanshahar, Jalandhar, Kapurthala, Moga, Patiala, Ropar, Fatehgarh Sahib, Sangrur, major part of Mansa, northern part of Ferozepur and Bhatinda, Hoshiarpur, Gurdaspur,and Amritsar districts . There is a rise of water levels in remaining area of the state. The rise in water levels is attributed to the continuous seepage of water from network of unlined canals and distributaries and due to the negligible draft from groundwater in the area.

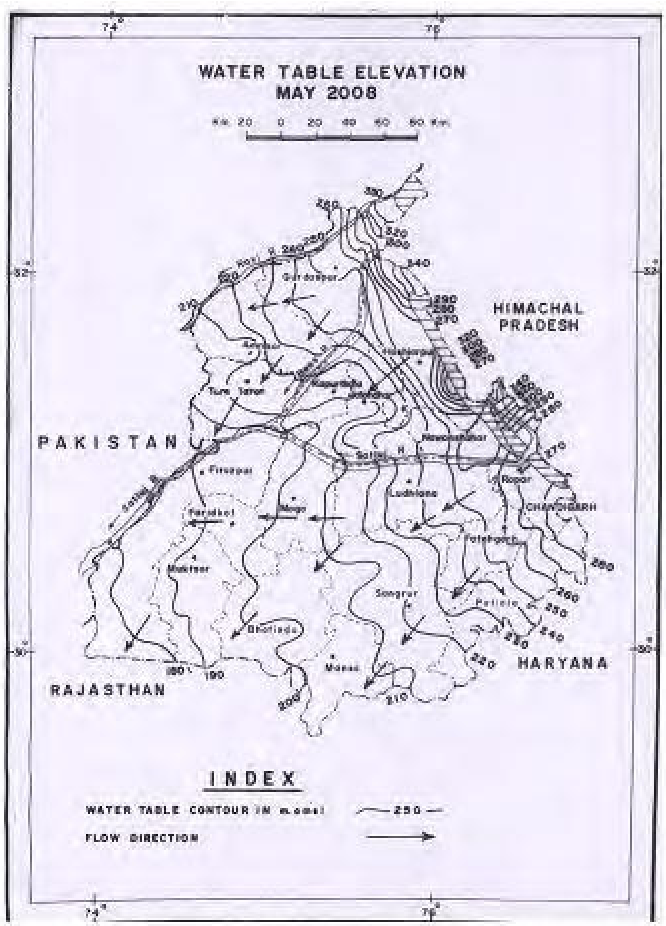

Fig4. Map showing regional groundwater flow direction

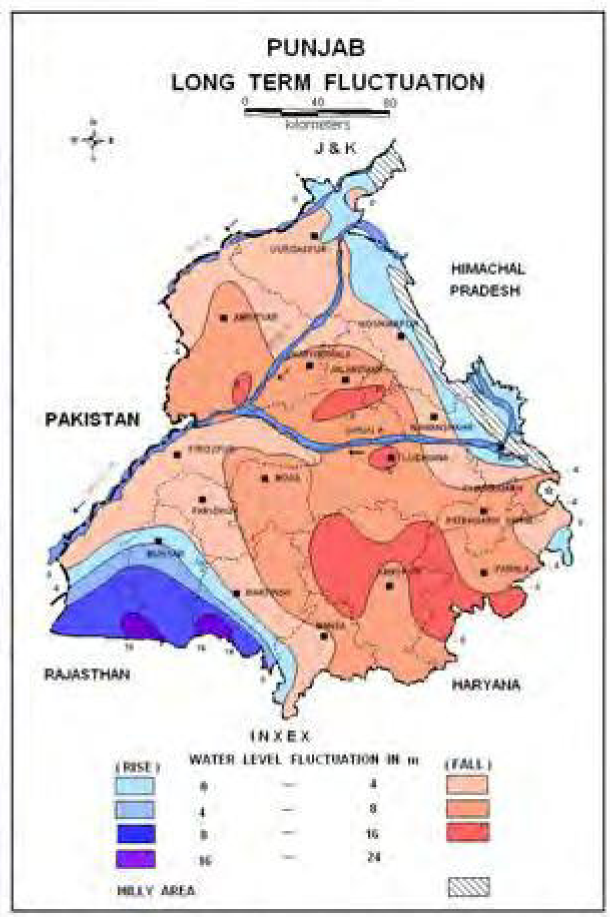

Fig5. Map showing long term groundwater fluctuation

Ground Water Resources

Ground water resources of Punjab state have been computed as on 31.03.2004, and the Replenishable ground water resources of Punjab state have been assessed to be 23.78 BCM, and the net annual draft of the state has been estimated to be 31.16 BCM. There is thus an overdraft of 7.38 BCM . This overdraft has resulted in declining water tables and the blocks becoming over exploited. As per the last estimates, out of 137 blocks in the state, 103 fall under Over exploited category, 5 in critical, 4 in Semi critical and 25 in safe category. Spatial distribution of the block with their category has been depicted in map showing Ground Water Development in Punjab State.

DISCUSSIONS

Water resources, whether surface or underground, have gained tremendous importance in the national as well as international context. Within a country also, due to water scarcities, it is important to assess the ground water that is flowing across the boundaries .In the context of Punjab state, sharing its international boundary with Pakistan falling in the Indus basin, it is all the more important that the disposition and design of the trans-boundary aquifers be studied in detail so as to assess the quantities of water that are flowing across the border.

Based on the available data discussed in the preceding paragraphs, it is established that the slope of the water table is towards west and south-west, which follows land surface slopes. The major recharge areas to the ground water aquifer also occur in the mountains and hills falling in Punjab and J&K. The disposition of the deeper aquifers also indicates that whether these are confined or semi-confined, their slope is towards west. Thus apart from any natural flows that regularly take place due to the difference in the head, any pumping activity that is taking place downstream direction will negatively impact the upstream aquifers. Thus, as a first approximation, ground waters of Punjab are flowing across the international boundary towards Pakistan. The need is to assess and quantify the flows as well as study the chemical quality of the water flowing across. It is also important to assess the long-term behavior of these flows in case of increased pumping due to water shortages all over the region. In case of trans-boundary aquifers across the international boundary no information on aquifer geometry is available so no composite fence of aquifer disposition could be generated as to ascertain the nature and behavioral pattern of aquifers.

However, Central Ground Water Board has taken up study of trans-boundary aquifers within India where aquifers across the states of Haryana and Uttar Pradesh were studied during Upper Yamuna Project. A composite fence diagram across the state boundaries had also been prepared. The main aim of the project was to study the effect of pumping of ground water through augmentation tubewells in Haryana might be having on the Yamuna river flows and ground water resources of Uttar Pradesh. The project used a multidisciplinary approach and some important findings of the Project were:

- Monthly river regeneration between Tajewala to Wazirabad does not show any appreciable decline due to augmentation/other modes of draft. .
- Augmentation drafts have local effects in declining the water table but it appears that the same is being recouped by ground water flow to a major extent. Its effect is minimal close to river Yamuna.
- Augmentation draft has only about 20% share from the water table aquifer. Its and other modes of drafts on the water table aquifer in the area studied are negligible.
- The present quantum of ground water draft is having little injurious effect on the unconfined aquifer and can be attributed to:
- Further augmentation draft may be permitted in the area without affecting the river regeneration but that draft must be from deeper aquifers and the allocation of the augmentation draft must be further down the present augmentation canal project. Such a scheme, however, may create local depressions.

- Continuance of the augmentation draft in future may generate decline in water table adjacent to river in U.P. area as well without appreciably declining river regeneration.
- Any large-scale ground water development upstream of the present location of augmentation canal project may effect the river regeneration.

It can be summarised from the above that Central Ground Water Board has the technique and methodology available to study the trans-boundary aquifers. It is anticipated that similar conditions do exist in the trans-boundary aquifers lying across India and Pakistan. Further, recharge area for the aquifers either unconfined or confined do lie in India only except for vertical recharge taking place through rainfall in Pakistan. As mentioned in previous paragraphs, based on the ground water exploration studies in these areas, thick fresh water aquifers have been deciphered on the Indian side of international border and it is anticipated that substantial quantities of ground water do flow across the border. The thickness of fresh water confined aquifers up to the depth explored (300-500m) varies greatly especially in the Upper Bari Doab area. The fresh water aquifers are thick in the North of Upper Bari Doab, where thickness of more than 100 m in the Northern part of the basin is prevalent. In the southern part (Valtoha block) thickness of fresh water aquifer diminishes to less than 50m.

The following steps are required to study the disposition, behavior, potential etc of trans-boundary aquifers (After: Internationally Shared (Transboundary) Aquifer Resources Management, Their significance and sustainable management- A Framework Document, IHP-VI, Series On Groundwater No.1, November 2001, UNESCO, Paris 72 pp)

I. Identification of Transboundary Aquifers
II. Spatial Distribution Of Parameters
III. Ground Water Hydraulics Of The Aquifers
IV. Management Issues
V. Pre-Requisites for Sound Management

I. Identification Of Trans-Boundary Aquifers

In contrast to surface water that is easily identifiable, ground water aquifers are poorly known and recognized. It is thus essential to view the entire trans-boundary aquifers, including all that are hydraulically connected directly by lateral or indirectly through vertical contact or through fractures and low permeability formations. For this data sharing amongst the countries is very important. The data gaps can then be identified and filled by carrying out further scientific studies in the area.

II. **Spatial Distribution of Parameters**

There are some parameters and factors that affect the behavior and development potential of aquifers and need to be studied. These are:

- Hydraulic parameters
- Rainfall and Recharge Zones
- Confined and Unconfined areas
- Natural discharge zones
- Present and planned ground water development zones
- Water quality, potential risks of its deterioration; and
- Vulnerability to polluting agents

In transboundary aquifers, one or more of the above factors may be more important than the other on either side of the boundary.

III Ground Water Hydraulics of the Aquifers

The ground water flow changes when an aquifer is placed under stress by pumping out water from it. This is in response to the changes in the piezometric heads due to pumping. However, this may lead various consequences as:-

- Modification of the ground water flow pattern : Ground water flow passing an international boundary cannot be measured directly. It is estimated from parameters like transmissivity, hydraulic gradient, cross section etc and through mathematical models. Abstraction on one side of the border may alter the flow through the border.
- Modification of the piezometric surface : Ground water abstraction through wells results in modifications of piezometric heads in the form of a concentric cone of depression. These cones of depression may extend across international borders.
- Deterioration of the water quality : Ground water of the aquifers are also affected due to development. Saline water ingress from coastal areas can increase and in inland salinity areas due to upcoming saline water may intrude the otherwise fresh water aquifers.
- Pollution : Anthropogenic pollution can result in aquifer pollution and the polluted ground water may travel to the other side of the international boundary.

IV Management Issues

So far there are no agreements on sustainable management of trans-boundary aquifers, especially in the Indian sub-continent. Sustainable management of the ground water resources requires a multidisciplinary approach even for the international aquifers. There might be a need of agreement between countries sharing aquifers to preserve the natural outflows and abstracting ground water equivalent to the average annual recharge. Even in aquifers having large storages, the amount and rate of extraction should be subject to multilateral agreements.

V Prerequisites for Sound Management

The UNECE (United Nations Economic Survey for Europe) survey of transboundary aquifers and other studies have confirmed the need for having a unified and consistent knowledge base as a prerequisite for the management of transboundary aquifers. Ideally this should be developed within a conceptual model of the whole transboundary aquifer, providing a firm foundation that supports sound development through risk based management. Determination that a particular rate of groundwater withdrawal or general management plan is sound depends on in-depth understanding of the groundwater system.

This understanding begins with knowledge of basic hydrological processes. Relating this to specific situations requires understanding of the extent and nature of the aquifer, how it relates to other aquifers and hydrogeologic features, how the recharge and discharge of water takes place within the aquifer, and where potential sources of contamination are located. Without such understanding the use of a transboundary aquifer cannot be confidently planned. This conceptual model should be augmented by a consistent programme on both sides of a boundary to monitor basic hydrologic parameters, such as precipitation, groundwater levels, stream flow, evaporation, and water use. The monitoring programme will provide the data essential to generate a quantitative perspective on the status of the groundwater system and to validate the conceptual understanding. The data must be consistent with the conceptual model. If not, the conceptual model may need to be revised.

Good and reliable information is crucial to facilitate co-operation among aquifer stakeholders. All stakeholders should have easy access to good, reliable data on abstractions, water quality, and aquifer water levels. Current information technology allows information to be made available to an unlimited number of users easily and economically. With such an approach it should be possible to establish mutually accepted rules, adopted by all parties, based on a holistic definition of the aquifer system and principles of equivalence of impacts of abstraction.

ACKNOWLEDGEMENTS

The authors express their deep sense of gratitude to Dr S.C.Dhiman, Chairman, Central Ground Water Board, for having provided the guidance in writing of this paper. The authors have drawn lots of information from the Framework document – Internationally Shared (Trans-boundary) Aquifer Resources Management prepared by IHP, even to the extent of quoting the document verbatim at a few places. Several reports of Central Ground Water Board for Punjab state were also consulted and the data contained in those reports was generated, analyzed and interpreted by several colleagues. The efforts and contributions of all the colleagues is gratefully acknowledged.

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R.C.Jain, Bhujal News, 25:1&2(2010), 21-27

Transboundary Aquifers: Global significance for Social and Environmental sustainability

R.C.Jain
Regional Director, Central Ground Water Board, Dehradun

INTRODUCTION

Transboundary aquifers are as important a component of global water resource systems as are Transboundary Rivers; yet, their recognition in international water policy and legislation is very limited. Existing international conventions and agreements barely address aquifers and their resources. Unlike transboundary surface water, transboundary aquifers are not well known to policy makers. Available international law does not adequately address the three dimensional spatial flow and storage in ground water and has limited application in conditions where impacts from neighboring countries can take decades, given that ground water response is slow compared to surface water (Yamada 2008). Its national sustainable management seems to be hampered by weak social and institutional capacity, and poor legal and policy frameworks. In a transboundary context, this can be even further amplified because of contrasting levels of knowledge, capacities and institutional frameworks on either side of many international boundaries(Puri,2002). Many transboundary aquifers are under environmental threats caused by climate change, growing population pressure, over-exploitation, and human induced water pollution.

Almost 96% of the planet's freshwater resources are to be found in underground aquifers, most of which straddle national boundaries. The aquifers, which contain 100 times the volume of fresh water that is to be found on the Earth's surface, already supply a sizeable proportion of our needs. Globally, 65% of this utilization is devoted to irrigation, 25% to the supply of drinking water and 10% to industry. Underground aquifers account for more than 70 percent of the water used in the European Union, and are often the only source of supply in arid and semi-arid zones. Aquifers supply 100 percent of the water used in Saudi Arabia and Malta, 95 percent in Tunisia and 75 percent in Morocco. Irrigation systems in many countries depend very largely on groundwater resources - 90 percent in the Libya, 89 percent in India, 84 percent in South Africa and 80 percent in Spain.

GLOBAL PROGRAM

In order to gain a global assessment to study and better manage Transboundary aquifer resources, a number of agencies joined together in a major venture, the World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP created in 1999 at the UNESCO General Conference of the Commission for the Geological Map of the World (CGMW). The programme aims at collecting, collating and visualizing hydrogeological information at the global scale, to convey groundwater related information in an appropriate way for global discussion on water issues and to give recognition to the invisible underground water resources within the World Heritage Programme. WHYMAP also brings together the colossal efforts in hydrogeological mapping, at regional, national and continental levels. The principle focus of the WHYMAP program is the establishment of a modern digital Geographic Information System (GIS) in which all data relevant to groundwater are stored together with its geographic reference. In its final form the WHYMAPGIS will contain a significant number of thematic layers, local and shallow aquifers, transboundary aquifer systems, depth/thickness of aquifers, groundwater vulnerability, geothermalism, stress situations of large groundwater bodies and "at risk" areas. The first of such thematic maps based on the WHYMAP, the "transboundary" distribution map (scale 1:50,000,000) has been published (Struckmeir et al., 2006).

