Groundwater Environment in the Changing Context in LAHORE City

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1st Regional Workshop on "Groundwater Asia"

Asian Institute of Technology, Thailand
5-7 August, 2019

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- Introduction of Lahore City;
- Climate characteristics of Lahore and previous climate change impact studies on Lahore;
- Trend of change in land use and land cover in Lahore;
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- GW availability and usage (historical trend);
- Trends in key drivers of GW stress in the city e.g. population;
- Information on GW monitoring wells and trends of GW level in monitoring wells;
- The Way Forward.

Lahore – The City of Gardens

- Lahore is the capital of the Pakistani province of Punjab and is the country's second-most populous city after Karachi.

- Lahore's origins reach into antiquity. The city has been controlled by numerous empires throughout the course of its history, including the Hindu Shahis, Ghaznavids, Ghurids, and Delhi Sultanate by the medieval era.

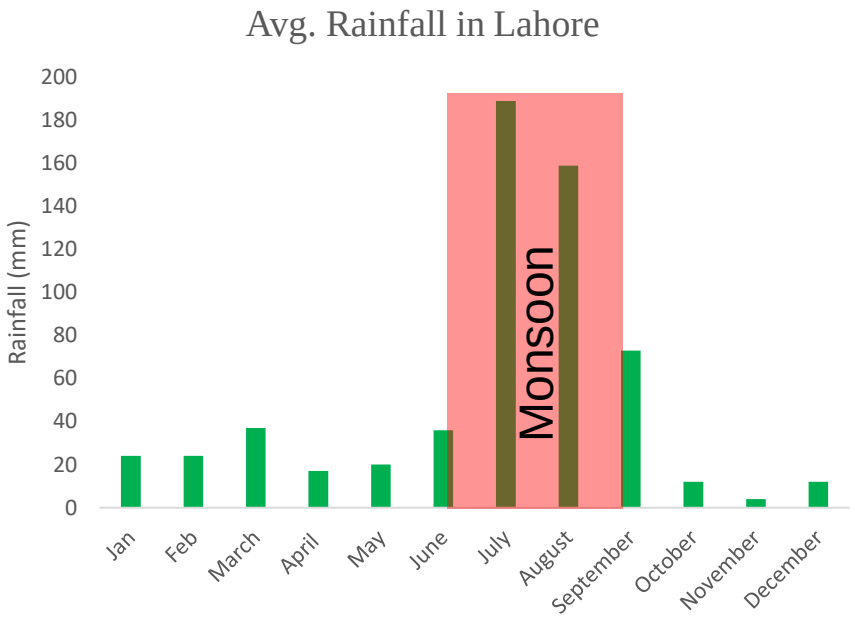
- Lahore is home to numerous monuments from the Mughal Dynasty, Sikh Empire, and British Raj. The architectural style of the Walled City of Lahore has traditionally been influenced by Mughal and Sikh styles e.g. Lahore Fort, Shahi Masjid Lahore, Lahore Museum etc.

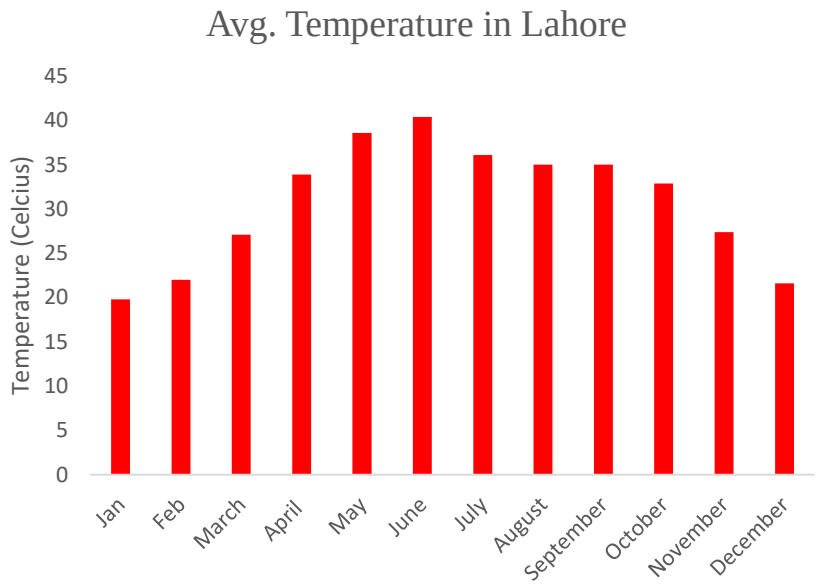
- Besides the city is famous for its wonderful gardens which are major attractions for the tourists e.g Shalamar Garden, Bag-e-Jinnah, Jallo Park etc.

Climate Characteristics of Lahore

- Lahore has a semi-arid climate (Köppen climate classification BSh). The hottest month is June, when average highs routinely exceed 40 ° C (104.0 ° F). The monsoon season starts in late June, and the wettest month is July, with heavy rainfalls and evening thunderstorms with the possibility of cloudbursts. The coolest month is January with dense fog.

