

Asian Transboundary Aquifers Inventory and Mapping

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Abstract: Transboundary aquifer (TBA) is an aquifer system that exists in more than one state. As an important component of the groundwater system, proper management and rational utilization in trans-boundary aquifers are significantly important for promoting sustainable development and good-neighbor relationships. The Transboundary Aquifers will not implicate by the country's political boundary as it follows the natural boundary lines. Within the framework of the UNESCO's International Hydrological Programme (IHP-VI & VII) activities for the International Shared Aquifer Resource Management (ISARM), the inventory on TBA in Asia both preliminary and detail has accomplished. Those TBAs are classified in to two types: regional and local grade. A of Asian Transboundary Aquifers Map has advanced. The updated map provides the situation of the regional TBAs identify as the actual shape. Countries with the TBAs should strengthen cooperation for coordination and joint management of groundwater resources in order to achieve sustainable use.

Keywords: Transboundary aquifer, Groundwater, Asia, Inventory, Mapping

Introduction

Groundwater aquifers are hidden resources available to humankind. The Transboundary Aquifers will not implicate by the country's political boundary as it follows the natural boundary lines.

The updated regional inventory of Transboundary aquifers will form a basis to create awareness among the political leaders, policy makers and planners to improve scientific knowledge and to develop a toolkit for management of TBAs.

This update map will be used to create awareness and interested member states can cooperate together in bringing out detailed plan for managing the transboundary aquifers between

themselves.

During the preliminary inventory on Transboundary aquifers in Asia (IHP VII Technical Document in Hydrology, 2010; Struckmeier, W. et al.) most of the minor Transboundary aquifers are missed as we did not have the detailed hydrogeological map of Asia.

Since China Geological Survey in cooperation with UNESCO-IHP, IAH and other several national international partners is completing the Asian Hydrogeological Map in 1:8 million scales, the project team intends to use this map as a base map and update the preliminary inventory Asian Transboundary Aquifer Map (IGRAC, 2009; IGRAC, 2012).

The updated map will provide missed Transboundary aquifers in Asia and the situation of the regional TBAs will identify as the actual shape of the Transboundary aquifers, instead the circle

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figured in the previous map. Those TBAs will also be classified in to two types: regional and local grade.

The beneficiaries of the map are the policy-makers, managers, hydrologists, hydro-geologists, teachers, students and other citizen, who are interested on Transboundary aquifers in Asia.

Within the frame work of the UNESCO's Inter-governmental Programme for the "International Hydrological Programme (IHP-VII) activities within the International Shared Aquifer Resource Management (ISARM), jointly undertake detailed mapping of Asian Transboundary Aquifers Map in close cooperation with China Geological Survey, China Academy of Geological Sciences and other relevant partners from Asian region responsible for development and management of groundwater water and transboundary issues (Institute of Hydrogeology and Engineering Geology, 1996).

Groundwater in Asia

Asia bordered on the Pacific Ocean in the east, Arctic Ocean in the north, Indian Ocean in the south and Mediterranean Sea in the west respectively. The area is 44 million square kilometers. The population of Asia is 3.5 billion. It is the largest continent both in area and population in the world. There are 48 countries and regions in Asia (Economic Commission for Europe, 2007). Geographically, it could be divided into East Asia, Southeast Asia, South Asia, West Asia, Central Asia and North Asia. Countries with a population of more than 100 million are China, India, Indonesia, Japan, Bangladesh and Pakistan. The length of coastal line of Asia is 69,900 km. There are many islands and peninsulas. Kalimantan is the third largest island in the world. The characteristics of topography Asia are the big gurgitation of earth's surface, high in the central and low around, alternate with apophysis and depressed. The mountains, highlands and hills count for three fourths of the total area. Another one fourth is plain whose area is 10 million square kilometers.

Pamirs as the epicenter, series of mountains eradiate and extend to the fringe of continent. The Qinghai-Tibet altiplano whose average altitude is 4,500 m is named as fastigium of the world. Everest, as the highest mountain in the world, is wit an altitude of 8,844.43 m. The plains are situated in the outboard of mountains and tableland. These are North China plain, Northeast China plain, Middle and lower reaches of Yangtze River plain, Hindustan river plain, Ganges river plain, Mesopotamia plain and west Siberian Plain, etc. The Dead Sea is the lowest depression in the world with altitude 400 m under sea level.