The "WHYMAP-Transboundary" confirms that regional aquifers sometimes extend over large areas and the flow paths of groundwater in them, crossing national boundaries, can extend over tens or hundreds of square kilometers. The area of the largest systems known on our planet can even reach over 2 million sq km, and be shared by several countries. With thick saturated sediments, of up to 1,000 m, they form vast underground water storages. Although there could be massive groundwater resources in stock, in arid regions, with little contemporary renewal from rainfall, aquifers can be particularly vulnerable to overexploitation. The preliminary summary-inventory of the global distribution of transboundary aquifers shows that there are at least 273 such aquifers in the global continental land mass. First-ever world map of transboundary aquifers (UNESCO,2008) showing the inventory of 273 shared aquifers - 68 in the Americas, 38 in Africa, 65 in eastern Europe, 90 in western Europe and 12 in Asia depicts the aquifer locations and also provides information about the quality of their water and rate of replenishment by rainfall (Fig.1).

LINKAGE TO SOCIAL DEVELOPMENT

The presumed linkage between water resources of transboundary aquifers and social development is widely accepted. Recently international forum devoted to international water resources, e.g., the World Summit on Sustainable Development in Johannesburg, the World Water Forum in Kyoto, and the Dushanbe Fresh Water Forum, have stressed that human survival depends not only on national but also on international water. It follows that the role of transboundary aquifers in society and its security cannot be separated from any considerations of the natural and built environments (Puri, 2001). In this context, ''aquifers and rivers'' interdependency should be better appreciated the dry-season base flow of many rivers may be derived from transboundary aquifers. Large numbers of poor people in Africa, South America, and Asia rely directly on dry-season transboundary water resources for their subsistence (Puri, & Aureli, 2005) .

The ''water poor'' in the transboundary aquifers context are those impacted by the following :

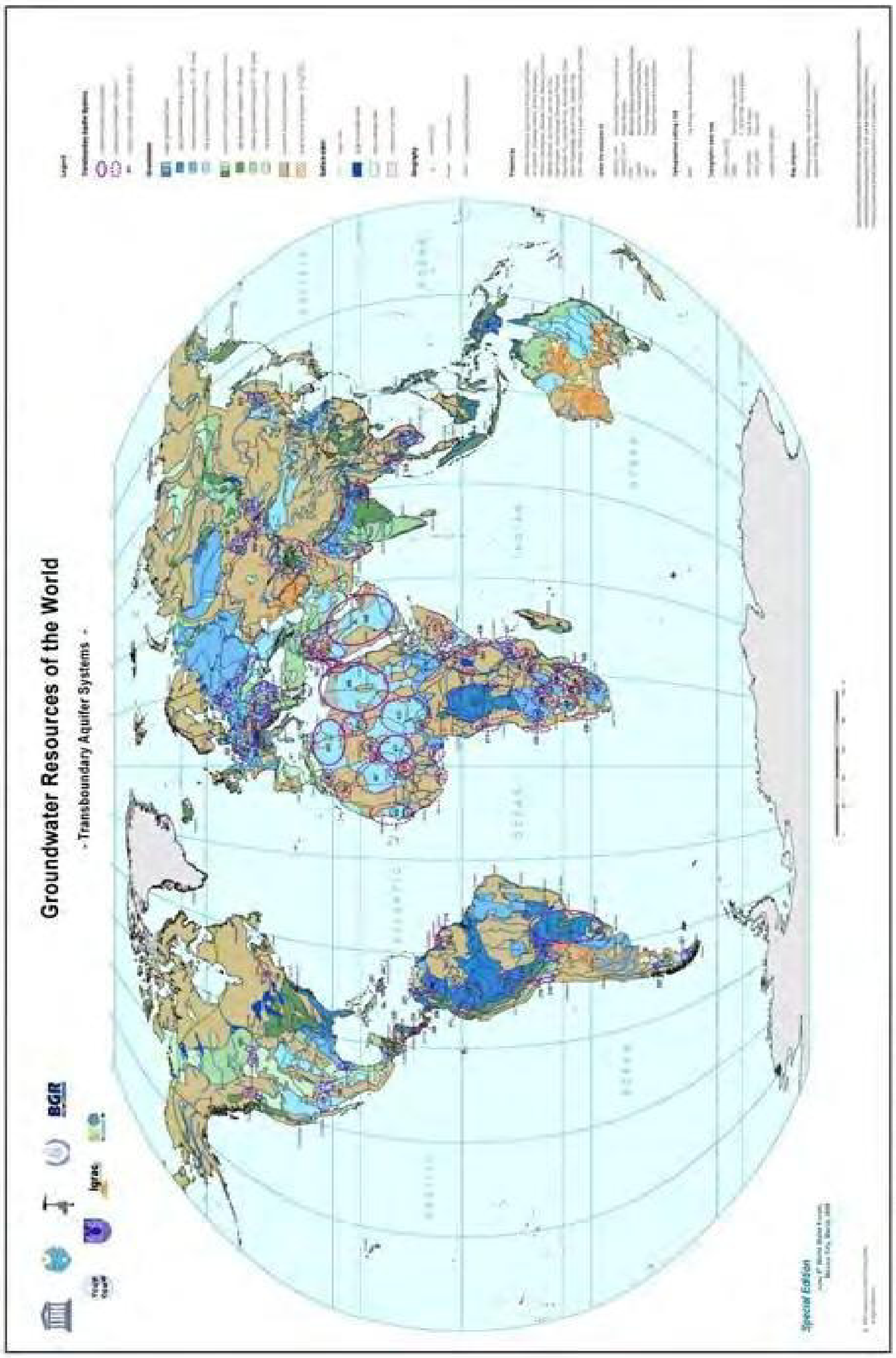
- Persistent threat to their natural livelihood base from hydrologic extremes
- Dependence of livelihood on cultivation of food or gathering of natural products that rely on transboundary waters
- Excess pumping resulting in greater drawdowns, and increased costs to the poor in terms of energy
- Contamination of transboundary water resources, and inability to use, or have no access to, an alternative source
- Vulnerable people who spend several hours a day collecting potable water, and whose security, education, productivity, and nutritional status is thereby put at risk
- Those living in areas with high levels of water-associated diseases (bilharzia, guinea worm, malaria, trachoma, cholera, typhoid, etc.) without means of protection

To date, social assessments for poverty alleviation taking account of transboundary water resources are rare. The interrelationship between integrated water resource management and poverty has not yet been generally recognized, as might be noted from the lack of reference to ''water poverty'' in many Poverty Reduction Strategy Papers (Burke & Moench,2000).

ENVIRONMENTAL SUSTAINABILITY

The immense diversity of aquifer types and their configurations suggest that no one uniform approach is likely to apply to all transboundary aquifers. It is clear therefore that case studies under different conditions will be needed. Case studies should be so selected that each makes a contribution to the overall understanding to the management of transboundary aquifers. For the full understanding of Transboundary aquifers, more important will be the socioeconomics, i.e., the users of the resources, including the demands placed on the aquifers for a sustainable environment, especially where aquifer discharge maintains important habitats.

Fig.1.Ground Water Resources of the World-Transboundary Aquifer System



Source: UNESCO publication WHYMAP2008

STRATEGY FOR THE SELECTION OF CASE STUDIES

In selecting case studies, the factors that may be used to identify priority transboundary aquifers should include the following aspects.

Persistent transboundary aquifer resource management problems including the following:-

- Poor prediction of aquifer yields on one or either side of the national boundary
- High variability in transboundary aquifer properties and therefore high uncertainties
- Presence of unused or underused ground water resources on or other side of the national boundary
- Conflicting demands for the transboundary aquifer resource,such as between irrigation and industrial uses
- Significant environmental concerns arising from current water management practices
- High likelihood that current transboundary aquifer management practices are depleting the resource, either through overexploitation or by pollution.

There could be several other criteria applied in selecting the case studies, some of which could be focused on ensuring the study is not unnecessarily complicated. The characteristics that will make a transboundary aquifer suitable as a case study could include the following (UNESCO,1993) :-

- The aquifer is well defined and is hydrologically distinct ideally excluding major inter-basin transfer arrangements
- Strong national and local support can be developed for the case study aims
- Good history of surface and ground water hydrometric data collection in at least some of the key sites
- Broadly comparable socioeconomic situations (If, for example, there is significant industrialization on one side, this could complicate analysis including demand forecasts. As a consequence, the details of dealing with such changes may be given greater prominence than the overall approach to improving the transboundary aquifer resource management.)
- On the whole, there is only one international boundary crossing the aquifer system, as bilateral evaluations are thought to be more effective, at least during the case study stage.

IMPACTS OF “GLOBALIZATION”

While in the national context the principles of depletion and contamination of groundwater resources are well observed and understood, though perhaps not well managed, in the transboundary context these same issues take on an order of magnitude greater in complexity. What does this mean? From a pure natural science perspective, no impact other than that initiated from, and transmitted through, the aquifer system is feasible. However, there is increasing evidence among the socio-ecological community that globalization is a central feature of the coupled human-environmental systems, or as termed by them, socio-ecological systems. Approximately 40% of the global population lives in one or another transboundary river or aquifer system, this is an intuitive observation in terms of the impact on the more obvious human ecologies. The impacts are less tangible, but not less significant on natural resources transboundary aquifer systems and interconnected with it.

In considering the drivers that affect quality and quantity in transboundary aquifers, most researchers accept that apart from the impacts of climate change, they are also subject to easily discernible local changes such as land use change, urbanization and associated with these changes a bewildering input of substances that enter the groundwater flow systems. They also accept that such change is global i.e. worldwide, and it is proceeding at an unprecedented pace, and in geographic scope, affecting river basins and aquifers in term of quantity and quality. This is confirmed in various assessments such as the Millennium Ecosystem Assessment (Emerton & Bos,2006) that has shown that global ecosystem degradation involving loss of ecological capital is intense in 2002, humanity's global ecological footprint was exceeded by 23%. If this trend continues, the globalized human economy (comprising of demand on natural resources, including water from aquifers) is in ecological overshoot, from the impacts of global interdependence on goods and services (Margat,2006).

In translating the impact of this change into aquifers, it is widely reported that aquifers are being overdrawn i.e. the groundwater resource is being pumped beyond the rate at which it is recharged consequently, in the majority of such aquifers, water is being drawn from storage (IWMI,2005) . As yet there are no definitively agreed figures of the global total of withdrawal from storage. Nevertheless, if one were to simply adopt the figure provided for one globally significant aquifer system, the High Plains Ogallala Aquifer in the United States, this alone is stated by Konikov and Kendy (2005) to be equivalent to a sea level rise of 0.025 mm, as noted above. If, to this is also added the volume drawn from storage in the North China Plains Aquifers, the Indo-Gangetic Plains Aquifers, the Guarani Aquifers and the Mexico Aquifers, for which somewhat unreliable figures are available, though the order of magnitude is well known, then the global "loss of transboundary aquifer storage" become an issue beyond intellectual interest. When combined with the risks to aquifer functions and to aquifer dependent ecosystems, the issue needs urgent quantification.

Why does loss of global aquifer storage require urgent quantification? Because economic losses, translated through environmental and livelihood losses will be difficult to reverse. The decline in flexibility of ecosystems that are linked closely with aquifers and groundwater in the lower income countries, may reach a "tipping point" beyond which they cannot be revived.

TECHNICAL AND FINANCIAL ISSUES

Groundwater, and especially transboundary groundwater, is often referred to as an "undervalued" resource, where an ecosystem approach underwritten by economic valuation can help in qualifying this significant, but vague characteristic, to quantify the degree of under-valuation in social and economic terms. The core of the issue is, paradoxically that groundwater presents many opportunities and advantages for national economic development and environmental sustainability. In many regions of the world, groundwater represents a reliable and resilient source of freshwater, upon which people have become increasingly dependent. Groundwater development has significantly enhanced local productivity and makes the resource accessible to a wide range of individual users. Mechanized boreholes/tubewells have allowed the access to be "on demand" and "just-in-time". However, as a consequence of this apparent success the social, economic and environmental systems that depend on groundwater are under threat from groundwater overexploitation.

The evolution is dynamic and it is important to recognize the change of attitudes over time to these recent and rapidly expanding problems. Cheap and reliable borehole pumps were only introduced in the 1950's and the scale and intensity of the abstraction have only been apparent in the last quarter of the twentieth century. Prior to this, groundwater was seen as a ubiquitous and reliable source of high quality water. As groundwater exploitation from increasingly deep transboundary aquifers grow, often with incentives of inappropriate national energy and agricultural pricing subsidies, drawdown effects are extending beyond national boundaries. However, the impacts of increases in energy prices are slowly being felt and as some countries experience dwindling tax revenues, they are forced to phase out national energy subsidy schemes. If the phase outs are not synchronized across national boundaries in transboundary aquifers, the consequences can be significant. Access to affordable energy is emerging as a priority groundwater issue and, as the economic fundamentals are imposed, there are also adverse social impacts as groundwater falls out of the economic reaches of the individual farmers as the consequence of limited economic access to energy and capital to pump increasingly deep groundwater. However, as groundwater depletion is being increasingly recognized as a major environmental issue, international funding institutions can also be expected to restrict financing groundwater resources development.

LEGAL AND INSTITUTIONAL ISSUES

The scientific principles involved in the sound management of transboundary aquifers are well known and understood by groundwater specialists. These include an appreciation of the full system, i.e. from sources of recharge, to the regions of discharge, as well as the quantity and quality issues along the flow path. Usually the system is well described by the use of conceptual models through which groundwater specialists from across national boundaries can communicate well. Unfortunately sustainable management of transboundary aquifers goes well beyond developing consistent conceptual models. It needs in addition, synchronization of legislation, equivalence in institutional structures and consistency in socio-economic drivers and also a coherent application of the environmental protection criteria (World Bank,1999). Developing cooperation for sound management therefore requires an equal attention to these other drivers, which must follow upon the hydrogeological conceptual consistency. One of the key issues in developing cooperation is strengthening institutions such as Basin Commissions or Joint Bodies, so that these aspects can be addressed. There exists extensive literature and substantial experience in developing cooperation for the sound management of transboundary river basins. While many of the principles from this experience can be applied to aquifers, there are issues peculiar to aquifer behavior that should be precisely defined in the system so that cooperation can be made effective.

CONCLUDING REMARKS

To conclude, this paper was intended to infuse the aspects of social, environmental, legal and institutional issues into the development, interpretation, and application of international legal concepts and norms relevant to sustainable management of transboundary and international ground water resources. There is presently a dearth of scientific knowledge among government officials, legislators, policymakers, jurists, and legal scholars about these aspects. This is especially evident in the treatment afforded to ground water resources in past international agreements and academic writings. Decision makers and lawyers alike must develop a stronger understanding of transboundary aquifers and processes so as to overcome common misconceptions, mislabeling, and general misunderstanding about precious water resources. The absence or ignorance of this basic knowledge, in many respects, has resulted in the poor management of scarce water resources throughout the world; at times, it has resulted in serious harm to people and the environment. While not a panacea, the inclusion and understanding of underlying science in the decision-making process can serve to achieve more balanced, scientifically based, and thoughtful decisions. Only through a full understanding of the various social, environmental, institutional, legal and policy issues, as well as the underlying science involved, can states use, manage, and protect their transboundary and international resources prudently and effectively and in such a way that the resources provide adequately for both present and future generations.

ACKNOWLEDGEMENTS

The author would like to acknowledge Dr. S.C.Dhiman, Chairman, CGWB for the encouragement to compile this paper. Thanks are also due to Shri Sushil Gupta, Member (SML),CGWB & Shri S.Kunar, Member(SAM) for the useful consultations and guidance .