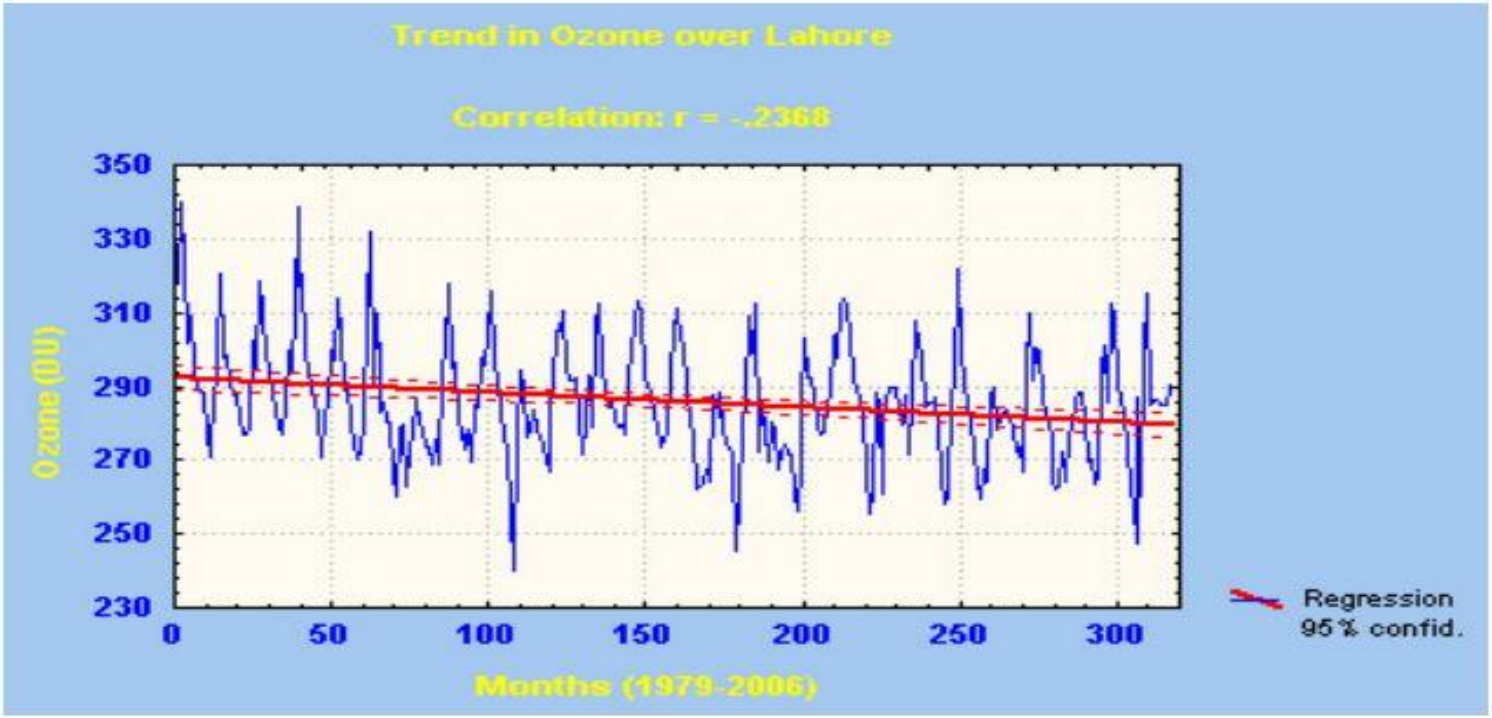
- Lahore lies at the edge of Indian - Monsoon regime due to which only a small fraction of monsson spell enters Pakistan and ends at Lahore as the monsoon season is more dense in the area of Upper Bari Doab which is in Indian Punjab.





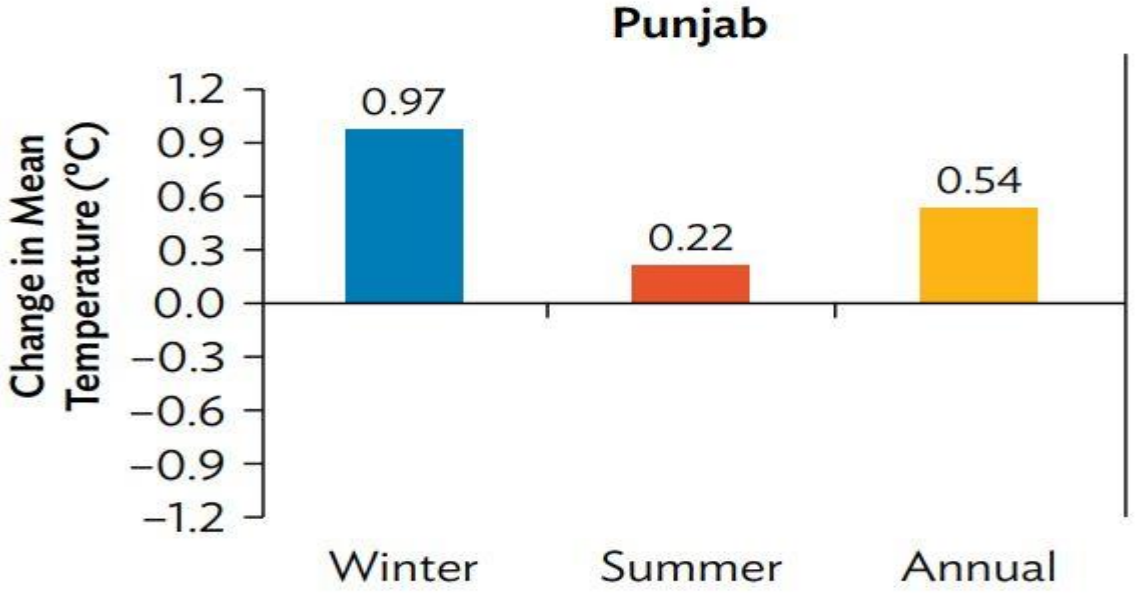
Climate Change Study on Lahore by SUPARCO

- The **Space and Upper Atmosphere Research Commission (SUPARCO)** carried out a satellite research study on the climate of major cities of Pakistan including Lahore during 1979-2006 and reached the following conclusions:
- The ozone layer around the globe of earth is depleting continuously (as shown below) due to which many problems are taking place global warming is one of them.
- The surface ozone ranges from 6-40 ppb at Karachi, 8.5-44 ppb at Lahore, 6-32 ppb at Islamabad, 11-24 ppb at Quetta, 3-33 ppb at Rawalpindi and 4-46 ppb at Peshawar and causing severe ;



Causes and Impacts of Climate Change in Lahore

- Green House Gas (GHG) emission is the major cause of ozone depletion and Pakistan is ranked 31 in total GHG emission which is causing rise is regional and global temperature. The overall increase in temperature from 1960 to 2007 is shown the figure below for three seasons (Climate Change Profile of Pakistan by Asian Development Bank).
- According to IPCC Fourth Assessment Report (2007), “Glaciers in the Himalaya are receding faster than in any other part of the world and, if the present rate continues, the likelihood of them disappearing by the year 2035 and perhaps sooner is very high if the Earth keeps warming at the current rate.”



Landuse and Landcover Trend in Lahore

S.A. Shirazi in 2009, carried out **Temporal Analysis of Land Use and Land Cover Changes in Lahore-Pakistan** using remote sensing for the period 1992-2009 with the following objectives:

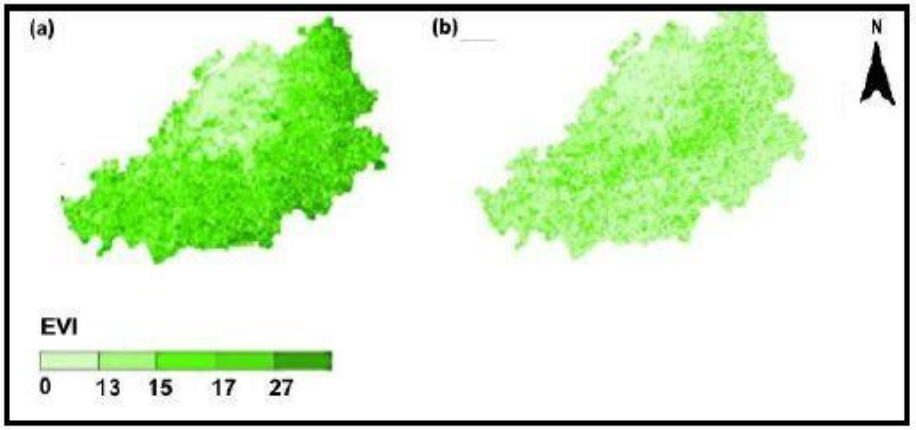
1. To Identify and delineate different land use/land cover categories in Lahore using temporal remote sensing data (Landsat images);
2. To find temporal land use/ land cover changes in Lahore district (CDGL) and to detect the changes especially in built up areas, vegetative cover and open areas and;
3. To determine the magnitude of LULC changes in the city of Lahore.