There are many rivers in Asia. Most of those are sources from central mountains and radial flow to every direction. The major rivers flows into Pacific Ocean are Heilongjiang-Amur River, Yellow River, Yangtze River, Pearl River and Mekong River etc. The major rivers flows into Indian Ocean are Indian River, Ganges River, Salween River, Ayeyarwady River, Tigris River and Euphrates River etc. The major rivers flows into Arctic Ocean are Ob River, Yenisei River, and Lena River etc. The inland Rivers are situated in central and west arid area of Asia. The majors are Sill River, Amu River, Ili River, Talimu River and Jordan River etc. The lakes in Asia are not in a large number compared to other continent. They could be posteriori to 5 groups, North Asia, Central Asia, West Asia, Qinghai-Tibet tableland and Middle-lowest Yangtze River. Some lakes are famous for their peculiar characteristics. The Caspian is the biggest salt lake in the world. Lake Baikal is the deepest lake in the world and biggest fresh lake in Asia. The Dead Lake is the lowest depression. Lake Balkhash is an inland lake with both fresh water and salt water (Zai-sheng Han et al., 2008).

The three climate zones are Frigid Zone, temperate zone and Torrid Zone which across the continent of Asia. The climatic types are various and complex. The Southeast Asia, South Asia and southeast part of East Asia are in the humid monsoon torrid zone. Central Asia, West Asia and the inland part of East Asia are in the arid zone. The area between both zones and the most part of

North Asia are in the semi humid semiarid zone. Precipitations are various in different areas in Asia. The main direction of rainfall is descending from the humid southeast to the northwest part. There are abundant rain fall near the equator zone. The annual rainfall is more than 2,000 mm. There are rainless all over the year in the southwest and central Asia. The precipitation is less than 150 mm in a large area.

Groundwater resources in Asia are various. Some regions are underlined by aquifers extending over large areas, while the floodplain alluvial deposits usually accompanying the largest rivers. The sedimentary rocks, especially Quaternary loose 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. There is small rainfall and strong evaporation in inland arid area of central Asia. However the thawing of glaciers and snow from high mountains is favorable to recharge groundwater. The loess plateau in central Asia has specific topography. Continuous aquifers are only distributed in loess tableland. The carbonate rocks are widely distributed in Southeast Asia. In South China and Indochina peninsula, there are stratified limestone of late Paleozoic and Mesozoic in which karst is considerable developed. The reef karst could be found in coastal island. A lot of Quaternary volcanic rock is extensively distributed on the circum-Pacific islands, which forms asymmetrical rings aquifers. The piedmonts of volcanoes mostly occurs spring water with good water quality (Shammy Puri et al., 2005; Raya Marina Stephan, 2009).

Inventory of Transboundary Aquifers in Asia

transboundary aquifers or transboundary aquifer system means respectively, an aquifer or aquifer system, parts of which are situated in different States. Those 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 (UNESCO, 2003; Igor S. Zektser et al., 2004). There are several transboundary aquifers, involving two or more countries in Asia. There are concomitances of rivers passing through several countries, such as Indian River, Mekong River, Ganges Rivers and Heilongjiang-Amur River. Research on transboundary aquifers is significant for the management of groundwater resources of neighboring countries or regions.

Transboundary aquifers in Asia have been briefly discussed. They are based on groundwater systems analysis. For the countries such as China, Russia and India inhabit large areas. The number of international transboundary aquifers in Asia is less than those of other continents. Those aquifers in Asia are important for building a society where all civilizations coexist harmoniously and accommodate each other. According to the groundwater resource data collected, the groundwater systems in Asia are analyzed. We have collected the essential and the missed transboundary aquifers data. The Transboundary aquifers in Asia have been classified into two grades. The regional Transboundary aquifer extension is more than 3,000 km². The Local Transboundary aquifer extension is less than 3,000 km². There are 100 Transboundary Aquifers are inventoried. The number of regional transboundary aquifers are 55 in Asia and number of Local ones are 45.

The list of the two grades is in the Table 1 and Table 2. The order for TBA is use 3 digit numbers. First digit – hundreds digit:

- 0-Regional TBA in East Asia
- 1- Local TAB in East Asia
- 2 -Regional TBA in Southeast Asia
- 3- Local TAB in Southeast Asia
- 4 -Regional TBA in South Asia
- 5- Local TAB in South Asia
- 6 -Regional TBA in Central Asia
- 7- Local TAB in Central Asia
- 8 -Regional TBA in West Asia
- 9- Local TAB in West Asia

The second digit and third digit Number could list TBA in each the appoint sub-region.