REFERENCES

- Burke, J. J., and Moench, M. H., 2000, *Groundwater & Society, Resources, Tensions and Opportunities*, UN DESA, New York.
- Emerton, L., and Bos, E., 2006, *Value. Counting Ecosystems as an Economic Part of Water Infrastructure*, IUCN, Gland, Switzerland and Cambridge, UK. p. 88.
- IWMI, 2005, *The Global Groundwater Situation: Overview of Opportunities and Challenges*,2nd World Water Forum, The Hague.
- Konikov, L., and Kendy, E., 2005, Groundwater depletion, a global problem, *HydrogeologyJournal* **13**:317–320.
- Margat, J., 2006, *Water Resources of the World*, UNESCO Publication.
- Puri, S., 2001, *Internationally Shared Transboundary Aquifer Resources Management – A Framework Document*, UNESCO. IHP-VI Serial Documents in Hydrology.
- Puri, S., 2000, Issues in developing cooperation for the sustainable management of transboundary aquifers, in: *From Conflict to Cooperation; Challenges & Opportunities in Water Resources Management*, Proceedings of UNESCO International Conference, 21–22 November 2002, Delft.
- Puri,S.,and Aureli,A.,2005.transboundary Aquifers: a Global Programme to Assess, Evaluate and Develop Policy.Groundwater,Vol.43,No.5,pp.661-668.
- Struckmeir, W., et al . 2006, *WHYMAP and the World Map of Transboundary Aquifer Systems*, Special Edition from World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP) ,BGR/UNESCO, Paris, France and Hanover, Germany.
- UNESCO, 1993, *Transboundary River Basin Management & Sustainable Development*, 2 Volumes . Technical Documents in Hydrology.
- UNESCO/BGR ,2008,Ground Water resources of the World, Trans boundary aquifer systems.
- World Bank, 1999, *Groundwater, Legal & Policy Perspectives*, Proceedings of a World Bank Seminar, Technical Paper 456.
- Yamada,c.,2008, Fifth Report on Shared Natural Resources : Transboundary Aquifers .International Law Commission, Sixtieth Session,2008

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Transboundary Aquifers In Rajasthan, Issues & Management

Manoj Srivastava
Regional Director, Central Ground Water Board, Jaipur
O.P.Poonia
Scientist, Central Ground Water Board, Jaipur

INTRODUCTION

Water is an essential commodity for living world. Nature has distributed this precious resource depending on geomorphology, geo-formations and climate etc of the area. Human being has however divided the resources by putting International boundary across this wealth of the nature. The world's 263 transboundary lake, river basins & aquifer systems include the territory of 145 countries and cover nearly half of the Earth's land surface.

Over the last 60 years there have been more than 200 international water agreements and only 37 cases of reported violence between States over water. We need to develop opportunities for cooperation that transboundary water management can provide for current and future generations. It is cooperation and not conflicts which can bear the fruits of efficient water management across the globe. It is understood that the opportunities for cooperation in transboundary water management can help to build mutual respect, understanding and trust among countries and promote peace, security and sustainable economic growth. Whether, we are on upstream or downstream of same drainage, we should treat ourselves on the same boat and needs to develop cohesive & coordinated approach of water management across the International boundaries. Indian States sharing International Boundary with Pakistan include Jammu & Kashmir Punjab, Rajasthan and Gujarat.

GENERAL INFORMATION

Districts of Rajasthan Sharing International Boundary with Pakistan are Ganganagar, Bikaner, Jaisalmer, and Barmer having total length in Rajasthan of the tune of 1070 Km (Fig 1). Sindh and Punjab are adjoining Provinces of Pakistan adjacent of Rajasthan State.

The terrain along border is rugged and inaccessible due to loose sand dunes and less road network. The border area is mostly barren and thinly populated. Geomorphologically, Thar desert is having landscapes of various types of dunes and inter-dunal depressions in major parts. Arid climate prevails in the transboundary area having even less than 200mm average annual rainfall. Rainfall is highly variable, irregular & erratic and the area is reeled under frequent droughts spells of 2 - 3 years durations. In

Fig 1: Districts of Rajasthan Sharing International Boundary with Pakistan

India, the trasboundary area is drained by the Ghaggar river while in Pakistan Indus, Jhelum, Chenab, Ravi, Vyas and Sutlaj drains the area.(Fig-2a &b) A large area of western Rajasthan and adjoining Pakistan has no natural drainage due to duny nature of terrain and low rainfall.

Fig-2a

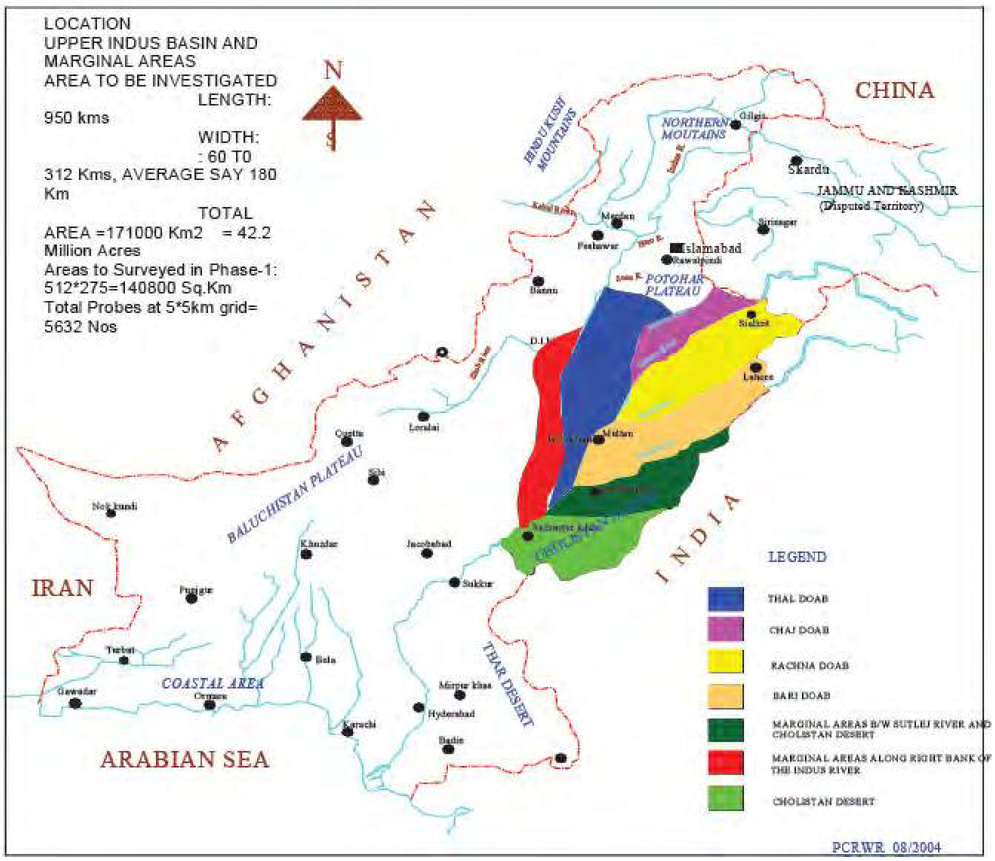


Fig-2b

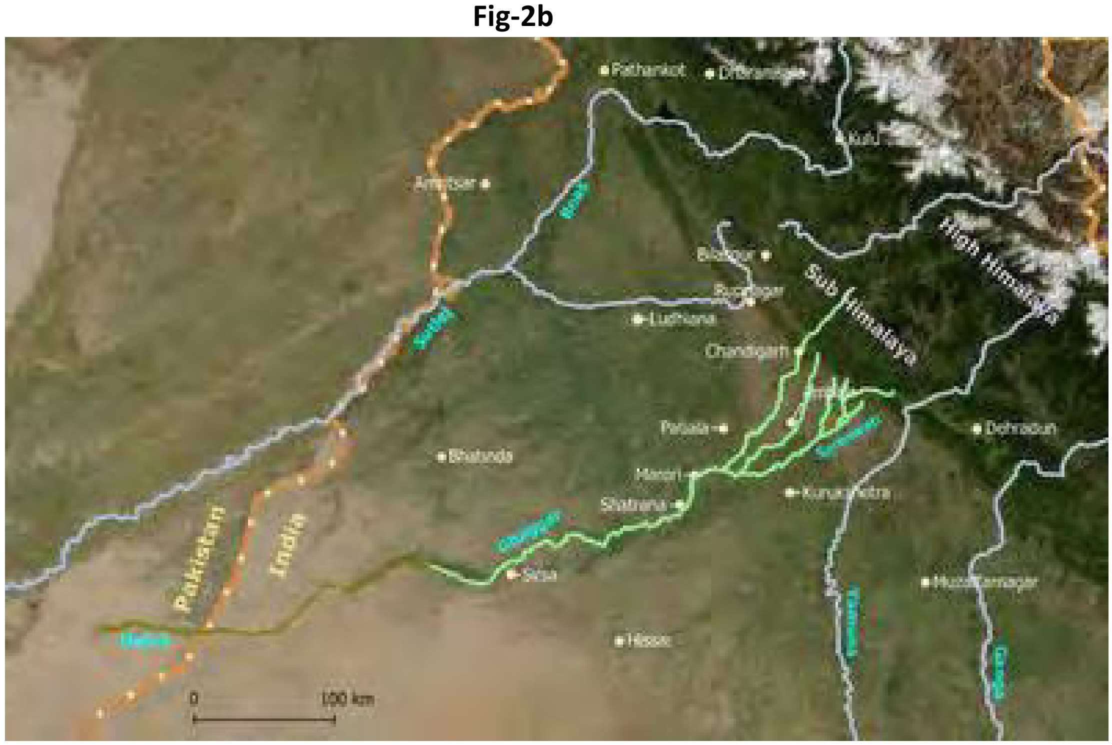


Fig-2a&b. Drainage system in India & Pakistan

A network of irrigation canals exist since pre-independence times in Pakistan. On Indian side Indira Gandhi Nahar almost runs parallel to the border in Ganganagar, Bikaner and Jaisalmer districts. The canal system in India and Pakistan is shown in Fig 3a and 3b respectively.

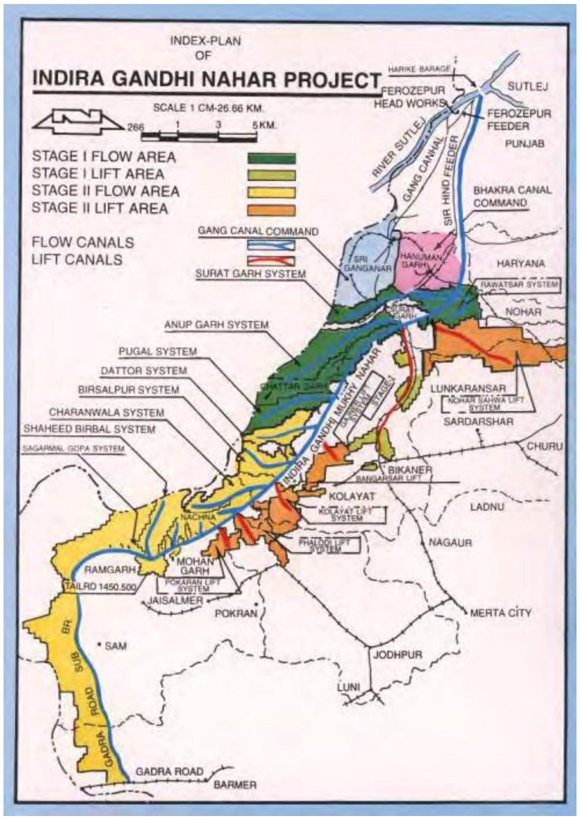
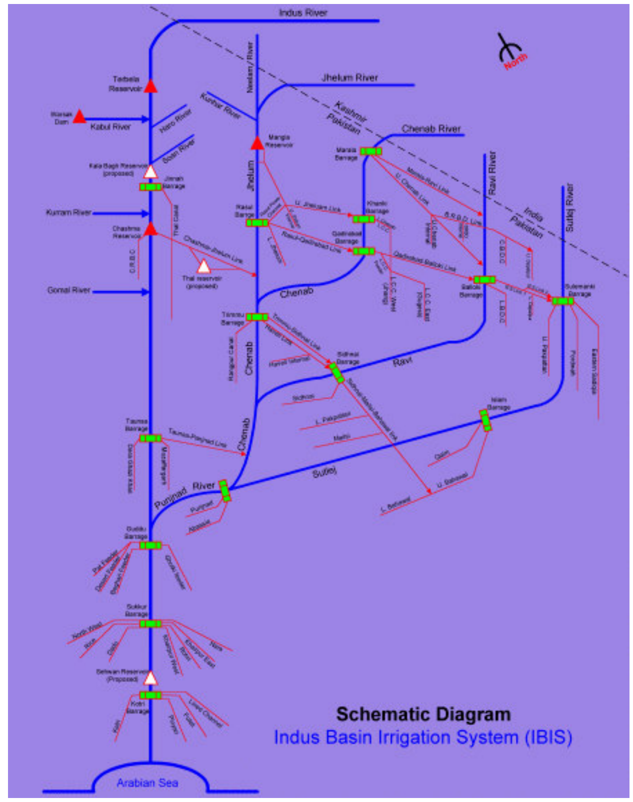


Fig 3a: IGNP Canal System, India



3b: Canal System in Indus basin, Pakistan

GEOLOGY

Geologically the area comprises of pre-cambrian granites and rhyolites, Lathi, Jaisalmer, Baisakhi and Badesar formation of Jurrassic age, Sanu, Khuiala, Banda, Akli, Kapurdih formation of Palaceocene – Ecocene age, alluvium and aeolian sand of quaternary age. The geological succession in Western Rajasthan is as follows in Table-I

Table-I. Geological Succession in Western Rajasthan

AGE	GROUP/SERIES	LITHOLOGY
Quaternary	Wind blown sand, Alluvium	Sand, silt, clay, kankar
Tertiary	Mandai Series Akli/Kapurdih/Jogira/ Mar/Banda/ Khuiala/ Palana Series	Loose sandstone, betonitic clay & fuller's earth
Mesozoic	Abur/Fatehgarh Series Parihar Series Bhadesar Series Baisakhi Series Jaisalmer Series Lathi Series	S.St, Lst, clay & lignite Felspathic Sst Ferruginous Sst Calcareous Sst Fossil Lst & Sst Sandstone & shale
Palaeozoic	Badhaura Formation Marwar super Group	Sandstone & boulders Jodhpur, Bilara & Nagaur Sandstone Shales & Limestones
Proterozoic	Intrusives & extrusives	Rhyolites and Granites

The geological section of western Rajasthan in Ganganagar and Bikaner districts has been represented in the fig 4.

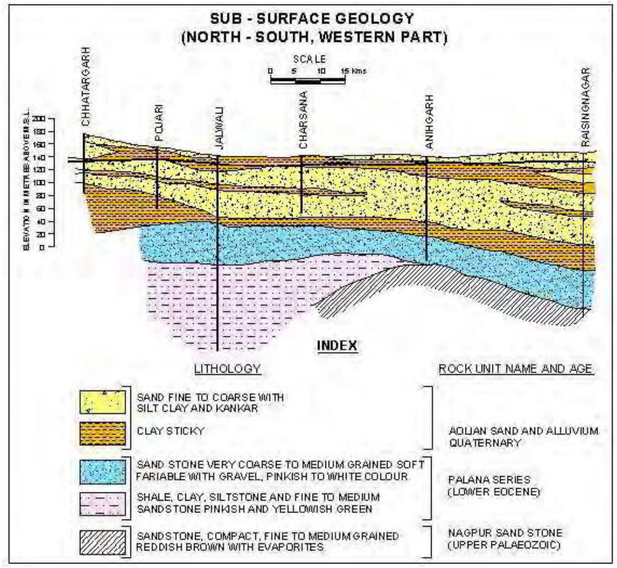


Fig 4: Sub-surface Geology of Western Rajasthan (Ganganagar & Bikaner)

HYDROGEOLOGY

International Hydrologic Programme (IHP) launched Internationally Shared Aquifer Resources Management (ISARM) project to evaluate world's transboundary aquifer systems. However, the available information reveals that Quaternary alluvium and aeolian sediments consisting of sand, silt, clay, kankar form aquifers in major parts of the transboundary areas (Fig 5) while Tertiaries also form aquifers in Barmer district (Fig 6). Successive Pre-Quaternary aquifers occur towards Aravalli hills in Rajasthan and towards Baluchistan Plateau in Pakistan. Depth to water levels widely varies from 5m in canal command areas to over 100 m below ground level(bgl) in other areas

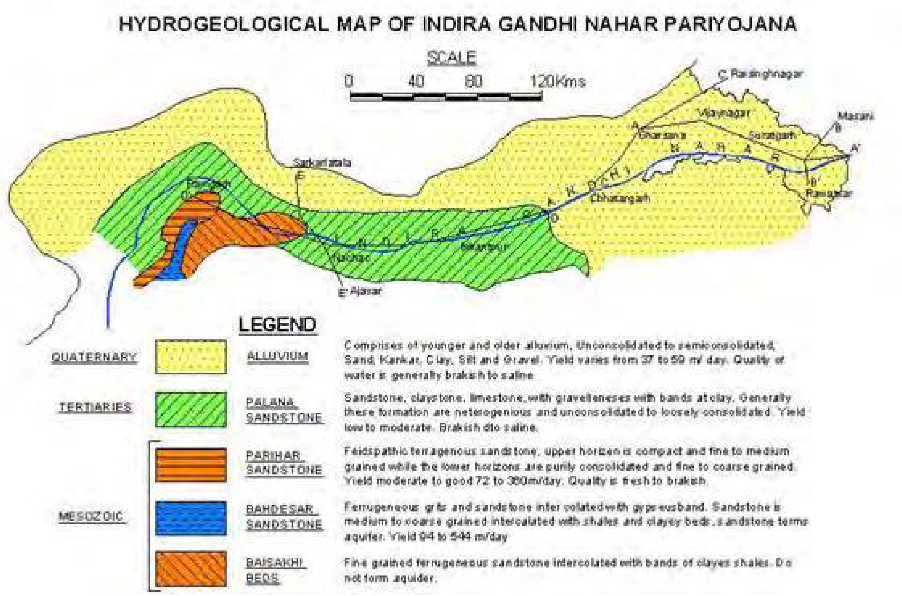


Fig 5: Transboundary Aquifer along Indira Gandhi Nahar Pariyojna in Rajasthan

Semi-Consolidated Formations:

Tertiary formation sediments are predominately argillaceous consisting of fine grained sandstone, limestone shales, clay, fullers earth and gypsum. Tertiary formation consists of alternate layers of clay and shales associated with fullers earth & bentonitic clay which are unproductive. The major part of the formation contains saline ground water. Tertiary sandstone form potential aquifer in Girab-Gadra–Khaniyani area of Barmer district and Sanu-Khuiyala area of Jaisalmer district. Depth to water level varies from 60 mbgl to more than 80 mbgl. Yield of the formation generally is less than 10 litres per second(lps).