The results of the study are as below:

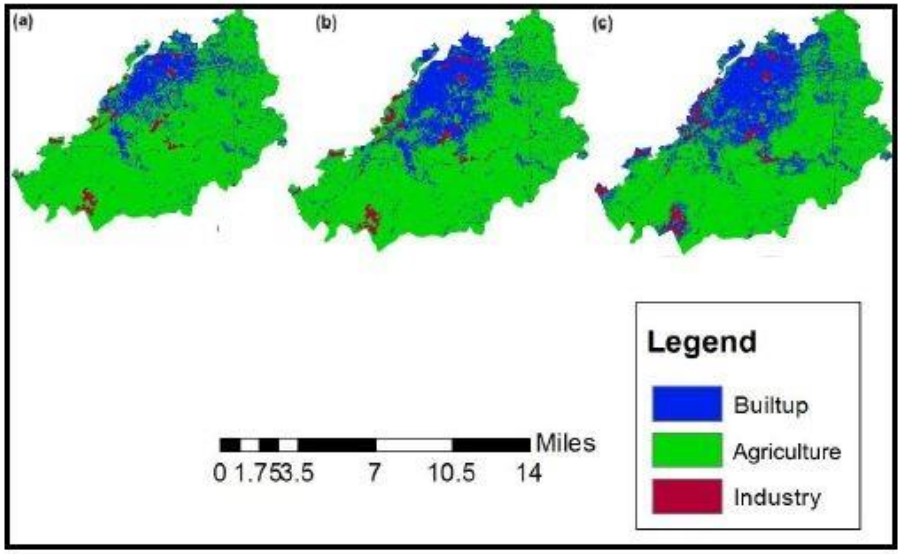
LULC Categories	1992		2001		2009		Annual Change (sq.km)
	Area (sq.km)	Area (%age)	Area (sq.km)	Area (%age)	Area (sq.km)	Area (%age)	
Build-up-Area	911.14	51.42	1012.11	57.12	1268.85	71.61	21.04
Vegetable Cover	645.06	36.40	417.51	23.56	249.7	14.09	**-23.26**
Open Areas	174.69	9.86	288.1	16.26	179.26	10.12	0.27
Water Bodies	15.95	0.90	25.31	1.43	34.95	1.97	1.12
Mixed	25.06	1.41	28.97	1.63	39.25	2.21	0.83
Total	1771.9	100.00	1772	100.00	1772.01	100.00	

Landuse and Landcover Trend in Lahore

- Results of the study show that with the urbanization and due to migration of population from rural to urban areas in the search of better education and job opportunities, the built-up area is increasing drastically over the years with the astonishing annual change of 21 sq.km;
- While the agriculture cover area is suffering badly with the annual change of 23 sq.km annually;
- The trend of change in LULC can clearly be seen in these figures.



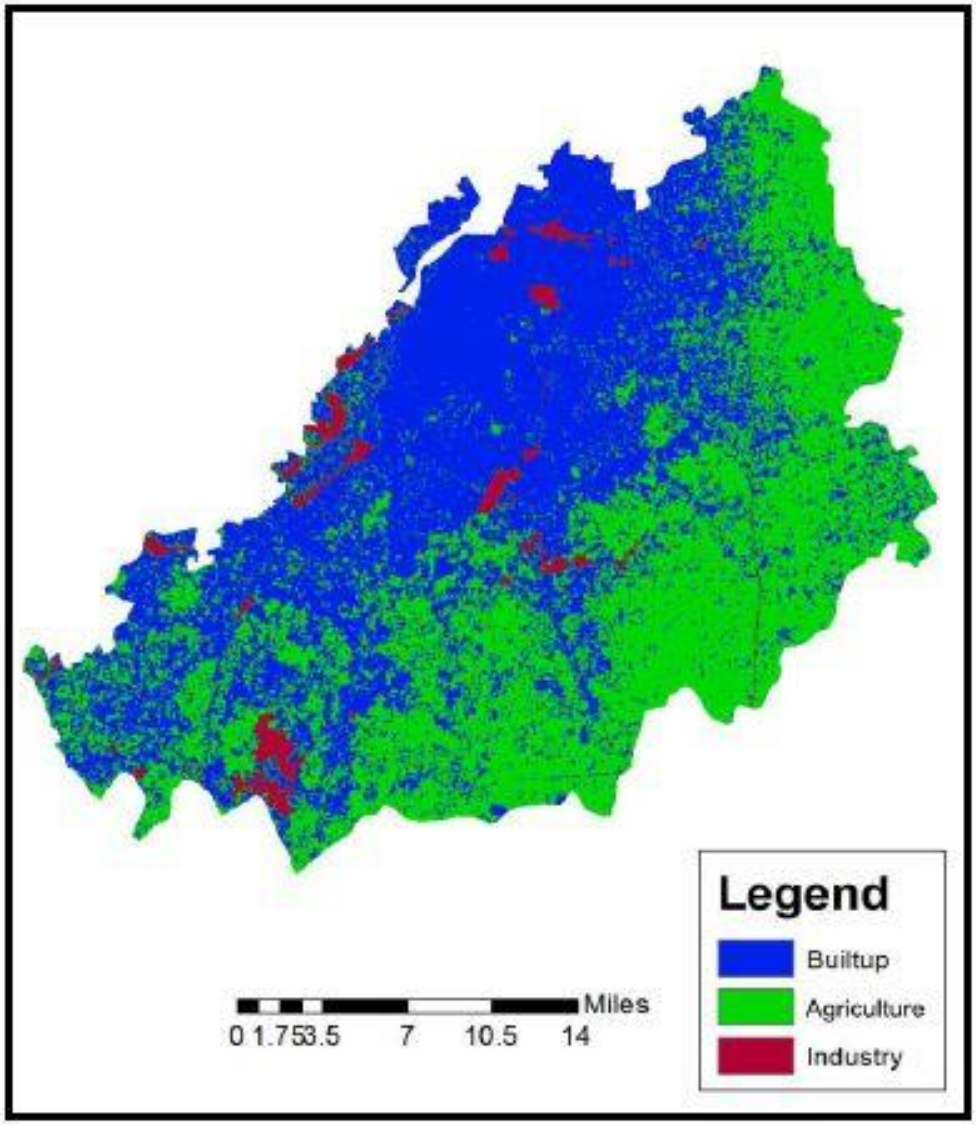
Enhanced Vegetation Index (EVI) Values for Year 2009 (a), and Year 2012 (b)