Table 1 Regional Transboundary Aquifer in Asia

East Asia

NO	Name of Transboundary Aquifer System	Countries of This TBA	Type of Aquifer System	Extension (km ²)
001	Middle of Korea Peninsula	North Korea, South Korea	1,2	12,731
002	Yalu River Basin	China, North Korea	2	20,534
003	Middle Heilongjiang - Amur River Basin	China, Russia	1	113,574
004	Zeya River Basin	China, Russia	1	76,689
005	Erguna River	China, Russia	1,	4,913
006	Ulz River Basin	Mongolia, Russia	1	18,256
007	Onon River Basin	Mongolia, Russia	2	4,465
008	Balj River Basin	Mongolia, Russia	2	9,094
009	Minj River Basin	Mongolia, Russia	2	5,100
010	Tsuh River Basin	Mongolia, Russia	2	3,974
011	Zelter Basin	Mongolia, Russia	2	5,599
012	Shishhid River Basin	Mongolia, Russia	2	19,745
013	Delger Big River Basin	Mongolia, Russia	2	22,813
014	Tes River Basin	Mongolia, Russia	1	7,900
015	Uureg Lake Basin	Mongolia, Russia	1,2,3	10,500
016	Bulgan River Basin	Mongolia, China	2	8,060
017	Dankhan Khudgln Sair	Mongolia, China	2	12,679
018	Onch Khaikhani Sair	Mongolia, China	1,2	12,896
019	Zamiin-Uud Basin	China, Mongolia	2	11,687
020	Numrug River Basin	China, Mongolia	2	6,185
021	Halh gol River Basin	China, Mongolia	1	3,588
022	Herlen River Basin	China, Mongolia	1,2	7,229
023	Ertix River Plain	Kazakhstan, China	1,3	30,233
024	Tacheng Basin	Kazakhstan, China	1	22,381
025	Ili River Valley	Kazakhstan, China	1,2	45,015

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

Southeast Asia

NO	Name of Transboundary Aquifer System	Countries of This TBA	Type of Aquifer System	Extension (km ²)
201	Beilun River Basin	China, Vietnam	3	3,716
202	Karst aquifer of Upper Zuojiang Valley	China, Vietnam	2,3	19,160
203	Hong River Basin	China, Vietnam	1,2,3	60,805
204	Downstream of Lancang River	China, Myanmar	2,3	39,509
205	Nu River Valley Aquifer	China, Myanmar	2,3	17,560
206	The Up of Mekong River	Myanmar, Thailand, Laos	1,2,3	31,841
207	The Mid of Mekong River	Vietnam, Laos, Thailand	1,2,3	106,816
208	Kele Plateau	Laos, Thailand	1,2	90,837
209	South Burma	Myanmar, Thailand	1,2,3	33,715
210	Mekong River Delta	Cambodia, Vietnam	1,2	223,422
211	Northern Kalimantan	Brunei, Malaysia	1	6,246

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

South Asia

NO	Name of Transboundary Aquifer System	Countries of This TBA	Type of Aquifer System	Extension (km ²)
401	Mid of Brahmaputra River	India, China	1,2	35,905
402	Southern of Himalaya Mountains	India, Bhutan	1,2	29,717
403	Ganges River Plain	India, Bangladesh	1	180,384
404	Southern of Himalayas	India, Nepal	1,2	311,589
405	India River Plain	India, Pakistan	1	394,625
406	Kabul River Aquifer	Pakistan, Afghanistan	1,2	6,219

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

Central Asia

NO	Name of Transboundary Aquifer System	Countries of This TBA	Type of Aquifer System	Extension (km ²)
601	West Altai	Kazakhstan, Russia	1	2,781,600
602	Chu Basin	Kazakhstan, Kyrgyzstan	1	14,300
603	Pretashkent	Uzbekistan, Kazakhstan	1	20,000
604	CHatkal-Kurman	Kazakhstan, Uzbekistan	1	257,700
605	Birata-Urgench	Uzbekistan, Turkmenistan	1,3	60,000
606	Amu-Darya	Uzbekistan, Kazakhstan, Turkmenistan	1	166,900

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

West Asia

NO	Name of Transboundary Aquifer System	Countries of This TBA	Type of Aquifer System	Extension (km ²)
801	Upper Jezira	Turkey, Syria, Iraq	1	10,293
802	Paleogene an Cretaceous aquifer	Saudi Arabia, Yemen, Oman, UAE, Kuwait, Iraq, Jordan, Syria	1,2,3	2,135,251
803	Hauran and Al-Arab	Jordan, Syria	2	28,900
804	Nahr el Kabir	Israel, Lebanon, Syria	1,2,3	12,500
805	Western Aquifer	Egypt, Israel, Palestinian Territory	1,2,3	14,400
806	Alazan-Agrichay	Azerbaijan, Georgia	1,3	3,050
807	Kura River Valley Aquifer	Azerbaijan, Georgia	1,3	4,808