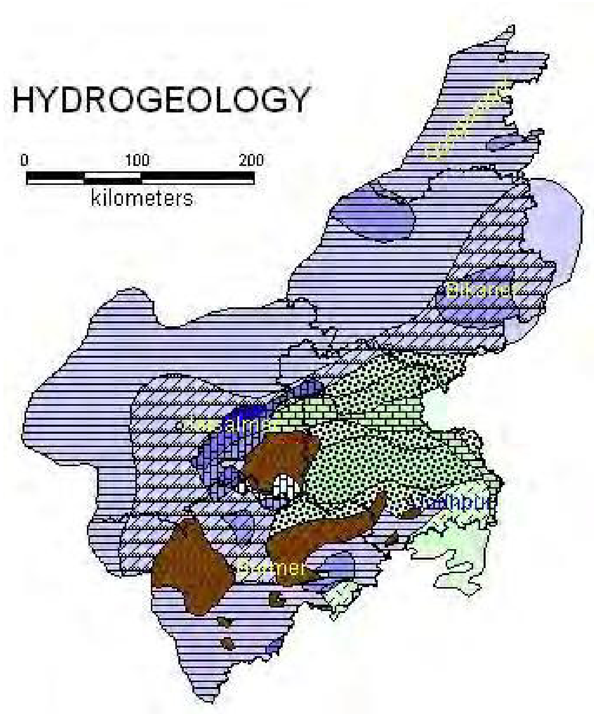
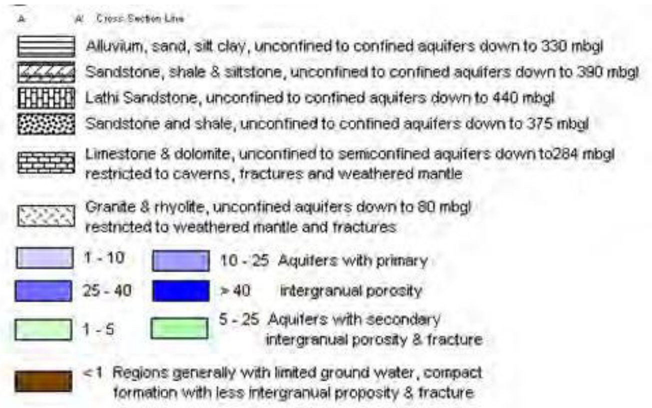


Fig 6: Hydrogeological Map of Western Rajasthan along Pakistan Border



Unconsolidated Formation:

The quaternary sediments comprising unconsolidated aeolian and alluvium are the important formations due to their wide spread occurrence. The sediments are composed of sand. silt, clay gravel, calcareous and ferruginous concretions and occur in northern, western and southern part of the area. Sand, gravel and admixture of these form fairly thick, extensive, discontinuous potential aquifer in southern part of Barmer district. However, a major part of alluvium contains saline ground water. The Ground water occurs under unconfined to confined conditions down to depth of 330 m. Depth to water level varies from less than 10 mbgl. to more than 60 mbgl. and become shallower towards the Luni river. Yield of the wells is generally less than 10 lps in this formation.

Depth To Water Level

Depth to water in the area varies largely from less than 10 to more than 100 m. bgl. However, over a major part of the area it varies from 20 m to > 60 mbgl. Deep water levels are observed in the Sam Block of Jaisalmer district, Sheo & Chohatan Block of Barmer district of Rajasthan.

Artesian Conditions in Thar Desert, Rajasthan

In the Thar desert , Jaisalmer is particularly known as drought prone district of the Region. There is scarcity of drinking water throughout the year. The area has inherent groundwater salinity in the upper aquifers and is occupied by thick pile of Tertiary and Quaternary sediments**.**

Central Ground Water Board has drilled an exploratory bore hole up to a depth of 202 m bgl at Jaluwala in Jaisalmer district close to international border. On the basis of the lithological and electrical log of the bore hole one promising granular zone has been demarcated at the depth of 180 m bgl under the upper saline ground water aquifers. Below the depth of this saline zone, in between 180 m to 198 mbgl, relatively fresh water was encountered with free flowing conditions. The flow of artesian well is 180 liters per minute, making available relatively the fresh water (potable) without lifting cost. Discovery of the artesian wells in desert is a important scientific achievement of the Central Ground Water Board. The fresh ground water is occurring under artesian conditions below the saline groundwater aquifers due to presence of confined beds of grey shales. The artesian aquifer comprises of coarse grained gravelly sandstone of Tertiary age.

In Pakistan also, Quaternary alluvium is the main aquifer system . Ground water flow is by and large westerly i.e. subsurface water from India is flowing towards Pakistan. The overall flow of subsurface water in Indus basin is southwestwardly. Quality of ground water is mostly saline on either side of the International boundary.

GROUND WATER QUALITY

In the area adjoining to international boundary along Rajasthan state, the EC ranges generally varying from 3000 to 10000 micro- mhos/cm and even higher. Groundwater development is not taking place significantly due to salinity, rugged terrain, low population density and availability of canal network on either side of the International border. Water logging is also taking place on both sides of border due to intensive irrigation in canal command areas. Ground water of fresh quality also occurs in pocket areas along the length & breath of the international boundary (Fig 7).

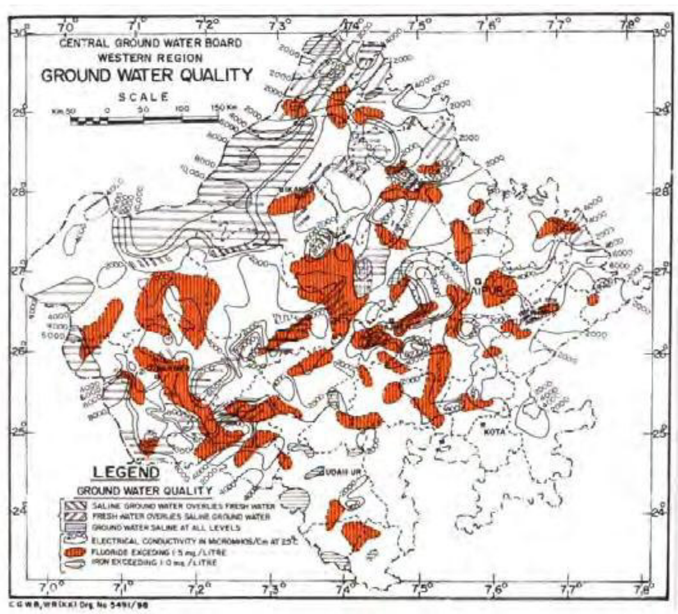


Fig 7: Map showing Chemical Quality of Groundwater, Rajastahan

ORIGIN OF A FRESH GROUND WATER BODY IN CHOLISTAN, THAR DESERT, PAKISTAN

Cholistan is the largest of four major deserts of Pakistan (Fig.8). It is bordered on the south by the Thar desert in Sindh province and on the east by the Rajasthan desert in India. The Cholistan desert covers about 26,000 km^2 which corresponds to 26% of the 110,000 km2 of the country's total desert area and 3% of its overall surface area.

Fig 8 : Cholistan Desert, Pakistan

The Thar Desert of Pakistan stretches along the border to India and is one of the most densely populated deserts in the world. Brackish to saline groundwater prevails. A locally restricted fresh groundwater resource was discovered by a comprehensive hydrogeological, geophysical, and isotope hydrological survey conducted from 1986 to 1991. The origin, recharge mechanism and age of the fresh groundwater resource were assessed. There is only fossil groundwater and this must be mined. Sodium is the predominant cation. Present groundwater recharge is absent or extremely low as the annual precipitation rate and the potential evapotranspiration rate amount to less than 200 mm/yr and about 2700 mm/yr, respectively. The results of this study delivered a hydrogeological concept on the origin and recharge of the fresh groundwater body. We found that the fresh groundwater was indirectly recharged during flash floods in low lands during the last pluvial period rather than directly replenished in the high mountain areas far in the east.

Hydrogeological Setting

The 18-Q m line of the apparent resistivity, related to 50 m depth below the surface comprises a 14 km wide and 98 km long strip. It traces a fresh groundwater body directed from east to southwest as the Old Hakra River (Fig. 9 &10). This apparent resistivity corresponds to an electrical conductivity of groundwater of less than 1500 μS/cm corresponding to 900-1200 mg/litre (Ploethner, 1992). The average fresh groundwater saturated aquifer thickness is about 100 m; the total volume comes to 10 km^3, which is almost completely embedded by brackish to saline groundwater. The electrical conductivity of the latter varies from up to 3400 at the top to 29000 μS/ cm at a depth of 100 m, and 52000 μS/ cm in the east.

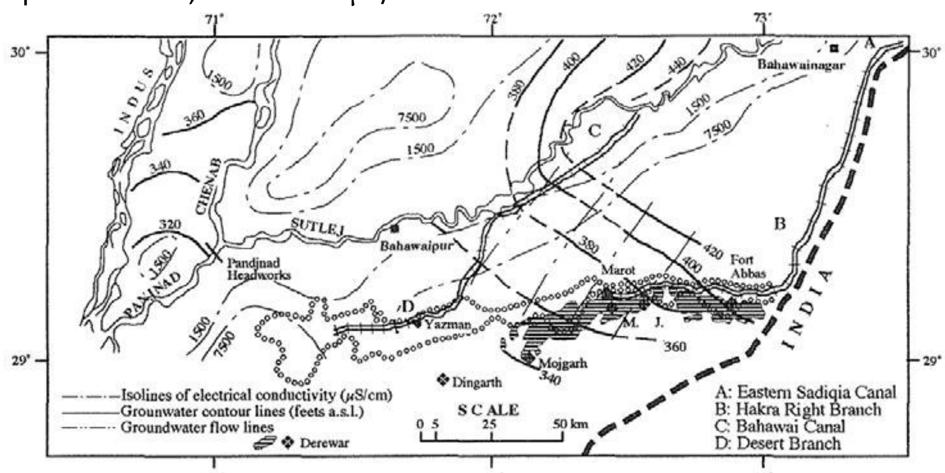


Fig 9: Map of Northern Cholistan**.**

(The former bed of the Old Hakra River is surrounded by circles. Hatched area is the extention of the fresh ground water resources, shifted to the south)

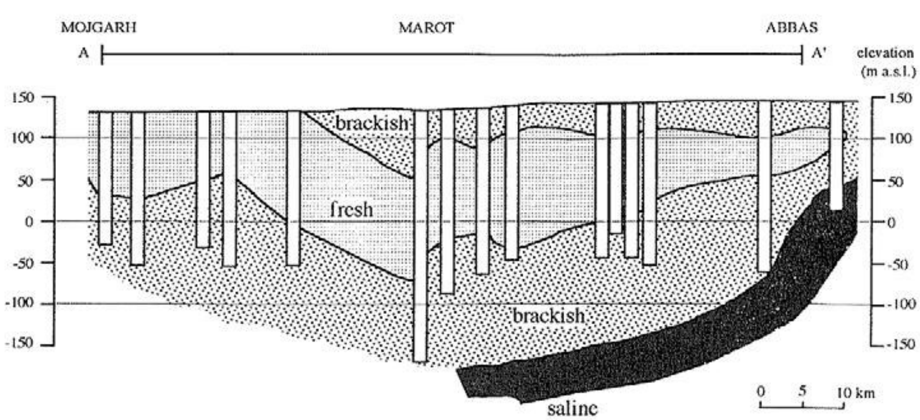


Fig-10.Hydrogeological Section of Old Hakara Aquifer (Ploethner, 1992)

The fluvial sediments consist of slightly calcareous and micaceous fine grained sands, covered and interbedded by sandy-silty clays. This setting is a typical semiconfined aquifer system. The total porosity was found by grain size analysis to be 40%, while the effective porosity, is assumed to be 15% (Ploethner, 1992). The unconsolidated sediments explored by drillings down to 500 m consist of medium to coarse-grained sands below about 100 m. The hydraulic gradient, *D,* from east to southwest is about 0.3*%.* The hydrochemistry of the fresh groundwater is of the Na-HCO3 or Na-HCO3-Cl type. It changes from Na-Cl-HC03 and Na-Cl-S04 towards the Na-Cl type with increasing depth and salinity.

The fresh groundwater meets the chemical standards laid down for drinking water. however, its suitability for irrigation purposes is limited due to the high proportion of sodium. The isotope hydrological study is needed to prove the occurrence of present-day recharge of the fresh groundwater resources occurs.

GROUNDWATER DEVELOPMENT IN RAJASTHAN

Ganganagar District- Tube wells of 30-70m depth tapping shallow unconfined aquifer have been developed with medium yield. In Ghaggar bed area, shallow tube wells up to 40m depth with moderate yields are in use. Native groundwater is saline in the district.

Bikaner District- The alluvial aquifer in bordering area is mostly saline with meager groundwater development.

Jaisalmer District- In northern part, alluvial aquifer are mostly saline with meager groundwater development. In NW corner of the district, alluvial aquifer is in limited patches at Kishangarh, Dharmi Khu, Ranau, Ghotaru area is fresh, however overall native quality is brackish to saline. Groundwater development is negligible due to scarce population and barren dunes.

Barmer District- In North Western part Tertiary aquifer in Sundra-Gadra area has better quality of water under unconfined to confined conditions. Alluvial & Tertiary aquifers in other parts have brackish to saline groundwater and tapped by tube wells for domestic/cattle uses.

CONCLUSION

- The long border of Rajasthan with Pakistan is mainly occupied by alluvial aquifer having native saline to highly saline groundwater.
- The underlying Tertiary formation also have saline groundwater with meager to moderate groundwater potential.
- Alluvial and tertiary aquifers of Barmer district have brackish to saline groundwater with isolated patches of better quality groundwater.
- In Pakistan part adjoining to Indian border, alluvium forms the principal aquifer. The quality is largely saline. Fresh water is found in small pockets and along some inferred paleo- channel courses.
- A network of irrigation canals exist since pre-independence times.
- Ground water development is very low due to saline ground water, rugged terrain, low population density and canal network in bordering areas.

RECOMMENDATIONS

- Fresh Groundwater development can be enhanced in Ghaggar bed area to utilize sub-surface flow going out across the border.
- Shallow freshwater cushion developed along IGNP canal can be tapped through shallow skimming wells, so as to prevent its westward dissipation. Conjunctive use of surface and ground water will also avoid water logging and salinity hazards in the vicinity of canal command areas.
- Canal water thus saved can be utilized in tailend/down stream areas of IGNP.
- Comparatively better quality groundwater is available in Sundra & Gadra of Barmer districts, which can be further developed for regional drinking water supply schemes in adjoining saline desert areas.
- Fresh Groundwater found in Kishangarh, Kuria Beri, Ghotaru & Ranau area in Jaisalmer cannot be utilized presently because of little settlements.
- Mutual trust and conducive relationship is pre-requisite between India and Pakistan for joint assessment and management of Trans- boundary water especially to tap aquifer systems for mutual benefits.