Classified Maps of Land-Use Land-Cover (LULC): Initial (a) 2009 (b), 2012 (c)

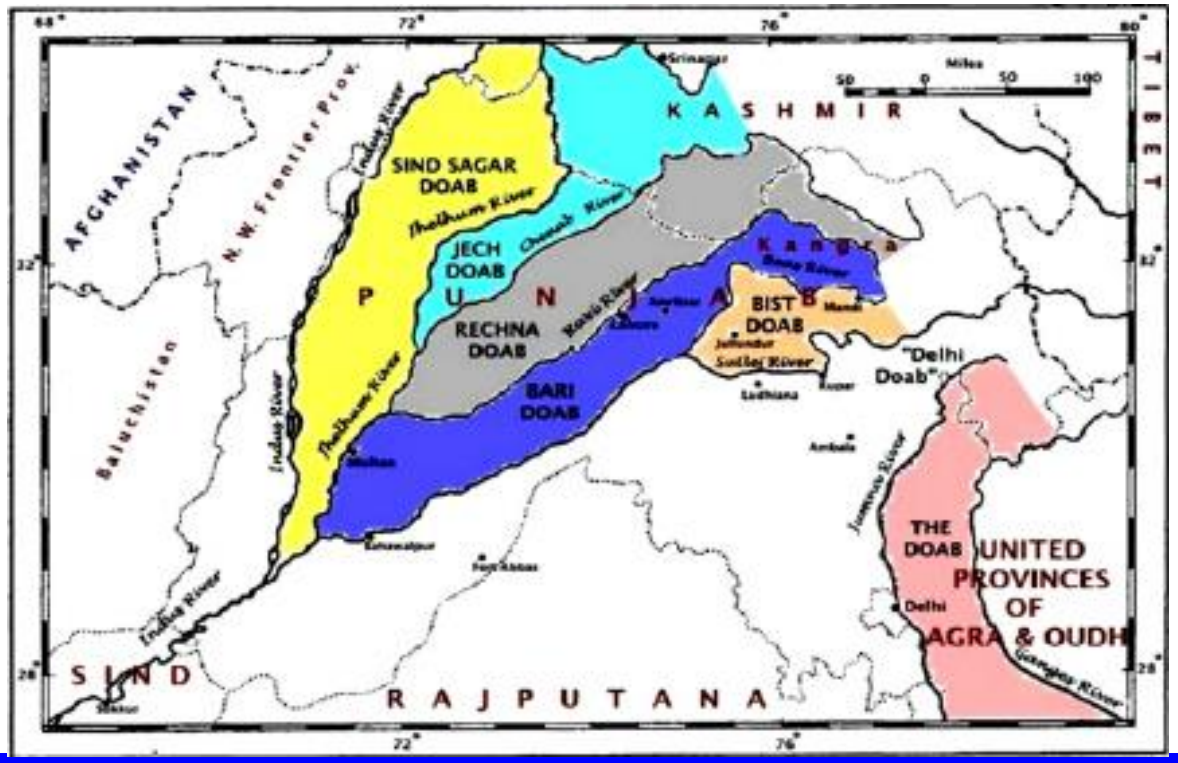
Landuse and Landcover Trend in Lahore

- Predicted LULC trend for the year 2025



Basin Boundary and Hydrology of Lahore

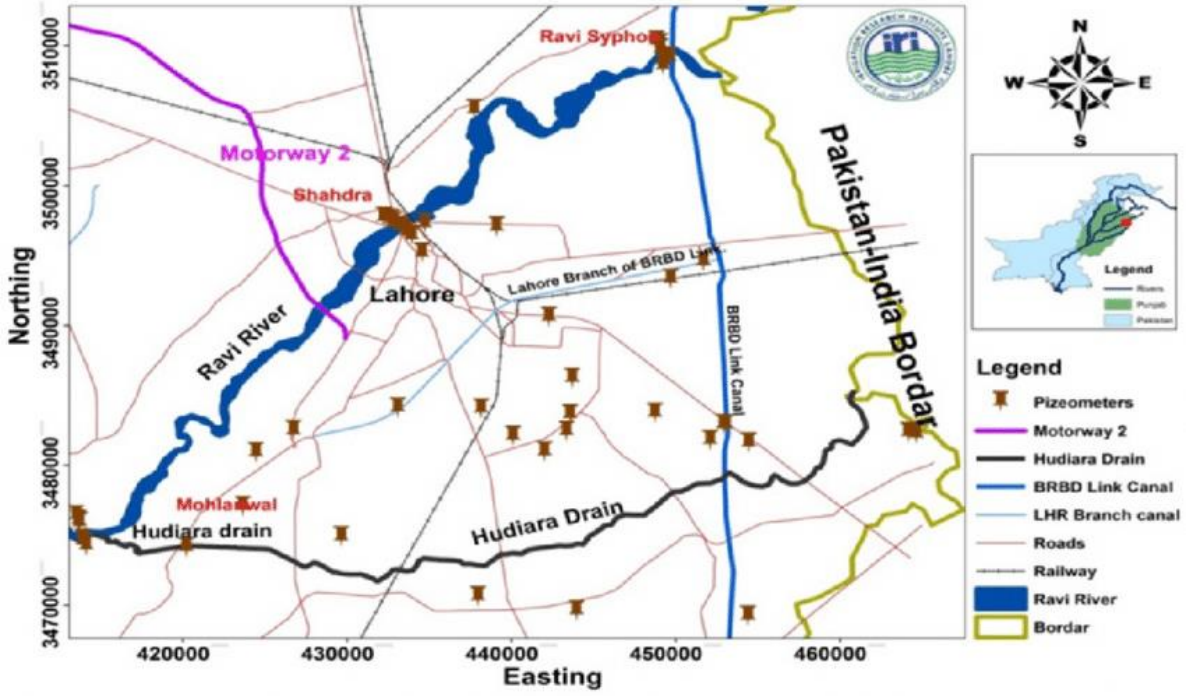
- Lahore is located in Bari Doab Area, by the Bank of Ravi River which passes by the northern side of the city.
- Doab is a term used in South Asia for the "tongue," or tract of land lying between two converging, or confluent, rivers. It is similar to an interfluve.
- Bari Doab is a piece of land between Ravi and Sutlej Rivers.
- The basin occupying Lahore is enclosed by foot hills near Kangra on eastern side and Himalaya in the north. In the west the boundary is extended upto Baluchistan and upto Indian Ocean in the South.