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

Table 2 Local Transboundary Aquifer in Asia

East Asia

NO	Name of Transboundary Aquifer System	Countries of this TBA	Type of Aquifer System	Extension (km ²)
101	Tumen River Delta	China, Russia, North Korea	2	2,329
102	Hiagt River Basin	Mongolia, Russia	1,2	1,168
103	Tsagaan khudgiin Sair	China, Mongolia	2	2,319
104	Dayshigiin khudgiin Sair	China, Mongolia	1,2	2,838
105	Tuoshigan River Basin	China, Kyrgyzstan	1,2	<3,000

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

Central Asia

NO	Name of Transboundary Aquifer System	Countries of This TBA	Type of Aquifer System	Extension (km ²)
701	Karaungur	Uzbekistan, Kyrgyzstan	1	200
702	Maylusu	Uzbekistan, Kyrgyzstan	1	500
703	Naryn	Uzbekistan, Kyrgyzstan	1	1,900
704	Iskovat-Pishkaran	Uzbekistan, Kyrgyzstan	1	600
705	Nanay	Uzbekistan, Tajikistan	1,2	100
706	North Talas	Kazakhstan, Kyrgyzstan	3	1,100
707	South Talas	Kazakhstan, Kyrgyzstan	3	1,200
708	Kasansay	Kyrgyzstan, Uzbekistan	1	100
709	Almos-Vorzik	Kyrgyzstan, Uzbekistan	1	600
710	Chust-Pap	Tajikistan, Uzbekistan	1	600
711	Syr-Darya 2	Tajikistan, Uzbekistan	1	1,600
712	Sulyukta-Batken-Nau-Isfara	Tajikistan, Uzbekistan	1,2	<3,000
713	Shorsu	Kyrgyzstan, Tajikistan, Uzbekistan	1,2	300
714	Sokh	Kyrgyzstan, Uzbekistan	1	2,400
715	Chimion-Aval	Kyrgyzstan, Uzbekistan	1,2	700
716	Yarmazar	Kyrgyzstan, Uzbekistan	1	400
717	Osh-Aravan	Kyrgyzstan, Uzbekistan	1	1,700
718	Ahangaran	Tajikistan, Uzbekistan	2	1,300
719	Kokaral	Tajikistan, Uzbekistan	2	900
720	Dalverzin	Tajikistan, Uzbekistan	2	2,000
721	Syr-Darya 3	Tajikistan, Uzbekistan	2,3	800
722	Dustlik	Tajikistan, Uzbekistan	3	1,900
723	Havost	Tajikistan, Uzbekistan	2,3	700
724	Zafarobod	Tajikistan, Uzbekistan	2	1,200
725	Zeravshan	Tajikistan, Uzbekistan	2,3	2,700
726	Karatag	Tajikistan, Uzbekistan	1	<3,000
727	Kofarnihon	Tajikistan, Uzbekistan	2	400
728	Selepta-Batkin-Nai-Icfor	Tajikistan, Kyrgyzstan	1,2	891
729	Vakhsh	Afghanistan, Tajikistan	1	<3,000
730	Amudaryia	Afghanistan, Tajikistan, Uzbekistan	1	1,500
731	Sherabad	Uzbekistan, Turkmenistan	1,2	700
732	Sarakhs	Iran, Turkmenistan	3	200

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

West Asia

NO	Name of Transboundary Aquifer System	Countries of This TBA	Type of Aquifer System	Extension (km ²)
901	Lenkoran	Azerbaijan, Iran	2	<3,000
902	Nakhichevan	Azerbaijan, Iran	2	<3,000
903	Vorotan-Akora	Armenia, Azerbaijan	2	<3,000
904	Herher, Malishkin and Jermuk	Armenia, Azerbaijan	2	<3,000
905	Nakhichevan	Azerbaijan, Iran	2	<3,000
906	Leninak-Shiraks	Armenia, Turkey	2	<3,000
907	Leninak-Shiraks	Armenia, Turkey	2	1,200
908	Northeastern Aquifer	Israel, Palestinian Territory	2	1,600

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

Mapping of Asian Transboundary Aquifers

Most transboundary Aquifers are inventory according the published study result file in the last several years. For the groundwater data in case of using different conventional in-situ technologies, it is need for consistency (United Nations, 2006; Zai-sheng Han et al., 2006; PURI S, 2001; W.F. Struckmeier et al., 2006). Some TBAs are inventory with the analyses on the Asian

groundwater resources map. Those provide groundwater data and information over large area. All the transboundary Aquifers are harmony with the Groundwater systems in Asia.