REFERENCES

- M. A. Geyh & D. Ploethner: Origin of a fresh groundwater body in Cholistan, Thar Desert, Pakistan.
- M. A. Geyh & D. Ploethner : An applied palaeohydrological study in Cholistan, Thar Desert, Pakistan
- Case Study Volume: Pakistan: The Cholistan desert: facing the challenges, World Water Development Report 3.
- Central Ground Water Board Western Region, Reports.

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Abhijit Ray, Bhujal News, 25:1&2(2010), 37-44

Transboundary Aquifers with Special Reference to Indo-Bangladesh Border

Abhijit Ray
Regional Director(Retd), Central Ground Water Board

INTRODUCTION

Transboundary aquifers are as important a component of global water resource systems as are transboundary rivers. For river system, the connection is visible and the mutuality is obvious. This is not the case for shared aquifers, since aquifers are invisible in their natural state. As in any transboundary resource, management of these aquifers may prove to be a daunting challenge, as it requires collaboration among various levels of water management institutions within a country and among the different countries involved. The challenge is compounded by the fact that there is no international convention, specially addressing transboundary aquifers.

Many aquifers today are being depleted, while others are being contaminated. Notwithstanding world's considerable reliance on this resource, groundwater resources have long received secondary attention as compared to surface water, while there are hundreds of treaties governing transbound of rivers and lakes, existing international conventions and agreements barely address transboundary aquifers and their resources. Many of the regionally extensive aquifers, on which humanity so heavily relies, cross international borders. But there is a considerable gap in the sound management, allocation and protection of such resources. Many shared aquifers are under environmental threats caused by climate change, growing population pressure, over exploitation and human induced water pollution.

It is estimated that there are about 273 shared aquifers in the world (68 in America, 38 in Africa, 155 in Europe and 12 in Asia). One of the largest aquifers in the world is the Gurani Aquifer or GAS (Gurani Aquifer System), extending over 1.2 million square kilometer, shared by Brazile, Argentina, Paraguay and Uruguay. Nubian Aquifer System caters to the needs of Chad, Egypt, Libya and Sudan. Iullemedan Aquifer extends over 50, 000 sq. km. in the semi-arid and tropical Savanna ecoregion of West Africa, Niger, Nigeria and Mali.

In order to prevent future disputes over transboundary aquifers and to maximize the beneficial use of this resource, international law must be clarified as it applies to transboundary ground water resources. International Association of Hydrogeologists and UNESCO's International Hydrological Programme have established the 'Internationally Shared (transboundary) Aquifer Resource Management (ISARM) Programme'. This multiagency co-operative programme has launched a number of global and regional initiatives. These are designed to delineate and analyse transboundary aquifer systems and to encourage riparian states to work towards mutually beneficial and suitable aquifer development.

TRANSBOUNDARY AQUIFERS WITH RESPECT TO INDO-BANGLADESH BORDER

Ganga – Padma Interfluve in parts of Bangal Basin: Ganga – Padma interfluve area of West Bengal constituting a part of Bengal Basin (Fig-1) as well as a part of adjacent area to Bangladesh border where the shallow aquifers are being extensively used for irrigation purposes, has been considered for discussion in this paper. In the area the sediments comprising the aquifers system that crosses the international boundary between India and Bangladesh, geologically known as the 'Bengal Basin', consist of a succession of Quaternary Alluvium sediments of varying thickness, deposited by Ganga-Brahmaputra-Meghna rivers and their distributaries.

Tectonic history of Bengal Basin: The Bengal Basin is bounded on three sides - west, north and northeast by Pre-Cambrian crystalline rocks, the eastern side by Tertiary hill ranges of Assam-Burma arc and in the south by Bay of Bengal. The Archaean shield area in the western boundary of Bengal Basin which gradually disappears below a thin veneer of alluvium towards east and a row of enechelon faults marks the basin margin. The stable shelf zone of the basin is dipping gently to the southeast and is practically undisturbed tectonically except for a row of normal faults passing through Jalangi-Debagram-Burdwan-West Ghatal area . The stable shelf zone is occupied by sediments of Mesozoic and Tertiary age beneath the recent to sub-recent alluvium, the thickness of which increases uniformly from west to southeast from 900 m to 2700 m. After the formation of Garo-Rajmahal gap in the Pleistocene, the sedimentation pattern in Bengal Basin changed completely and a tremendous rate of growth started in the southern part of the basin. The edge of the stable shelf is marked by a zone of flexture (the hinge zone of the basin). The "deeper parts" of the basin which lie beyond the hinge-zone, occupy most of the eastern and southeastern parts of Bangladesh.

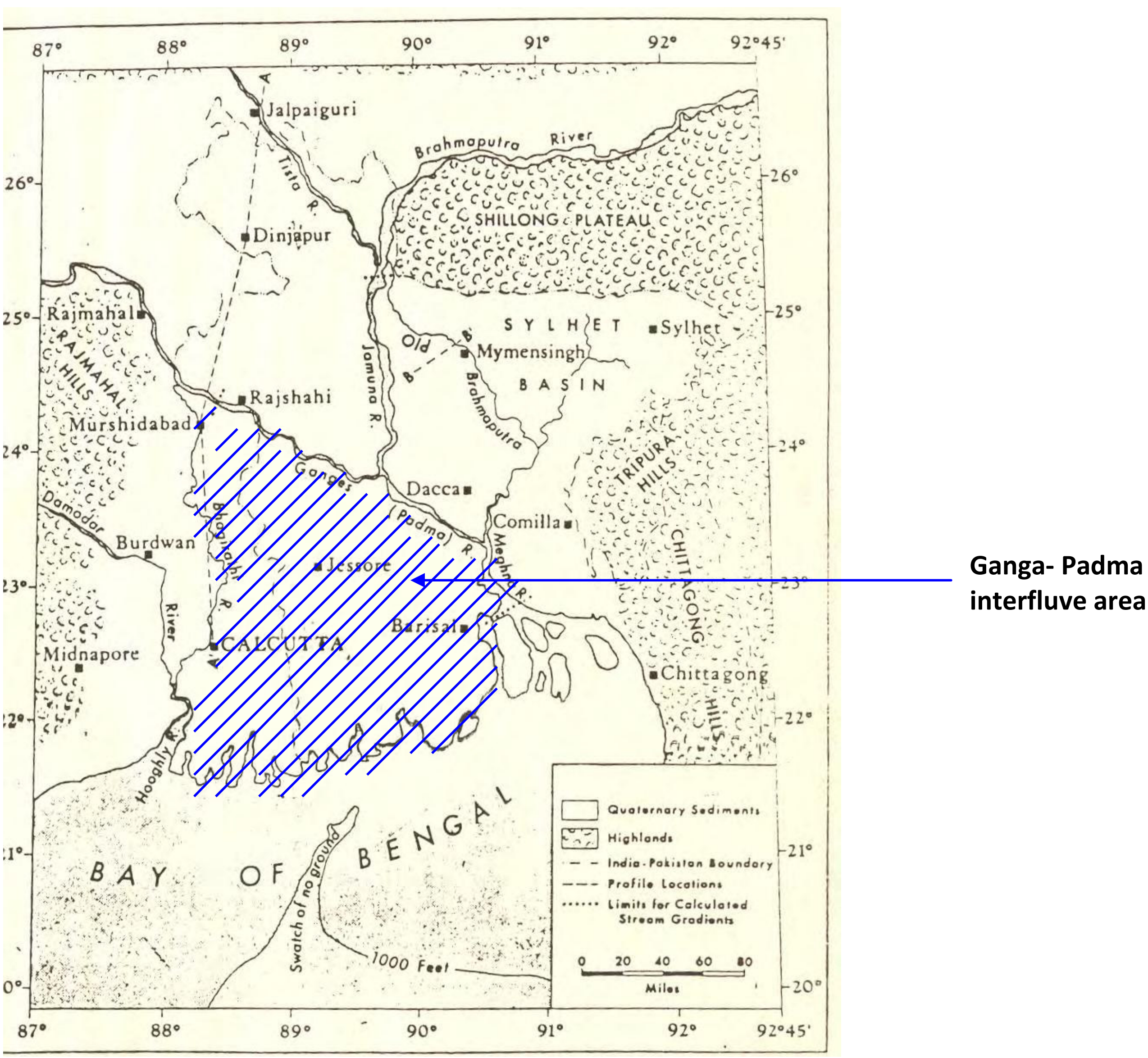


Fig 1 Quaternary geology of Bengal Basin (After Morgan and McIntire)

HYDROGEOLOGY OF GANGA/ PADMA INTERFLUVE OF WEST BENGAL ADJOINING TO THE INTERNATIONAL BORDER WITH BANGLADESH

Aquifer disposition: Ground water exploration, in the area lying to the east of the river Bhagirathi up to the international boundary falling in the districts of Murshidabad, Nadia and North 24 Parganas, reveals (Fig-2 a& 2b) that in general, three aquifer systems exist within the depth range of 100 mbgl, below 120 – 180 mbgl and 200 –250 mbgl. The individual aquifer system consisting of two to three aquifers (which vary from place to place), are separated by thin clay layers which are in lensoid form and are not regionally extensive. The material of the first aquifer system (10-40 m thick) is generally fine to medium grained sand. The aquifer material of the second aquifer system (5-30 m thick) is medium to coarse grained of Pleistocene age while that of the third aquifer system (5-20 m thick) coarse grained with gravel at places which is of Pleistocene to Tertiary age. The thickness (5-40 m) of the individual aquifer gradually decreases with the depth. In the northern part of the area, falling in Murshidabad and northern part of Nadia district the first aquifer gradually gets clubbed with the second aquifer without appreciable clay barrier.

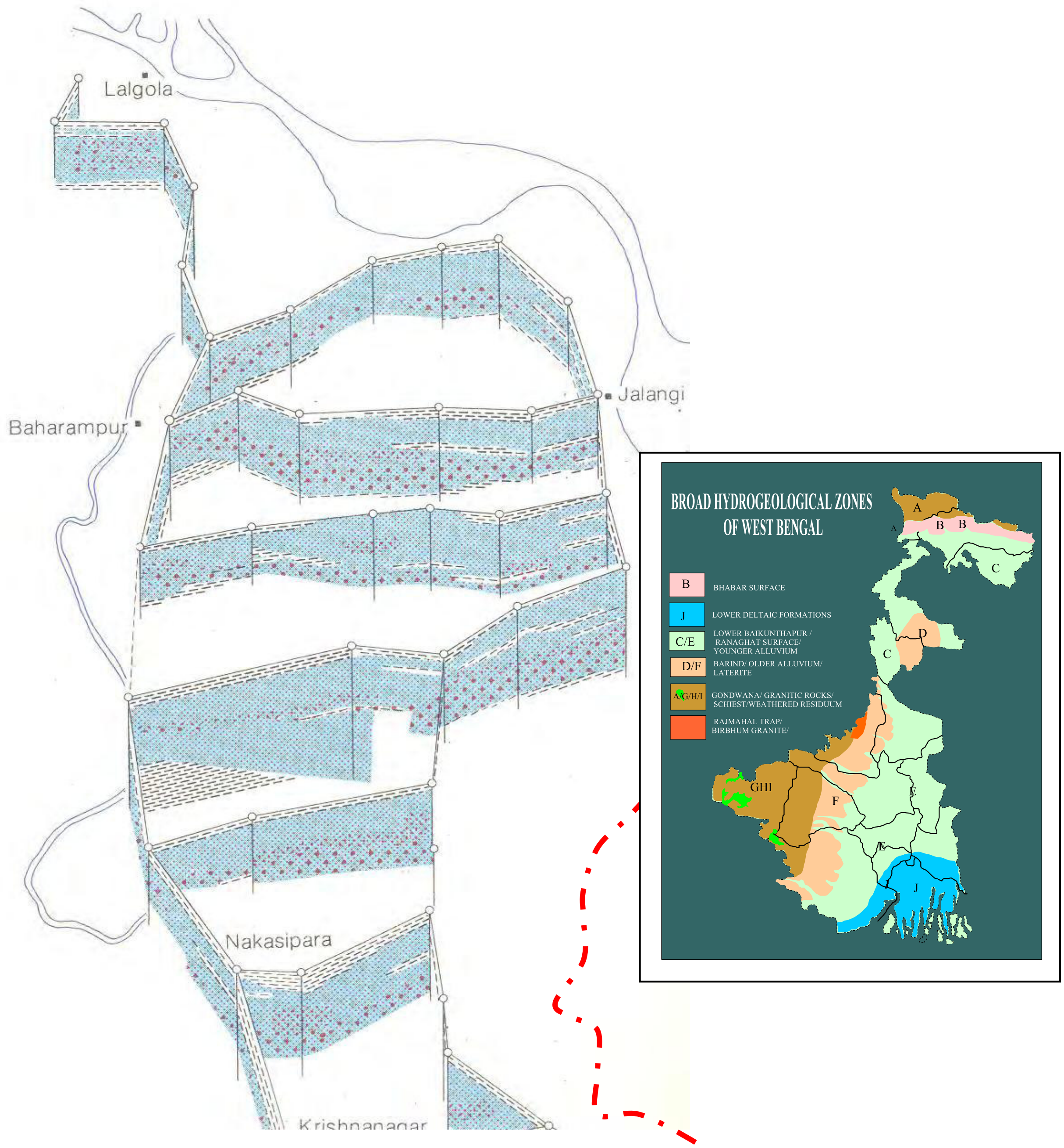


Fig 2a Sub Surface Lithological Correlation Adjacent to Murshidabad & Nadia District

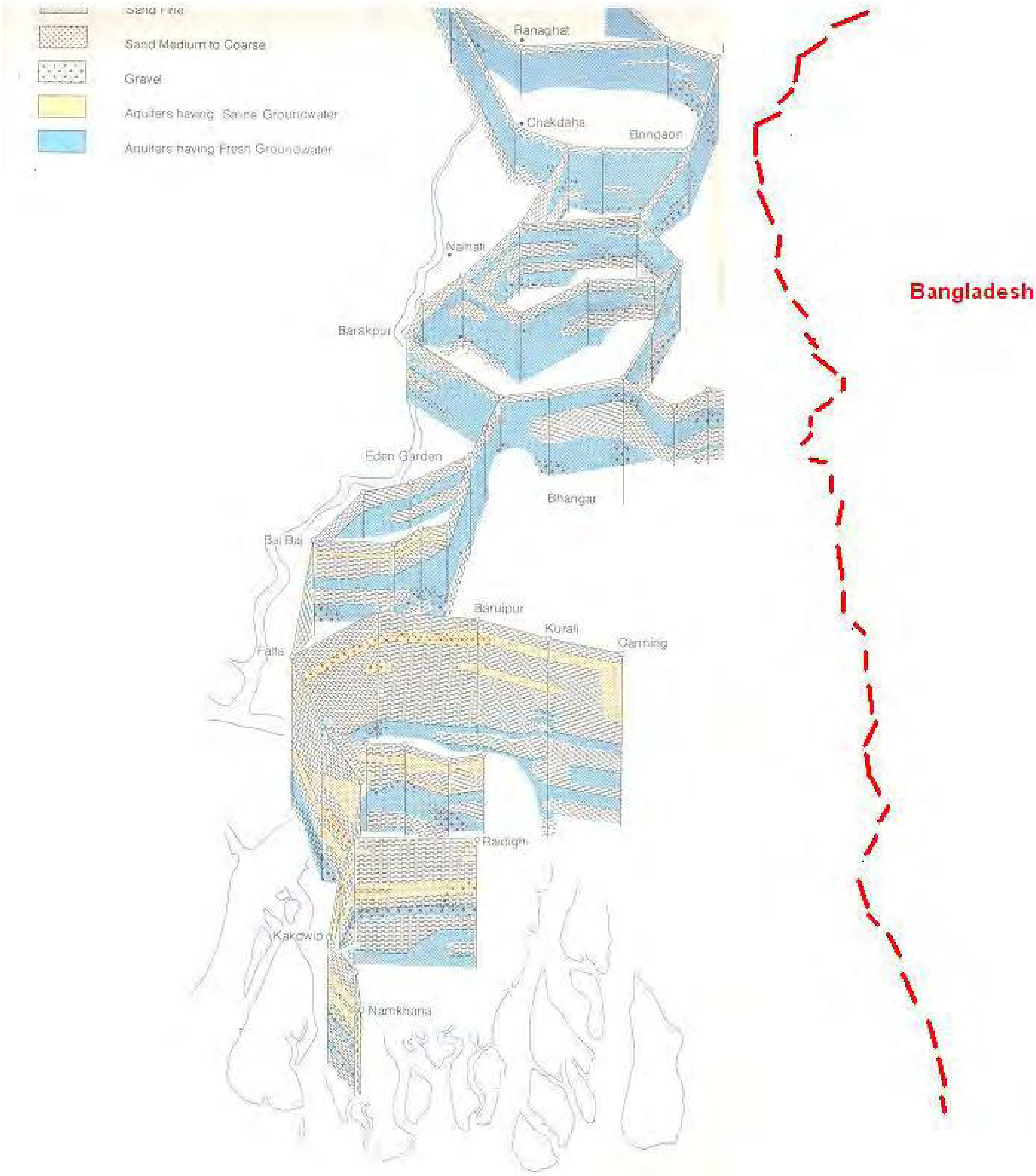


Fig 2b. Sub Surface Lithological Correlation In Southern Part of Nadia,North 24 Parganas & South 24 Parganas District Bordering Bangladesh

In the district of South 24 Parganas, aquifers at different depth levels are composed predominantly of fine to very fine sand. It has also been found that towards the south in the active delta part, the aquifers are separated by thick clay layers. These clay layers control hydrochemical properties of the different group of aquifers. The lower group of aquifers relatively fresh water bearing and generally occurs between the depths of 180 - 350 m. The clay blanket here ranges in thickness between 30 - 70 m and overlies a succession of sand and gravel sequence.