Basin Boundary and Hydrology of Lahore

Lahore Canal

- Lahore Canal once a part of Upper Bari Doab Canal (CBDC), now begins at the Bambawali-Ravi-Bedian Depalpur (BRBD) Canal that runs through the east of the city of Lahore, Punjab, Pakistan. The 37 miles (60 km) long waterway having average flow of 2600 cusecs, was initially built by the Mughals. It was then upgraded by the British in 1861.

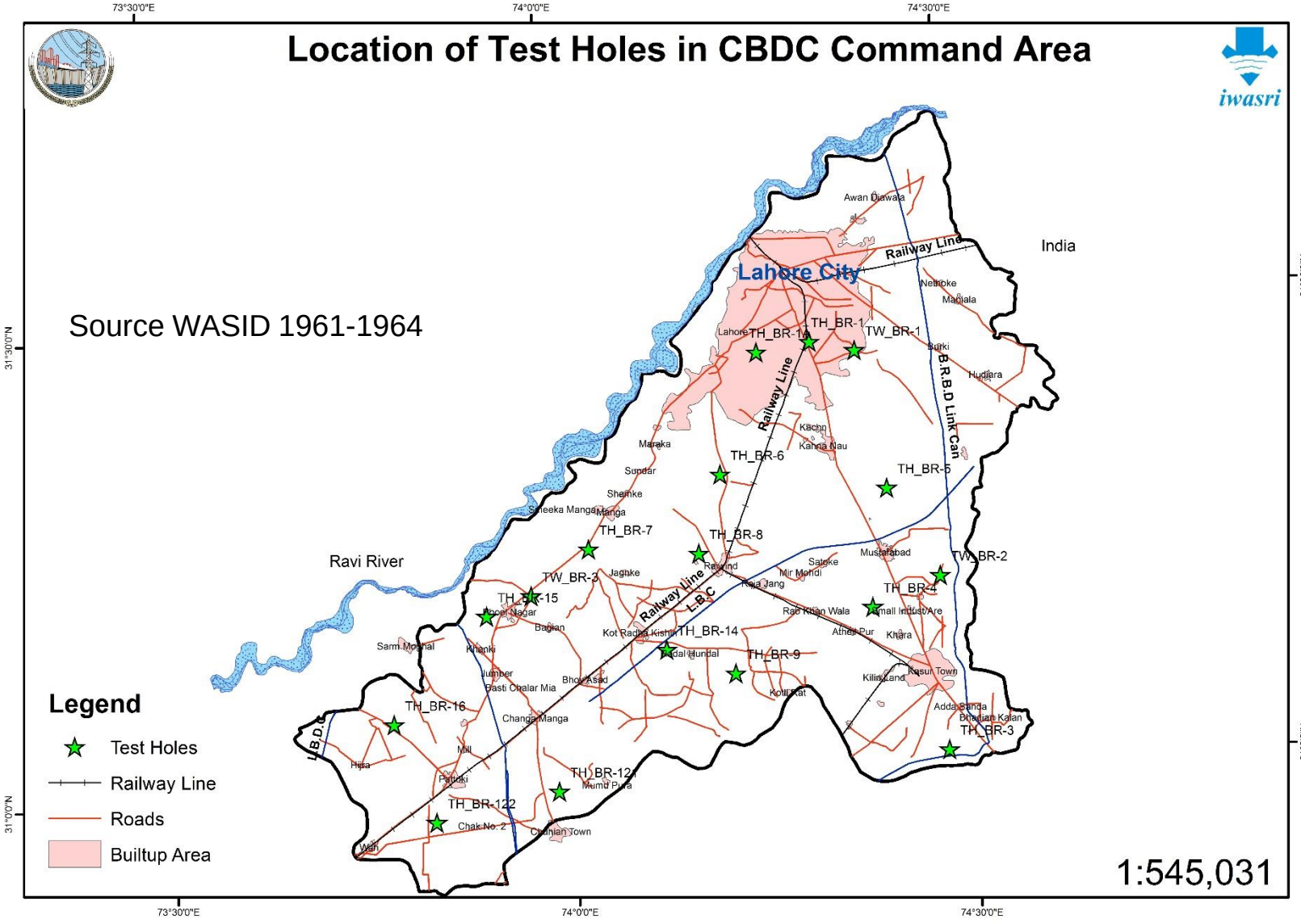


A view of Lahore Canal (Source: Wikipedia)

Characteristics of groundwater (GW) aquifers and Hydrogeological properties of aquifers.

- Lahore area is underlain by unconsolidated alluvial deposits of quaternary age. The aquifer is composed of unconsolidated alluvial complex formed by the contemporaneous filling of a subsiding trough - a foredeep adjacent to the rising Himalayan ranges.
- Contemporaneous filling and subsidence have given rise to an extensive sedimentary complex of more than 400 meters thickness(at three locations base was reached at 400m below NSL).
- The sediments have been deposited by the present and ancestral tributaries of the Indus River during Pleistocene-Recent periods.
- In accordance with its mode of deposition by large streams in constantly shifting channels, the alluvial complex is heterogeneous and individual strata have little lateral or vertical continuity.
- However, in spite of their heterogeneity, the alluvial sediments constitute a large aquifer, which on regional basis behaves as a homogeneous aquifer.

Characteristics of groundwater (GW) aquifers and Hydrogeological properties of aquifers.