The mapping of Asian TBA applies the equal - area Bonne's method of projection. This method is suitable for small scale and continental mapping. And it is accurate for calculated the extension area with the GIS system. The reference frame is WGS-84. The central coordinate is at longitude 90° east and latitude 40° north. The meshwork is 10°×10°. See Fig.1.

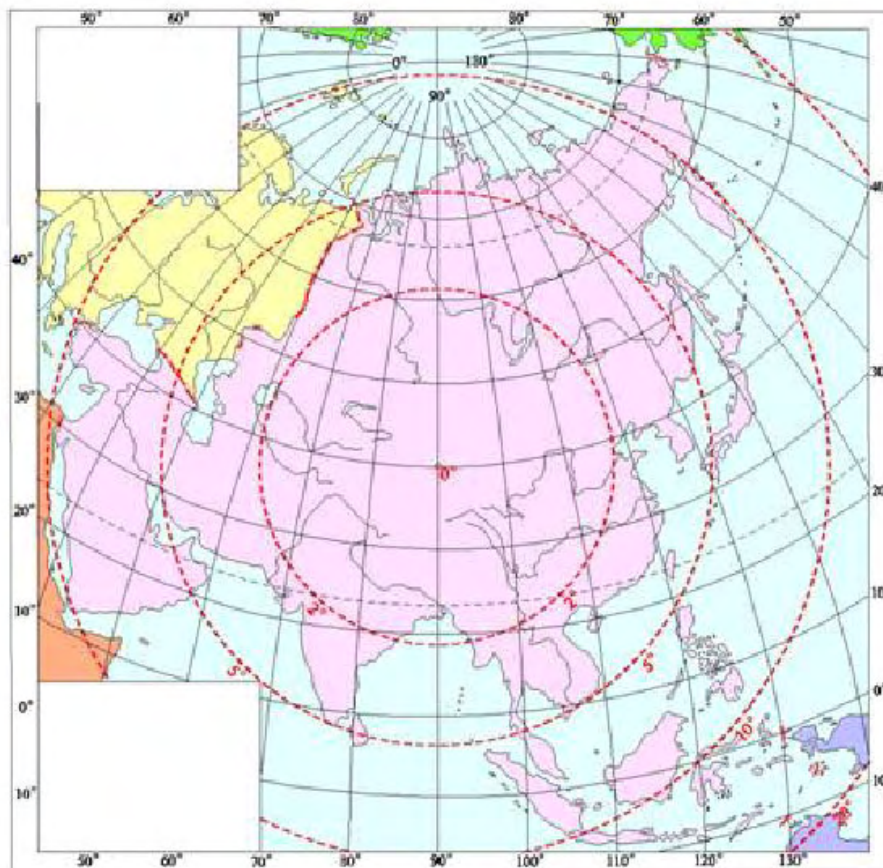


Fig.1 Bonne's Projection for Asian Map

The legends of the map are four parts:

A: Transboundary Aquifers

Regional TBA (The area of Aquifer is more than 3,000 square kilometers.)

0-Regional TBA in East Asia

2 -Regional TBA in Southeast Asia

4 -Regional TBA in South Asia

6 -Regional TBA in Central Asia

8 -Regional TBA in West Asia

Local TBA, (The area of Aquifer is less than 3,000 square kilometers.)

1- Local TAB in East Asia

3- Local TAB in East south Southeast Asia

5- Local TAB in South Asia

7- Local TAB in Central Asia

9- Local TAB in West Asia

B: Groundwater Resource

This part is divided into three groundwater resource zone, Continuous aquifer in plain and intermitten basin, Discontinuous aquifer in hilly area and Scattered aquifer. Different zone has different color. The depth of the color of each zone

represents the size of natural recharge modulus ($10^3 \text{ m}^3/\text{km}^2 \cdot \text{a}$).

C: Aquifer type

Pore Aquifer

Karst Aquifer

Fractured Aquifer

Fractured-pore Aquifer

D: Others

Area underlain by significant deep groundwater

Area abundant in atmospheric precipitation

recharge

Area deficient in atmospheric precipitation

recharge.