Ground water Condition: The depth to water level in the area under consideration varies from 2.11 to 6.70m bgl during post-monsoon period and 2.35 to 9.46 m bgl during pre-monsoon period (2008). Average seasonal fluctuation of water level varies from 1.47 to 4.14 m from April to November. The upper aquifer is developed mainly through Low duty to heavy duty tubewells used mainly for irrigation and are capable of discharging 30 to 150 m^3/hr. Deep tubewells are mainly constructed for drinking water supply and are capable of discharging 50 to 100 m^3/hr. Transmissivity ranges from 1000 to 4500 m^2/day in the upper aquifer and 758 to 2000 m^2/day in the deeper aquifer. Storativity of the aquifers ranges from $1.1x10^{-2}$ to $3.5x10^{-4}$.

Ground water quality : In general, ground water in shallow aquifers within the depth of 100 mbgl, except in South 24 Parganas and parts of North 24 Parganas districts (coastal area), is potable and within the permissible limit of drinking water standard as referred by BIS, except the occurrence of arsenic in sporadic manner. High arsenic in ground water (>0.05mg/l) has been detected in a sporadic manner in 79 blocks of west Bengal fringing the Bangladesh mainly within the depth of 80m bgl and most of the blocks are in the eastern part of the river Bhagirathi. It has been established that arsenic in ground water in this area is geogenic and mainly restricted within the recent to sub-recent alluvium deposits. Ground water exploration in the arsenic infested area reveals the existence of deeper arsenic free aquifer and tubewells constructed adopting cement sealing techniques are capable of yielding 10 to 30 lps of arsenic free water which are being supplied for drinking water purposes. High arsenic in ground water within the upper aquifer is also common in adjoining Bangladesh. In the coastal tract of West Bengal the top aquifers down to 150 mbgl is brackish which extends eastwardly into Bangladesh. Existence of deeper potable aquifer has also been Identified in West Bengal and suitably designed tubewells are capable of yielding fresh potable water in coastal tract of West Bengal.

Ground Water Resources: In the area under discussion, ground water occurs under unconfined condition in 52 blocks of the districts of Murshidabad, Nadia and North 24 Parganas and the dynamic ground water resources (as on March, 2004) of the blocks has been estimated based on the GEC 1997 methodology and 3rd M.I. Census, 2000-01, projected upto March, 2004 and reconciled with the concerned State departments. In the rest of the areas, falling in South 24 Parganas district and in 5 blocks of North 24 Parganas district, ground water occurs under confined condition and the ground water resource estimation for the area has not been done. The net ground water availability of the 52 blocks has been estimated as 491876 ham/ year. Large scale development has been done in the area, specially for irrigation through 1411 deep tube wells, 218842 shallow tube wells and 2 dug wells (as per 3rd Minor Irrigation Census, 2000-2001), which is reflected by 89% stage of ground water development figure in the area. The estimated gross ground water draft for all uses is 438490 ham, of which 95.55% (418969 ham) is for irrigation only. Based on the stage of ground water development and long term pre and post monsoon water level trend, 17 nos of blocks (11 in Murshidabad and 6 in Nadia districts) have been categorized as Semi-critical and the rest of the blocks (35 nos.) are under 'Safe' category.

Shared Aquifer : It is observed from the available literature that the first aquifer within the depth of about 100 mbgl as observed in the N-S profile of holocene sediments across Ganga delta (Fig-3) is continuing in Bangladesh (Bahadulabad-Gabargaon-Sirajgang—Sibaloya-Faridpur-Khulna-Mongla tract) (Fig-4) The information regarding deeper aquifers in Bangladesh is not available. However from the sub-surface lithological correlation diagram (Fig-5), it appears that the shallow as well as deeper aquifers continue beyond the international boundary. This is also corroborated by the fact that:

- Depositional history of the transboundary aquifers is the same being the part of the Bengal Basin.
- Regional ground water flow, which follows the master land slope, is towards south-east on the either side of the boundary. However, pattern of the water table configuration may behave differently in localized patches based on the draft component.

- In coastal tract of West Bengal, salinity in ground water is common which is also continuing in Bangladesh.
- The nature of crops grown by ground water is common in West Bengal and Bangladesh indicating same nature of chemical condition of soils.
- The ground water irrigation is common in both side of the boundary through low duty as well as heavy duty tube wells which indicates that the shared aquifers are potential and prolific in their water yielding capacities.
- The shallow aquifers (within 100 mbgl) in West Bengal are sporadically arsenic contaminated and the same scenario has been projected for Bangladesh also (Fig-6). Since the geogenic origin of the contamination has been established, the provenance of sediments in both the countries appears to be same.

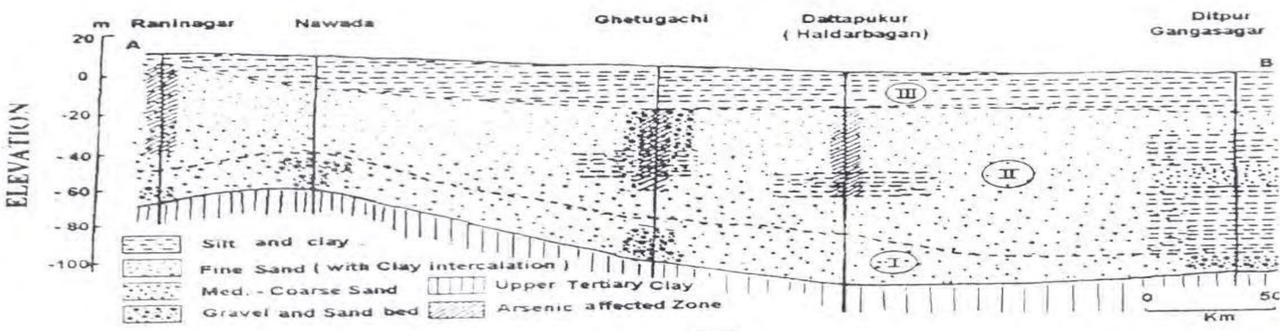


Fig-3 Profile of Holocine Sediments Across Ganga Delta (N-S) In West Bengal

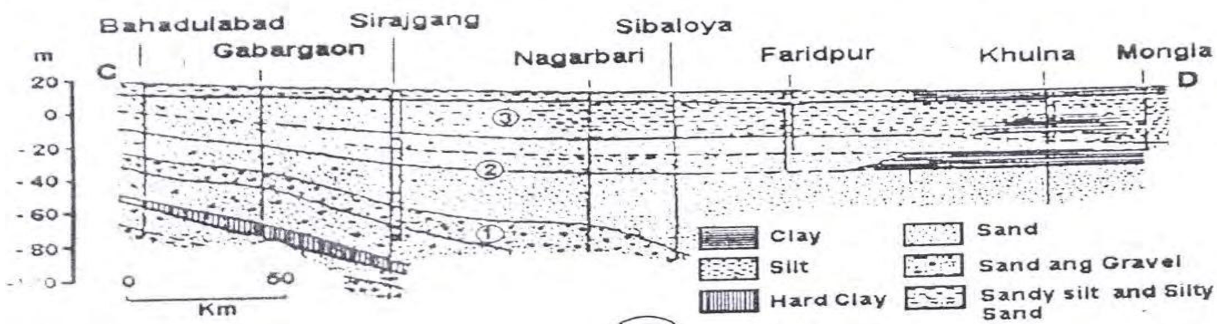


Fig-4. Profile Of Holocene Sediments Across Jamuna Flood Plain And Ganga Delta (N-S) In Bangladesh

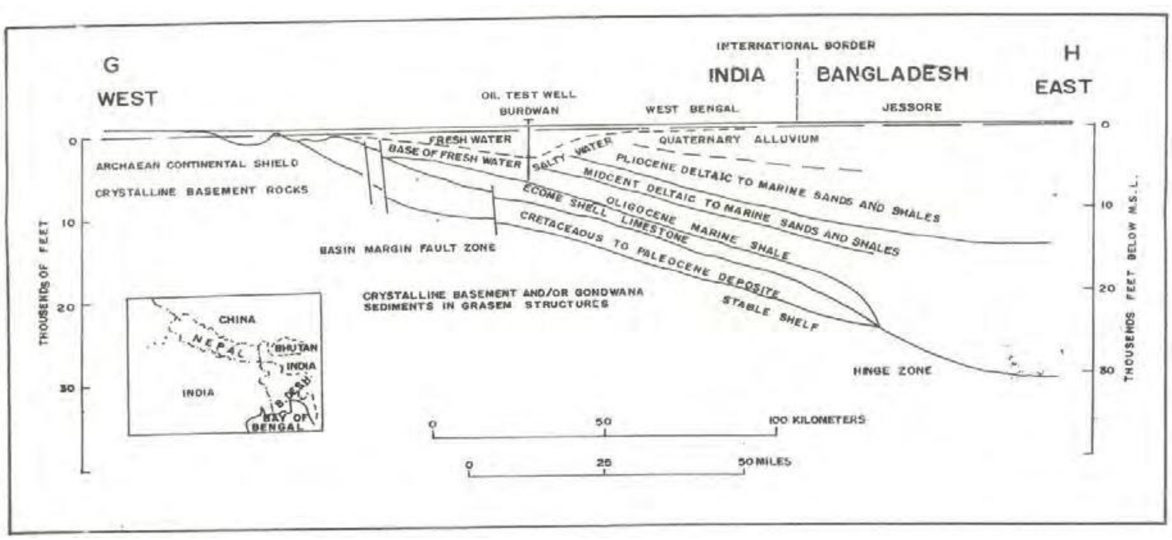


Fig-5. Geologic Section Across The Western Margin of The Bengal Basin

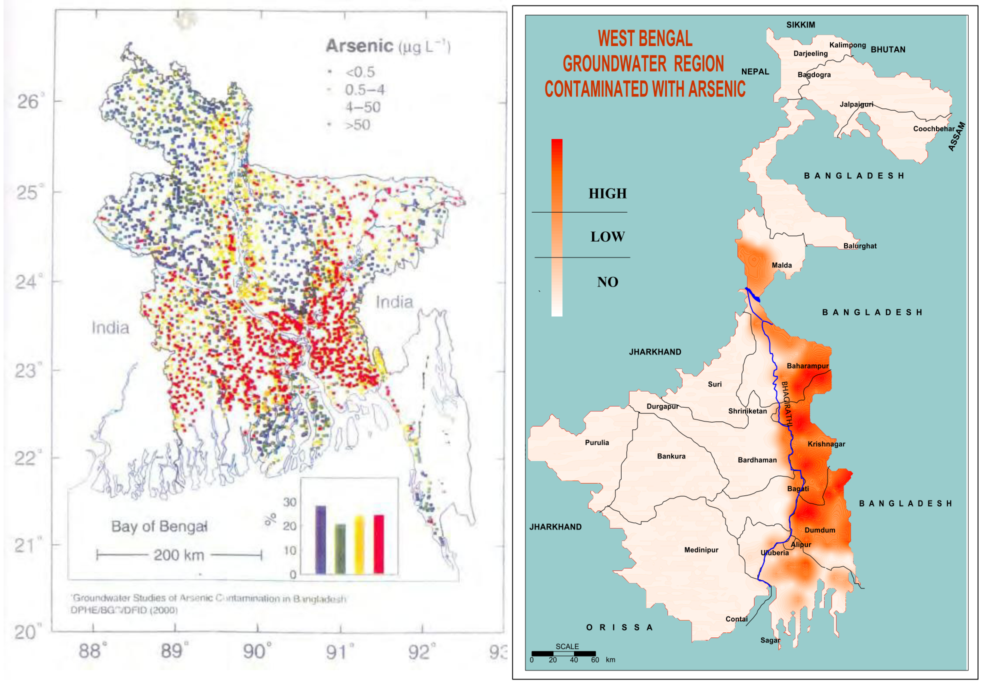


Fig-6. Arsenic Infested areas of West Bengal & Bangladesh

RELATION BETWEEN TRANSBOUNDARY AQUIFERS AND TRANDSBOUNDARY RIVERS/STREAMS

Source of Water for both surface water and ground water is the annual rainfall. Surface water commonly is hydraulically connected to ground water but their interactions are difficult to observe and measure. Streams interact with ground water in three basic ways.

1. Streams gain water from inflow of ground water through this stream bed (gaining stream),
2. they loose water to ground water by outflow through this stream bed (loosing stream),
3. they do both, gaining in some reaches and loosing in other reaches

However, ground water contributes to streams in most physiographic and climatic settings. An analysis indicates that on an average (which varies in time & space), 52% of the stream flow is contributed by ground water, which ranges between as low as 14% as high as 90%. Withdrawing water from shallow aquifers that are directly connected with surface water bodies, can have a significant effect on movement of water between these two bodies, specially when in number of wells withdraw water from safe aquifer over large areas.

The subsurface zone where stream water flows through short segments of its adjacent beds and banks is referred to as “Hyporheic” zone. The size and geometry of hyporheic zone surrounding streams vary greatly in time and space. Because of mixing between ground water and surface water in the hyporheic zone, a chemical and biological character of the hyporheic zone may differ markedly from adjacent surface water and ground water. Contaminated aquifers that discharge to streams can result in long term contamination of surface water, conversely streams can be source of contamination of aquifers.

It is therefore evident that any development and management plan on transboundary aquifers can not be viewed in isolation without considering the impact that the shared aquifers may undergo due to different international agreements and treaties on sharing of water from transboundary rivers.

STEPS TO BE ADOPTED FOR DEVELOPMENT AND MANAGEMENT OF TRANSBOUNDARY AQUIFERS (INDIA & BANGLADESH):

- The dynamic ground water resources of upper unconfined aquifer (upto depth of 100m bgl) in Bengal Basin have to be assessed in totality and its component in small sectors (like block/ taluk/ administrative division) can be assessed separately. This will give the replenishable ground water recharge into the aquifer as a whole as well separately in the different small sectors. Also the existing ground water draft needs to be calculated in Bengal Basin and its component in different sectors as described above. This can give a clear picture for future ground water resources to be utilized in different sectors. Accordingly the scope of development of the aquifer can be planned. This study is required to be done jointly with the team of both the countries (India & Bangladesh).

- In the vicinity of the International boundary it needs to be monitored that any pattern of ground water trough in the transboundary aquifers does not get developed due to significant ground water abstraction by the individual country. If possible measures/ legislation may be imposed in such cases in the vicinity of international boundary.