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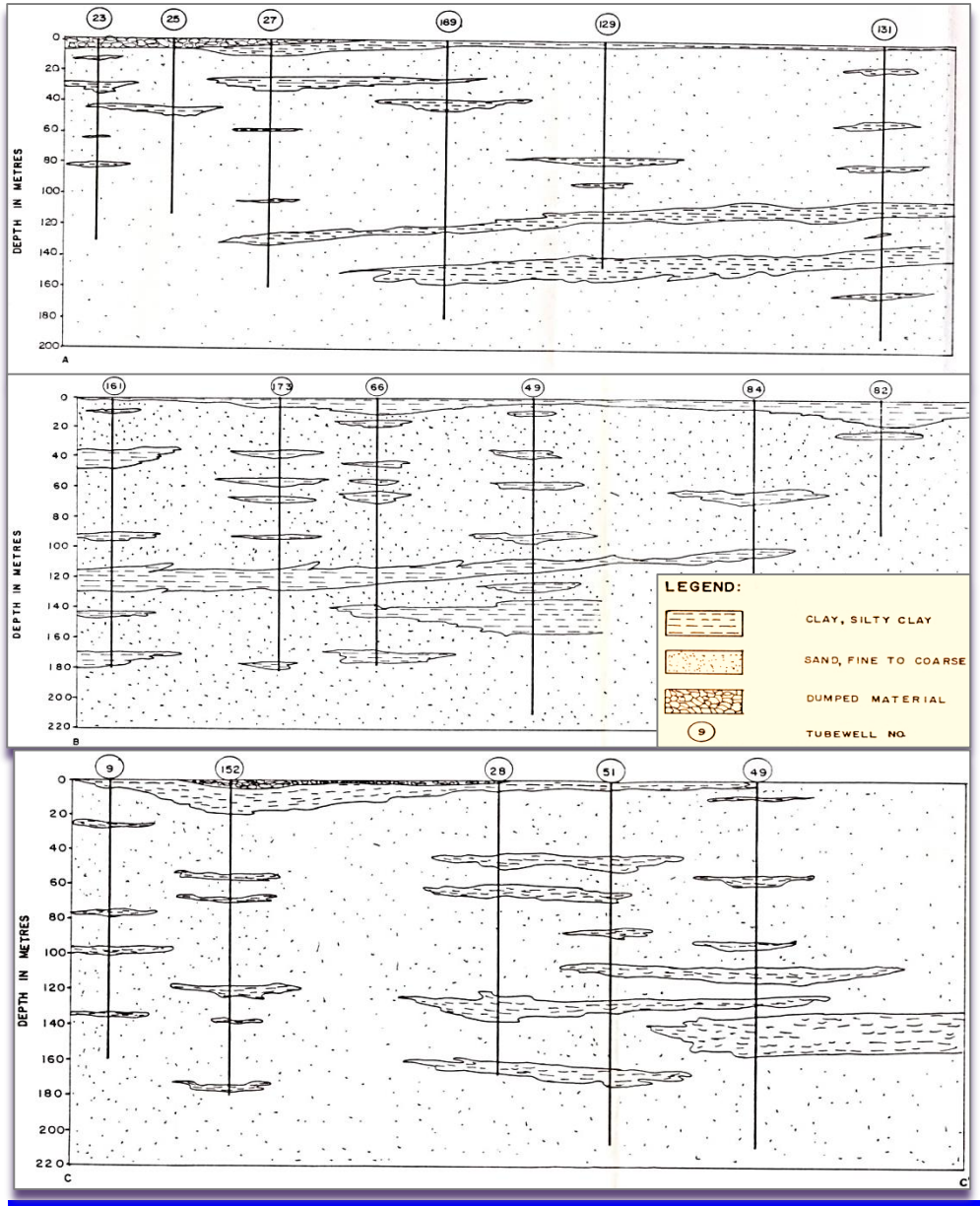


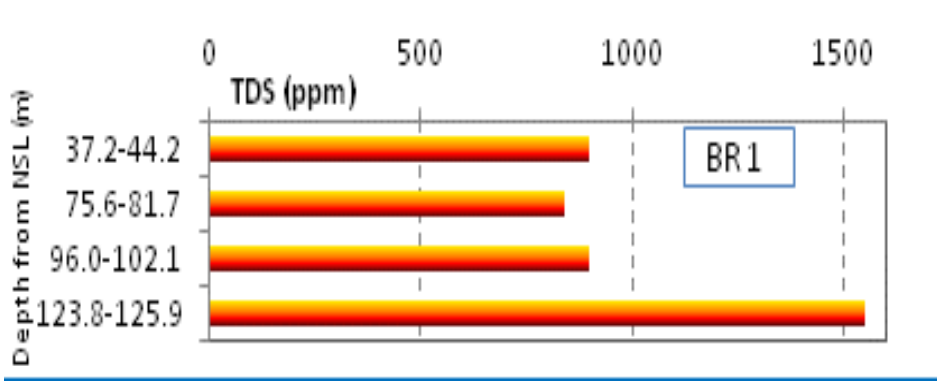
Drilling Depth (ft)	Graphic Log	Formation Description	Well Casing: Casing Detail	Well
0-25		CLAY	M.S. HOUSING 20 in Dia 270 ft	20"
25-35		CLAY with KANKAR		
35-50		Fine SAND		
50-60		Fine SAND with KANKAR		
60-70		Fine SAND		
70-80		CLAY		
80-95		Fine SAND		
95-120		Fine to Medium SAND		
120-140		Fine SAND		
140-170		Fine to Medium SAND		
170-185		Fine SAND		
185-200		CLAY		
200-210		Fine to Medium SAND		
210-260		Medium to Coarse SAND	M.S/F.G Overlap 30 ft	240 ft; 10"; 270 ft; 20"
260-270		Fine SAND		
270-285		Fine to Medium SAND	FIBER GLASS BLANK 10 in Dia 165 ft	
285-310		CLAY		
310-320		Fine SAND with KANKAR		
320-330		Fine SAND		
330-345		Fine SAND with KANKAR		
345-350		Fine to Medium SAND		
350-375		CLAY		
375-380		Fine SAND		
380-385		Fine to Medium SAND		
385-390		Fine SAND		
390-395		CLAY		
395-400		Fine SAND		
400-445		Medium to Coarse SAND	F.G. STRAINER 10 in Dia 30 ft	405 ft; 435 ft
445-530		CLAY	FIBER GLASS BLANK 10 in Dia 100 ft	
530-705		Medium to Coarse SAND	FIBER GLASS STRAINER 10 in Dia 105 ft	535 ft
			F.G. BLANK 5 ft	640 ft
			FIBER GLASS STRAINER 10 in Dia 55 ft	
			F.G. BAIL PLUG	700 ft; 710 ft
705-715		CLAY		

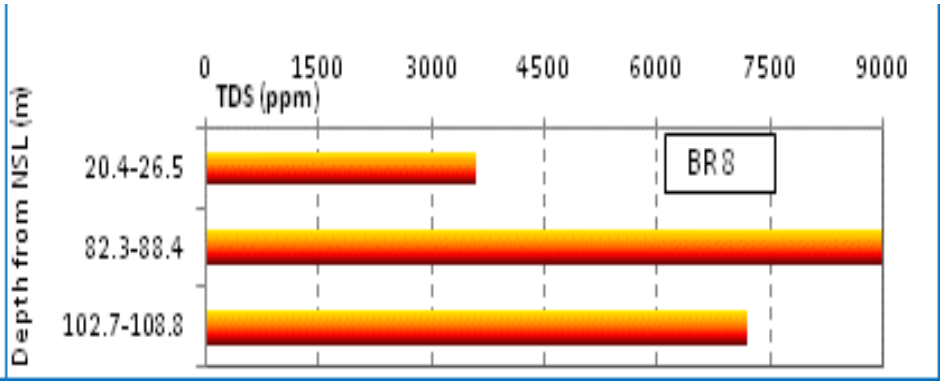
- Test tubewell TW-BR1 shows high transmissivity of about 2100 m^2/day when tested by WASID in 1960-64;

- Average Aquifer thickness was found 400m near Lahore City(assuming 80 m thickness contributing to groundwater flow).