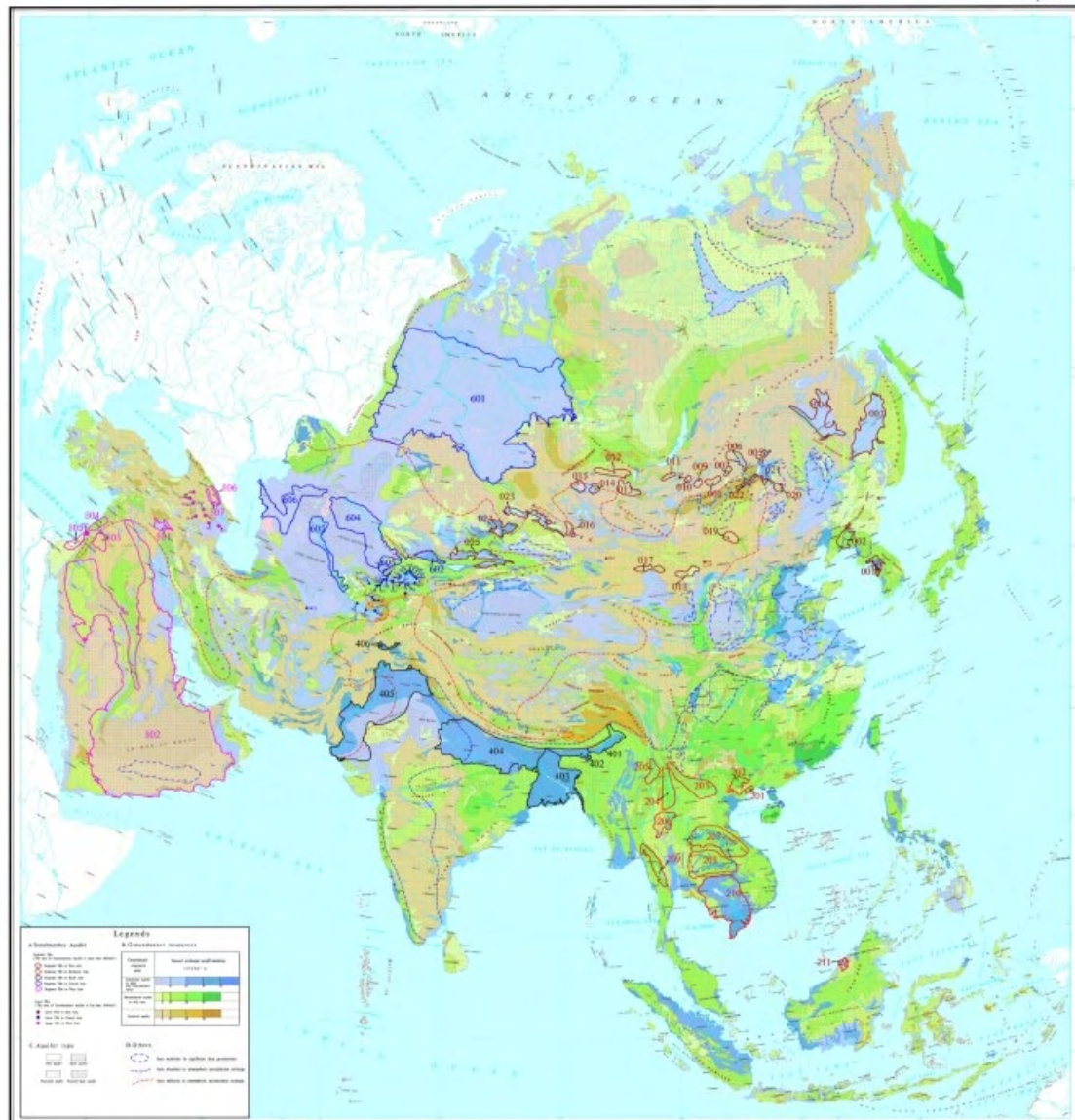


Fig.2 Asian Transboundary Aquifers Map

Conclusions

The updated regional inventory of Transboundary aquifers will form a basis to improve scientific knowledge and to develop a toolkit for management of TBAs. Using the Asian Groundwater Resources Map in 1:8 million scales, as a base map and update the preliminary

inventory Asian Transboundary Aquifer Map. 100 Transboundary Aquifers are inventoried. The Achievement is first step for detail mapping of Asian Transboundary aquifers. We need more comments from the experts in Asia and all over the world. We are very appreciating for them who give the modified or corrected suggestions on the map.

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