- In case of deeper confined aquifer (in these case aquifers below 120 m bgl) the recharge area of the aquifer has to be clearly assessed by the individual country. If recharge area of an aquifer of a country lies in other country (like some deeper aquifer in Bangladesh may have recharge area in India) then judicial measures may be adopted jointly by both the countries, so that the deepening of piezometric level of the aquifer in the territory of one individual country may not pose hazardous environmental impact like possibilities of contamination, land subsidence etc. on the other country. In this respect it is better to evaluate the ground water flow in a particular area and its judicious use so that regional flow pattern does not get unduly changed.

- Constant monitoring of water level and water quality in shallower & deeper aquifers has to be assessed jointly by both the countries specially adjacent to the international boundary which can give the future implementation policies for further ground water development of the transboundary aquifers.

- Aquifers contributing water to the surface water bodies like gaining rivers bordering the international boundary or flowing from one country to other should be developed cautiously to maintain the surface water flow as well as to prevent the possibilities of contamination of ground water from the surface water flows. Similarly the rivers loosing water/ recharging water into ground water bodies can be judiciously used to avoid further contamination.

- Scope for artificial recharge in the depleted aquifer may be taken up by the individual country in consultation with the neighboring country to recharge water of desired quality.

- Modern management practice for irrigation may be adopted for judicious use of ground water. In this context crop water requirement should be taken into account and low water required crop may be adopted changing the cropping pattern in the water level depleted areas.

- Cautious approach requires to be taken up during the construction of wells so that, upper arsenic contaminated aquifer does not get hydrologically connected with the deeper arsenic free aquifer during the construction of tube well/bore well. In this context it may be mention that cement sealing techniques has yielded positive results to get arsenic free water from deeper aquifer.

Transboundary Aquifers and Ground Water Resources of the Indian Sub-continent with Special Emphasis on North East India

G.C.Saha
Regional Director(Retd), Central Ground Water Board
S.Somarendro Singh
Scientist, Central Ground Water Board, Guwahati

Abstract

One half of the world populations are dependent on ground water for their everyday domestic uses, and hygiene. In fact, ground water is the most extracted natural resource in the world. The constant trend of emergent populations and mounting economies, many aquifers today are being depleted while others are being contaminated. In spite of the world's considerable dependence on ground water resource, secondary attention is being received as compared to surface water, especially among legislatures and policymakers. Today, while there are hundreds of treaties governing transboundary rivers and lakes, there is only one international agreement that directly addresses a transboundary aquifer. Given that many of the aquifers on which humanity so deeply relies cross international borders, there is a significant gap in the sound management, allocation, and protection of such resources. In order to prevent future disputes over transboundary aquifers and to maximize the beneficial use of this resource, international law must be clarified as it applies to transboundary ground water resources. Moreover, it must be defined with a firm basis in sound scientific understanding to ground water systems.

Transboundary aquifers are vital component of global water resource systems, though their recognition in international water policy and legislation is very limited. Study on transboundary aquifer systems is very important to the Hydrogeologist to encourage riparian countries and states to work cooperatively toward mutually beneficial and sustainable aquifer development. Ground water is usually part of a greater hydrologic system, sometimes with the surface or ground water of neighboring states. It is rare that a transboundary river is not linked to a domestic or transboundary aquifer.

The Brahmaputra basin provides a good model for transboundary water resources management and aquifer systems. North Eastern States comprises the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim. Hill ranges occupy about 70% of the total geographical area. The region has three principal drainage system viz. Brahmaputra, Ganga and Barak. All the drainage system confluences at Bangladesh. Albeit, the region receives highest rainfall and experiences floods during monsoon, there is acute shortage of drinking water in many parts of hilly terrains such as Cherrapunji, in Meghalaya, which is the second wettest place in the world. Though blessed with 1/3rd of the water resource potential of the country, the agro-economic condition of the region is poor as only a negligible amount of ground water resource (about 13%) has been utilized so far.

INTRODUCTION AND BACKGROUND

Transboundary aquifers have long been recognized (e.g., Bittinger 1972; Hayton and Utton 1989), however, their significance and function in environmental and human development has received limited attention from policy makers, unlike transboundary river basins (Bourne 1992). Consequently, there are neither global policies nor appropriate legal instruments to govern this vital natural resource. In an effort to remove this gap, following its 1997 Congress in Nottingham, UK, the International Association of Hydrogeologists (IAH) established a Commission on Transboundary Aquifer Resources Management (TARM) to promote their study and joint international cooperation. The inventory of European transboundary aquifers (Arnold and Buza´s, 2005) provides many valuable lessons for other regions and developing countries, not least that nomenclature and hydrogeological mapping across international boundaries still requires better coordination. The paper by Eckstein and Eckstein (2005) provides basic topologies of transboundary aquifers so that international law can be better formulated. The paper by Jarvis et al. (2005) investigates the hydropolitical complexities in the management of transboundary aquifers.

IDENTIFICATION OF TRANSBOUNDARY AQUIFERS

The recognition of transboundary aquifers should lead to mutual international acceptance of an effective and equitable management of shared resources. In contrast to surface water, groundwater resource boundaries are often very poorly known and so many transboundary aquifers remain only partly recognized. Nevertheless, it is essential to view the entire aquifer system, including all aquifers that are hydraulically interconnected, directly by lateral or indirectly through vertical contact or through fractures and low permeability formations (aquitards). Spatial distribution of aquifer parameters is important in the understanding of transboundary problems. The following factors may affect the behavior and the development potential of aquifers, includes:

- Hydraulic parameters;
- Rainfall and recharge zones;
- Confined and unconfined areas;
- Natural discharge zones;
- Present and planned groundwater development zones;
- Water quality, potential risks of its deterioration; and
- Vulnerability to polluting agents.

In transboundary aquifers one or more of these factors may receive a different weighting on either side of a boundary. There are several examples of transboundary aquifers where recharge is received on one side while the natural discharges (and sometime better yields) are across the border. Such conditions are found in the border areas of Meghalaya, India and Bangladesh.

Groundwater hydraulics that may have international implications: Water abstraction from an aquifer transforms and re-organizes the groundwater flow in proportion to the piezometric adjustments induced. This has a number of practical consequences in the study of aquifer boundary conditions.

Modification of the Groundwater flow pattern: Groundwater flow passing an international boundary cannot be measured directly. It is estimated from parameters and calculated through mathematical models. Abstraction on one side of the border may alter the flow through the border.

Modification of the Piezometric Surface: Groundwater abstraction from wells results in modifications of piezometric heads in the form of a concentric cone of depression. Cones of depression may spread beyond international borders.

Deterioration of the water quality: Water quality deterioration may take place as a result of development. The impacts could be transmitted from unilateral actions in one of the countries sharing the transboundary resource. Vulnerability of aquifer is higher when groundwater moves through formations where large interconnected fractures or cavities are present and encourage rapid flow as in the case of the karstic aquifers (Margat, 1992).Human activities at the ground surface, e.g. landfill of waste, can result in aquifer pollution. The polluted groundwater from one side of an international boundary can travel to the other. Once polluted, aquifer cleanup is slow and expensive; the detection of its sub surface distribution can also be expensive. One of the differences between surface and groundwater resources is the time needed to detect pollution. In the aquifer systems impacts generated by the present generation may be detected by the future generations.

TRANSBOUNDARY AQUIFERS IN ASIA AND NORTH EAST INDIA

The disposition of transboundary aquifer in Asia is shown in fig 1 and the transboundary aquifers of north east India are given in table 1

Transboundary aquifers in Asia:- Transboundary aquifers, as part of groundwater resource systems, are important for Asian countries. The aquifers are involved within the relationship between countries, regions, as well as along the international rivers. There are several transboundary aquifers, involving two or more countries in Asia. Research on transboundary aquifers is significant for the management of shared groundwater resources of neighboring countries or regions. Transboundary aquifers in Asia have been briefly discussed. They are based on groundwater systems analysis. These aquifers are important for building a society where all civilizations can coexist harmoniously and accommodate each other. According to the groundwater resource data collected, the groundwater systems in central, east, and south Asia are analyzed. The information about the groundwater flows should be exchanged among the Asian countries, which share the same transboundary aquifer system. These are basic requirements for the joint management of water resources.

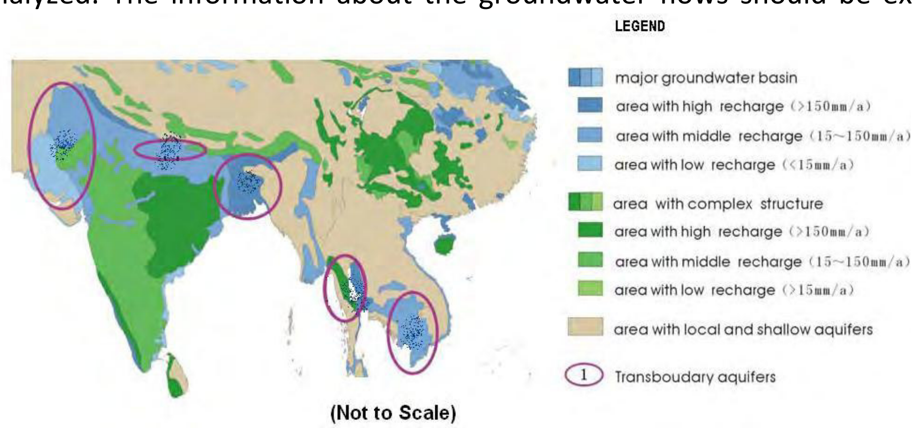


Fig.1. Map Showing Occurrence of Transboundary aquifers in Indian Sub-continent (Source: UNESCO, 2006)

Table.1 Transboundary Aquifers of North East India in the Indian Sub Continent

Sl No	Name of Transboundary Aquifer System	Countries sharing this aquifer system	Type of aquifer system	River Basin	Extension [km2]
1	Southern of Himalayas	Nepal, Bhutan and India	porous	Ganges-Brahmaputra-Meghna	65000
2	Ganges River plain	Bangladesh, India	porous	Ganges-Brahmaputra-Meghna	300000
3	South West Myanmar	Myanmar, Thailand and India	Fissure/ Fracture	Chinwin, Irrawaddy	53000

(Source: UNESCO, 2006)

Groundwater aquifers in North East India:- The Northeast is divided into isolated plains encompassed within hills, with a number of agro-climatic zones within them. It is characterized by heavy precipitation, extremely rich bio-diversity, fragile hills, high seismicity, and a drainage pattern marked by lateral valleys in the north and transverse valleys in the south, dissected by huge rivers and raging torrents. It was left with over 4500 km of external frontier with Bhutan, China, Myanmar and Bangladesh but no more than a slender 22 km connection with the Indian heartland through the tenuous Siliguri corridor, the Gateway to the Northeast. The Northeast spreads over a vast expanse of 255,000 sq. km with a relatively small population of fewer than 40 million today.

At the north-eastern extremity of Himalayas, a ittle beyond the peak Namcha Barwa, the geological formations turn sharply southwards and form the conspicuous arc forming the border of India and Burma (Myanmar), continuing into the Andaman and Nicobar islands and Indonesian Archipelago. The Burmese arc on the Indo-Burma border is an area about which very little is known, except for the meager information obtained from a few traverses. It is composed of the Patkai, Naga, Manipur, Lushai, Chin, Arakan and other ranges. The Median Tertiary belt of Burma lying to the east of these ranges corresponds to the Tertiary zone of Baluchistan, while the zone of the Shan Plateau, with its Pre-Cambrian, Paleozoic and Mesozoic rocks, is a foreign element beyond the original Tethyan zone, and belongs to South East Asia belonging to the Indo-China province.

The Brahmaputra originates in Tibet (5300m above MSL) and it enters India at Arunachal Pradesh after a distance of 1625 kms. It changes its direction towards the end of Tibet for North East India, then north and sweeping a miniature twist, and then drops down the Namcha Barwa massifs towards south and south west entering Indian Territory. The river travel 260 kms before debouching into Indian Territory, the Tsangpo, its name there, drops through height of 2200 metres.

The region shows an array of geological formations ranging in age from Precambrian to Quaternary. However, semi-consolidated sedimentary formations of Tertiary age developed along-with Precambrian rocks are the predominant formations of the region. The geological formations in North Eastern India are generally grouped under three main categories: i. Unconsolidated formations, ii. Semi-consolidated formations iii Consolidated formations

i. **Unconsolidated formations** :In Brahmaputra valley, major portion is underlain by Unconsolidated Formations of Quaternary age consisting of sands of various grades, gravels, pebbles and boulders with thin bands of clays and silts. The promising granular zones form the prolific aquifers capable of yielding 150 to 200 m^3/hr. On the south bank of Brahmaputra river finer clastics i.e. clays dominate over granular zones comprising of sands in the vicinity of Shillong plateau, Karbi Anglong Hills and Naga-Patkai Hills. The Older alluvium of Lower Assam districts occupies the piedmont zone towards the north bordering Bhutan. The narrow zone at the Himalayan foothill is known as the Bhabar zone and it supports grow of dense forests. To the south of the Bhabar zone and parallel to it, the flat Terai zone lays where the ground remains damp and sometimes, spring oozes out. The Terai zone is covered by tall grass. The Newer alluvium includes sand, gravel, pebble with silt and clay.

ii. **The Semi-consolidated Formations**: The Semi-consolidated Formations mostly comprises of siltstone, claystone, grits, sandstones, shales and conglomerates belonging to the Cenozoic age. The Tipam Group of rocks are predominant in the Synclinal valleys of Arunachal, Assam, and adjoining Manipur and Mizoram states. Namsang sandstones are found in some pockets of Upper Assam.

Based on water bearing and water yielding characteristics the Porous Formations may be further divided into the following four principal groups:

- Fairly thick and regionally extensive confined and unconfined aquifers explored down to a depth of 300 m with large yield prospects of 150 to 200 m^3/hr for drawdown within 8 m. These aquifers are generally found in the alluvial plains and low level terraces of the Brahmaputra valley.
- Moderately thick but discontinuous confined and unconfined aquifers found particularly on the south bank of river Brahmaputra. Thickness of unconsolidated formation is variable but generally does exceed 50m. This zone has good yield prospects of up to 150 m^3/hr for draw down of within 6m.
- Areas of ground water basins having thick but discontinuous confined to semi confined aquifers of fine to medium grained soft sandstone with low to moderate yield prospects of 30 to 100 m^3/hr for a drawdown of up to 20m or even more. Such areas are in the synclinal valleys of Cachar district (Barak valley) and adjoining areas. In Namsang soft sandstones of Dupitila Group, yield of 80 to 120 m^3/hr for draw downs of up to 12m have been found.
- Marginal areas of ground water basins having restricted lenticular aquifers generally of fine nature found in the areas fringing the Shillong plateau (bordering to Bangladesh), Karbi Anglong Hills Naga-Patkai range including the hilly areas of North Cachar Hills. Yield prospects are generally low (less than 50m^3/hr for considerably high drawdowns).

iii. The Consolidated Formations : The Consolidated Formations comprising crystalline rocks of gneissic complex generally occupy mainly Hills in Karbi Anglong, Kamrup and Goalpara districts of Assam and entire Meghalaya state. The compact siltstones, mudstones, shales and sandstones of Lower Tertiary age have also been included under the Consolidated Formations. Granite gneiss and Mica schists of Darjeeling, Phyllites, quartzites of Dalings and Phyllites, Dolomites and quartzites of Buxas occupy parts of Sikkim. In the fissured formations ground water is very much restricted to weathered residuum, fractured zones, having secondary porosity with yield prospects ranging between 5 to 30 m^3/hr. Springs including hot springs are found in the hill districts through North East India bordering to Myanmar, Tibet (China) etc.

Located in the international border between India and Myanmar, Chandel district of Manipur is endowed with an enormously diverse heritage of wetlands. In the eastern hilly slopes of the state a number of small streams join the Chinwin River in Myanmar. These rivers have a catchments area of 6953 sq km constituting 31% of the geographical of the state. The oldest rocks found in the State are mainly confined in the district close to Indo-Myanmar border and the rocks are grouped as Cretaceous rocks consisting of Chromite (Epilates), serpentine etc. The consolidated rocks confined to the eastern part of the Chandel district along the Myanmar border.

Groundwater Resources

Groundwater resources vary across the Indian sub-continent and Asia. Some regions are underlined by aquifers extending over large areas, while the floodplain alluvial deposits usually accompany the largest rivers. The sedimentary rocks, especially Quaternary unconsolidated sediments, are very thick with good storage space. The deep fissure water is relatively abundant in confined aquifers. In mountainous regions, groundwater generally occurs in complexes of joint hard rocks. However, the thawing of glaciers and snow in the high mountains is favorable to groundwater recharge. The carbonate rocks are widely distributed in Southeast Asia. In the Indo-china peninsula, there is stratified limestone from the late Paleozoic and Mesozoic in which karst is considerable developed. The piedmonts mostly contain spring water with a high water quality. Groundwater resources assessments have been taken in most countries in Asia. Evaluation and mapping of groundwater recharge and runoff of individual basins and regions are in progress.