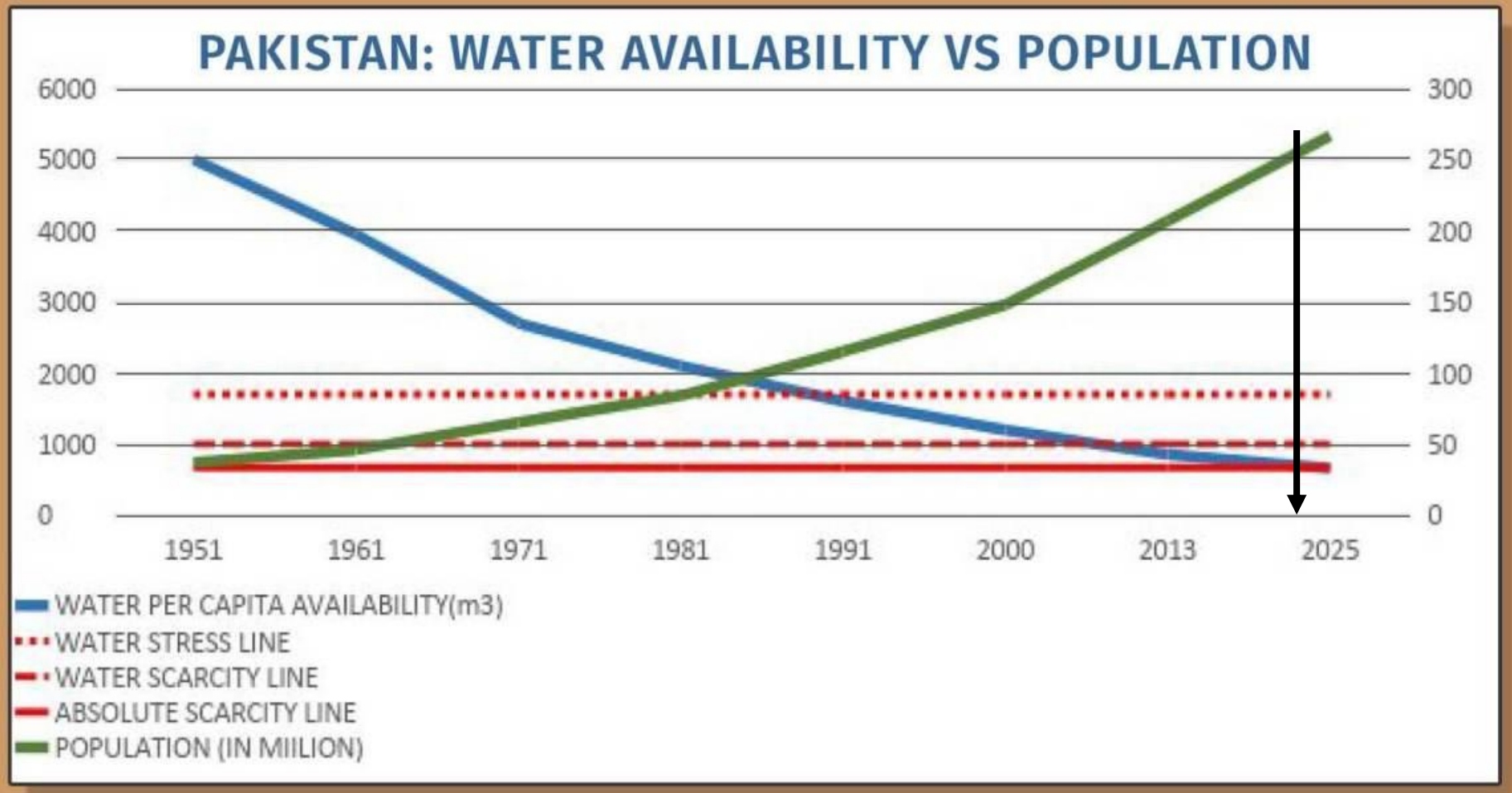
Hydrochemical Properties of Lahore Aquifer

Test Hole #	Depth (ft.)	Meq/l							Total Cat/An-ions	TDS (ppm)	Ec (µmhos/cm)	pH	SAR	RSC
		Ca	Mg	Na+K	CO_3	HCO_3	Cl	SO_4						
BR 1	124-145	1.60	2.57	11.1	-	7.24	2.04	6.05	15.33	900	1400	8.1	7.7	3.07
	248-268	1.60	2.97	9.28	-	6.60	2.00	5.25	13.85	840	1300	8.1	6.1	2.03
	315-335	1.60	1.98	11.7	0.16	6.68	2.00	6.44	15.28	900	1400	8.3	8.6	3.26
	406-413	1.12	0.67	24.3	-	8.00	3.96	14.2	26.18	1550	2380	8.1	25.0	6.21
BR 12	112-132	2.40	1.38	9.02	0.40	6.90	1.30	4.20	12.80	750	1160	8.3	6.5	3.52
	225-245	1.52	0.86	3.34	-	3.70	0.60	1.42	5.72	345	530	8.1	3.0	1.32
	292-312	1.28	1.10	4.16	-	3.20	0.64	2.70	6.54	390	600	8.1	3.8	0.8