The medium-scale hydrogeological survey has performed regional quantitative assessments of natural groundwater resources in most countries in Asia. Groundwater runoff is an important component of the hydrological cycle. Local hydrogeological conditions of different regions effect the distribution of groundwater runoff/precipitation ratios. Those ratios are less than 10% in the arid areas of central Asia, and more than 40% in the karstic areas of Southeast Asia. Groundwater monitoring networks have operated at national, regional and local levels in some parts of Asia. Groundwater levels constitute the most observed parameter and continuous water quality and natural groundwater discharge and abstraction networks are operational in urban areas. Groundwater assessment, monitoring, and data management activities are operated regularly in India, China, and other Asian countries. But it is observed less in other Asian developing countries.

The development of groundwater has increased in the past 30 years. The ratio of groundwater abstraction with mean recharge is done at the country level. There are many areas where the over-abstraction of groundwater occurs at the provincial level. Groundwater is crucial for human drinking and food security, especially in developing countries. The impact of groundwater use is positive and includes benefits such as increased productivity, food security, job creation, livelihood diversification and general economic and social improvement. In the long run, the impact of groundwater extraction might be negative especially in overexploitation situations, such as the permanent lowering of the water table, deterioration of water quality and saline intrusion in coastal areas. The social and economic dimensions of groundwater use as well as its benefits are important for development in Asia. The water availability per person/per year in Asian Countries are given in Table-2

Table 2. Water availability per person/ per year in Asian countries

Country	Total internal renewable water Resources (km^3 /year)	Groundwater produced internally (km^3 /year)	Surface water produced internally (km^3 /year)	Overlap: Surface and groundwater renewable (km^3 /year)	Water resources: total renewable (km^3 /year)	Water resources: total renewable per capita (m3/capita /year)	Populations in 2000 (In 1000=Th)
Bhutan	95	-	95	-	95	45,564	2085
Myanmar	880.6	156	874.6	150	1045.60	21,898	47.749
Nepal	198.2	20	198.2	20	210.2	9,122	23,043
Bangladesh	105	21.09	83.91	0	1,210.64	8,809	137,439
Japan	430	27	420	17	430	3383	127,096
Pakistan	248	55	243	50	418.27	2,961	141,256
Sri Lanka	50	7.8	49.2	7.0	50	2,642	18,924
China	2,879.40	891.8	2,715.50	727.9	2896.57	2259	1282,437
India	**1,260.54**	**418.54**	**1222.00**	**380**	**1,896.66**	**1880**	**1008,970**

Source: UNESCO Publication on Occurrence of Transboundary in Asia, 2006

Groundwater irrigation has also ensured security and helps alleviate poverty. For example, in India, the population increased quickly in the last 20 years, and it has a promising grain reserve of over 60 million tons and annual grain production touched a record high of 210 million tons in 2002-2003. Similarly, Bangladesh, dependent on foreign aid for a long time, had sufficient food supply in 1999-2000, and it was due to groundwater irrigation. Groundwater irrigation, especially in water abundant areas such as the eastern part of India, Bangladesh and Nepal can be an effective way to alleviate poverty. Since the 1970s, groundwater extraction has increased greatly in China, India, Republic of Korea and some other countries in South Asia.

CONCLUSION

North Eastern Region, though endowed with high rainfall, suffers from water shortage during the dry months particularly in hilly areas. As the incidence of rainfall is high, rainwater is considered to be a viable means to augment the water supply for domestic water needs. A perusal of long term water level trends indicated that there is no decline in water levels. Further the ground water development is also meager. On the other hand the scenario in hilly areas is different.

The average annual flow of Brahmaputra River is over 50 million hectre metre as measured at Pandu, Guwahati which is one-third of India's total surface water flow. This enormous potential is not required within the Assam valley or for that matter even within the neighboring country like Bangladesh. If proper storage of such monsoon flow in the region could be arranged in the hilly terrains of Arunachal Pradesh, with proper management of artificial recharge to ground water by constructing appropriate structures with arrangement for releases from the reservoirs, the water will not only meet the entire need for irrigation and drinking water supply of the states of Arunachal Pradesh, Assam and its neighboring states but will have enough to spare for other water short areas of India, without adversely affecting the interest of Bangladesh, who must be provided their requirement as per international norms.
The storage of water will increase the dry weather flow and depth of flow contributing to perennial river system and accessibility for irrigation and other domestic activities. As far as the trasboundary development of the Brahmaputra River system is concerned, the precious waters of this river should not go waste due to our laxity of policymakers and experts.

Groundwater demands and dependent environmental problems are driving forces for hydrogeologists. There are so many issues that need to be resolved.

- The main tasks are the assurance of groundwater for the livelihoods and food security of millions of people, the ustainable use of groundwater for sustainable socio – economic development, effective management of groundwater.
- The groundwater monitoring, dynamic assessment and groundwater dependent ecosystems conservation are the major ways to address these issues.
- Greater knowledge and the improvement of basic data through research are prerequisites for better management of groundwater systems.
- There is an urgent need for expansion in the knowledge of user and institutional perspectives in the groundwater knowledge base.
- It is necessary to have an integrated management of both surface and groundwater resources. Therefore, it can be seen that the benefits of groundwater have considerable impact in Asia and Indian sub-continent.

- The key challenge for hydrogeologists is to devise ways and means of reducing the adverse impacts of groundwater use without significantly reducing benefits. In this context, hydrogeologists have an important role to act in providing updated data and analyses that will help decision-makers in formulating implementable and socially acceptable policy responses.

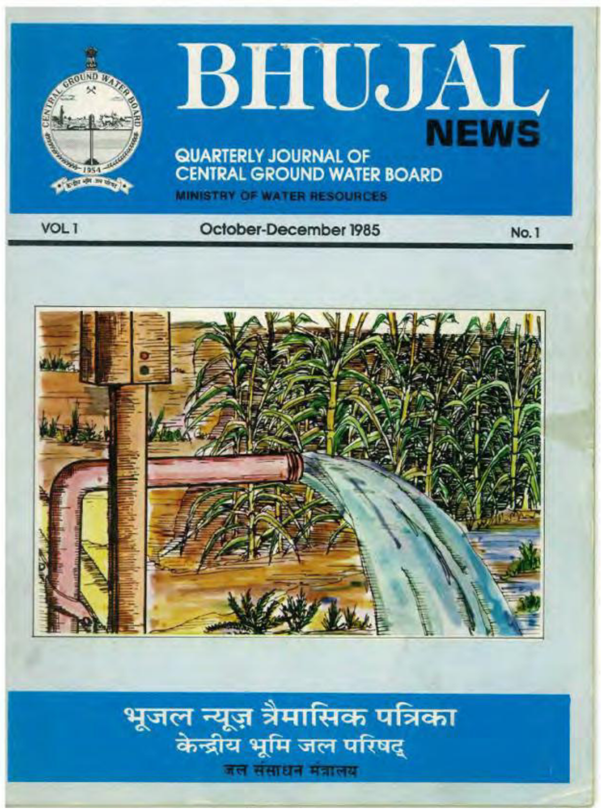
REFERENCES

- Aditi Mukherji & Tushaar Shah, 2005, Groundwater Socio-ecology and Governance: A review of institutions and policies in selected countries, Hydrogeology Journal (2005) 13:328-345
- Central Ground Water Board, Report of the Ground Water Resource Estimation Committee, Ground Water Resource Estimation Methodology -1997 (GEC'97)
- Geological Survey of India (1974). Geology and Mineral Resources of the States of India. Pt.IV. Misc. Pub.No.30
- International Association of Hydrogeologists (IAH). 2003. World Hydrogeological Map. IAH Commission on Mapping. http://www.iah.org.
- Institute of Hydrogeology and Engineering Geology, Chinese Academy of Geological Sciences, 1996, Hydrogeological Map of Asia 1:8 M, Geological Publishing House, Beijing, China
- Igor S. Zektser, Lorne G. Everett, 2004, Groundwater Resources of the World and their Use, UNESCO IHP-VI, Series on Groundwater No.6
- Karanth, K. R. (1987) Ground Water Assessment – Development and Management; Tata Mc Graw-Hill Pub.; New Delhi; 720 P.
- Krishnan, M.S.(91982) Geology of India and Burma: 6th Ed.:CBS Pub.: New Delhi:536 P
- Puri, S. 2003. Transboundary aquifers: International water law & hydrogeological uncertainty. Water International, IWRA 28, no. 2: 276–279.
- Todd, D. K. (1959) Ground Water Hydrology; 4th Ed.; John Willy and Sons Inc.; N.Y.; 535 P
- UNESCO (2008). Groundwater Resources of the World: Transboundary Aquifer Systems (Map).Worldwide Hydrogeological Mapping and Assessment Programme. Hannover, Paris: NESCO/IHP.
- UNESCO, 2003, World water Development Report: Water for People, Water for life, UNESCO and Berghahn Book, Barcelona
- United Nations, 2006, Water：A Shared Responsibility, the United Nations World Water Development Report 2, 2006.3,http://www.unesco.org/publishing
- UN, Water Resources Development in Asia and the Pacific Some Issues and Concerns//Water Resources Series, New York：1987, No.62
- UN, Groundwater in Continental Asia (Central, Eastern, Southern, South-eastern Asia)//Natural Resources/Water Series, New York：1986

S.Shekhar, Bhujal News, 25:1&2(2010), 53-54

Voyage of Bhujal News: Through 25 years:

The scientific journey of **Bhujal News**, a quarterly journal of Central Ground Water Board, Ministry of Water Resources, Govt of India started in 1985 with the publication of its 1st issue as Vol-1, No-1, October- December, 1985. Bhujal News in its 25 year of voyage has able to fulfill objective proposed in its first editorial by Shri T S Raju, the then editor, and rather able to establish itself as a fully scientific journal in Groundwater sphere of India. Bhujal News is a registered journal and has obtained the ISSN number in year1990



EDITORIAL NOTE

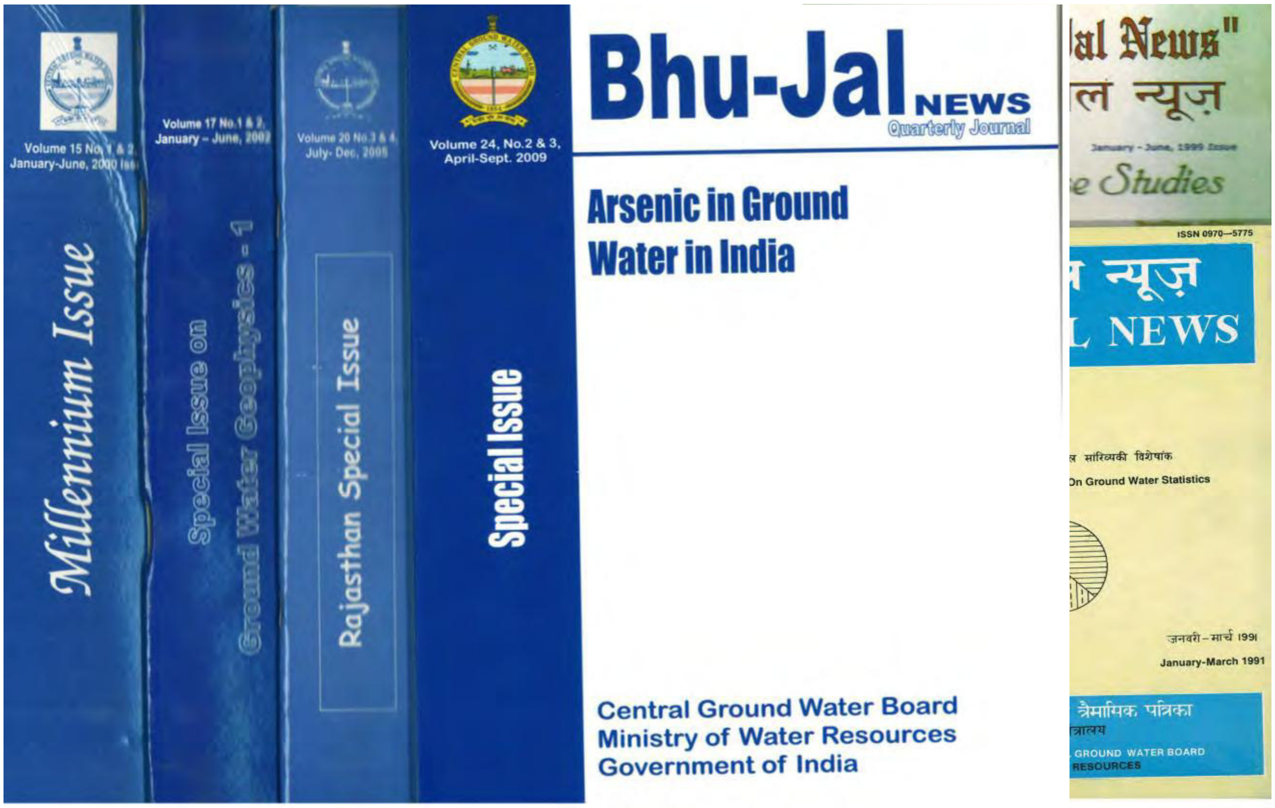
GROUNDWATER has assumed a critical importance to meet the growing needs of our nation in its ever increasing domestic, industrial and agricultural growth needs. The value of ground water as a source of Irrigation lies in the fact that it is dependable, even during the periods of scarcity and drought, is widely distributed and can be put to use with ease and speed. During the past few decades, rapid progress has been made in the development of groundwater resources in the country. To highlight the various activities and developments in the country related to this vital source, the Central Ground Water Board, Ministry of Irrigation & Power, has launched 'Bhujal News' a quarterly journal. This journal will cover the activities and achievements of all organisations at the National and State level engaged in the field of survey, exploration, assessment, development and management of groundwater resources in the country.

'BHUJAL NEWS' intends to bring out, in addition to the news on activities and achievements of the Central Ground Water Board and other Organisations, review articles and short notes on important aspects of ground water development and management, brief sum-ups of the important investigations for groundwater being undertaken in the country, especially in backward, tribal or drought prone areas, application of sophisticated techniques in groundwater resource evaluation, major ground-water development programmes planned and being undertaken and cover news on all activities related to groundwater in the country and brief review of the latest literature on Groundwater Science.

Sincere attempts have been made to make this first issue of 'Bhujal News' objective and informative. It will be endeavour of the Editorial Board to make the future issues of 'Bhujal News' more and more interesting, educative and useful.

During past 25 years Bhujal New apart from its regular issues has significantly highlighted emerging problems on groundwater of the country through number of special issues from time to time as -

- Ground Water Pollution, April-June,1990
- Drought, Jan- March 1988
- Ground Water Development, July- September 1990
- Ground Water Statistics, Jan-Mar,1991
- Central Ground Water Authority, Jul –Dec, 1997
- Conjunctive Use Studies, Jan – Jun, 1999
- Millennium Issue, Jan- June, 2000
- Ground Water Geophysics-I , Jan-June, 2002
- Ground Water Geophysics-II , Jan – Dec, 2003
- Rajasthan State, July- Dec,2005
- Uttaranchal State, Jan- Dec 2006.
- West Bengal State, Jan- March 2009
- Arsenic in Ground Water in India, April- September 2009



In this proud journey of 25 years Bhujal News has been benefited by the able guidance of our the then Chairmen Dr B.D.Pathak, Dr D K Dutt, Shri Abhay Prakash, Shri M L Lath, Dr R K Prasad, Shri Arun Kumar, Dr D K Chadha, Shri J S Burjia, Shri S.S Chauhan, Shri P.C Chaturvedi, Dr Salim Romani, Shri B M Jha, and Dr S C Dhiman(Present). The journey of Bhujal News has been taken to its present position by efficient efforts of its editors Shri T S Raju, Shri B M Jha, Shri A D Joseph, Shri R N Singh, Shri Abhijit Ray, and Dr S K Jain (Present).

Compiled by
Dr. S.Shekhar
Asstt Editor, *Bhujal News*