Water Availability in Pakistan

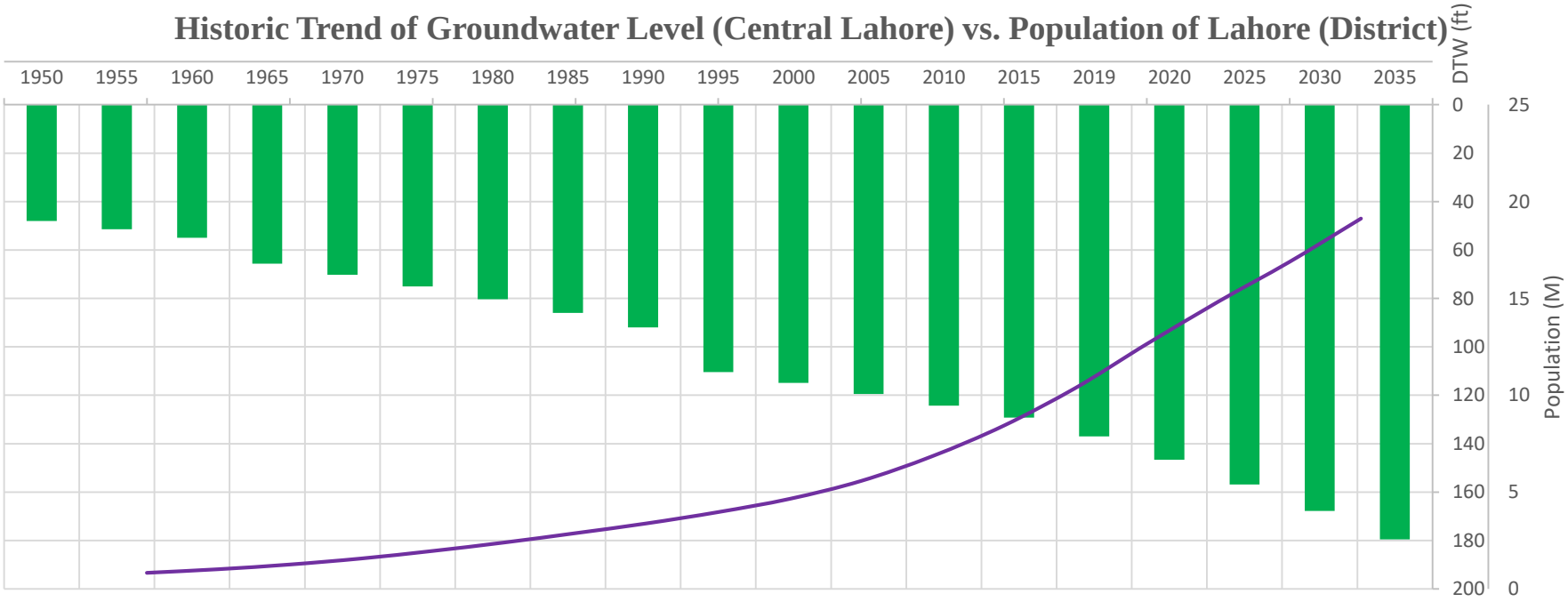


Groundwater Abstraction

Description/year	1987	2000	2010	2019
Depth to Watertable (ft)	25-65	35-105	40-135	60-152
No. of Tubewells	200	316	467	620
Total Abstraction, mgpd (cfs)	320 (593)	400 (742 cfs)	696 (1291)	1180 (2187)
Population (M)	3.5	4.83	7.5	12.4
Depth of GW abstracted (mm/d/Area)	462	578	1006	1704

Trends in key drivers of GW stress in Lahore

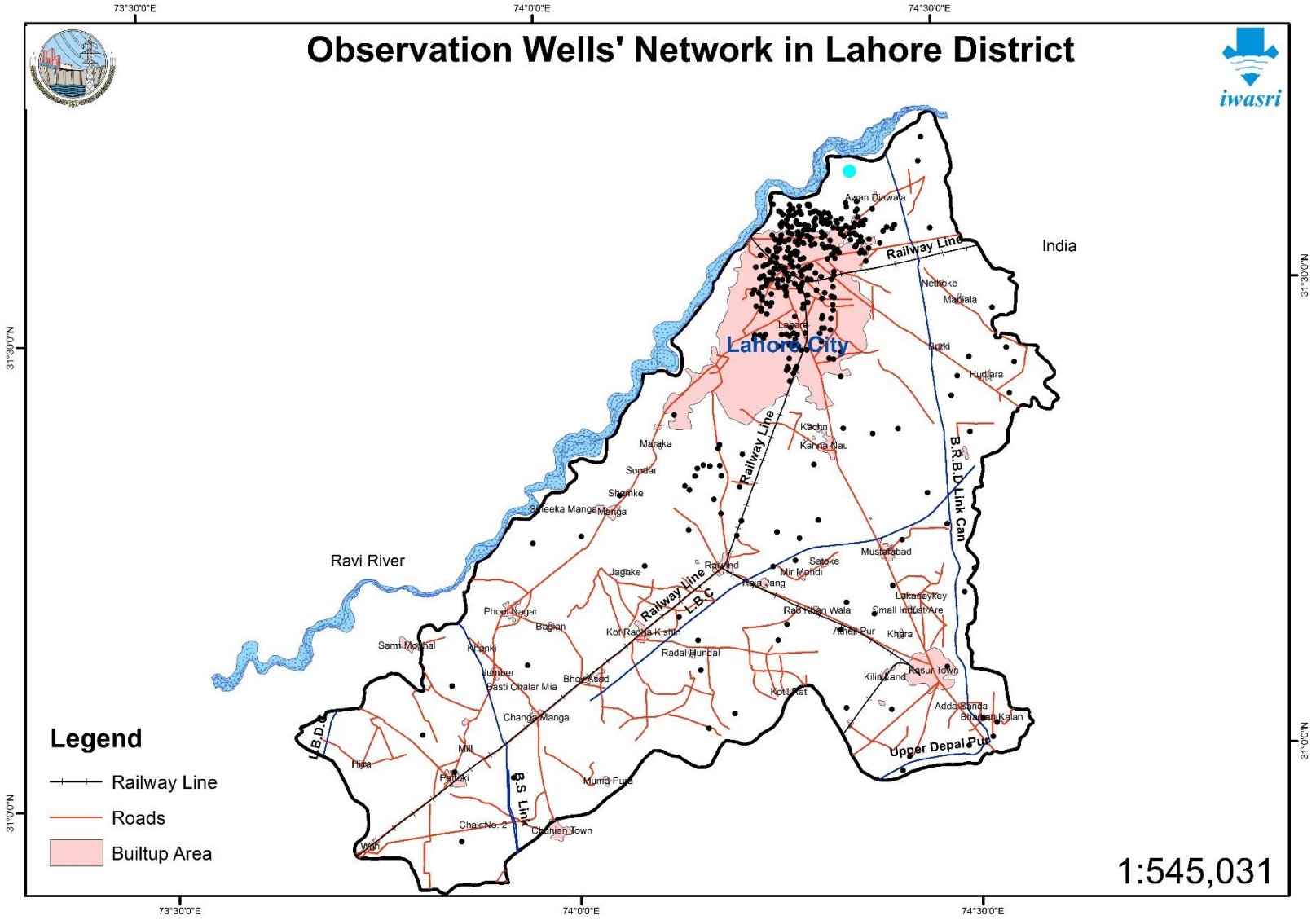
- Continuously Descending Groundwater Level in Lahore since 1950 due to shortage of water resources;
- Increasing Trend of Population and landuse change is major stress on Groundwater in Lahore.



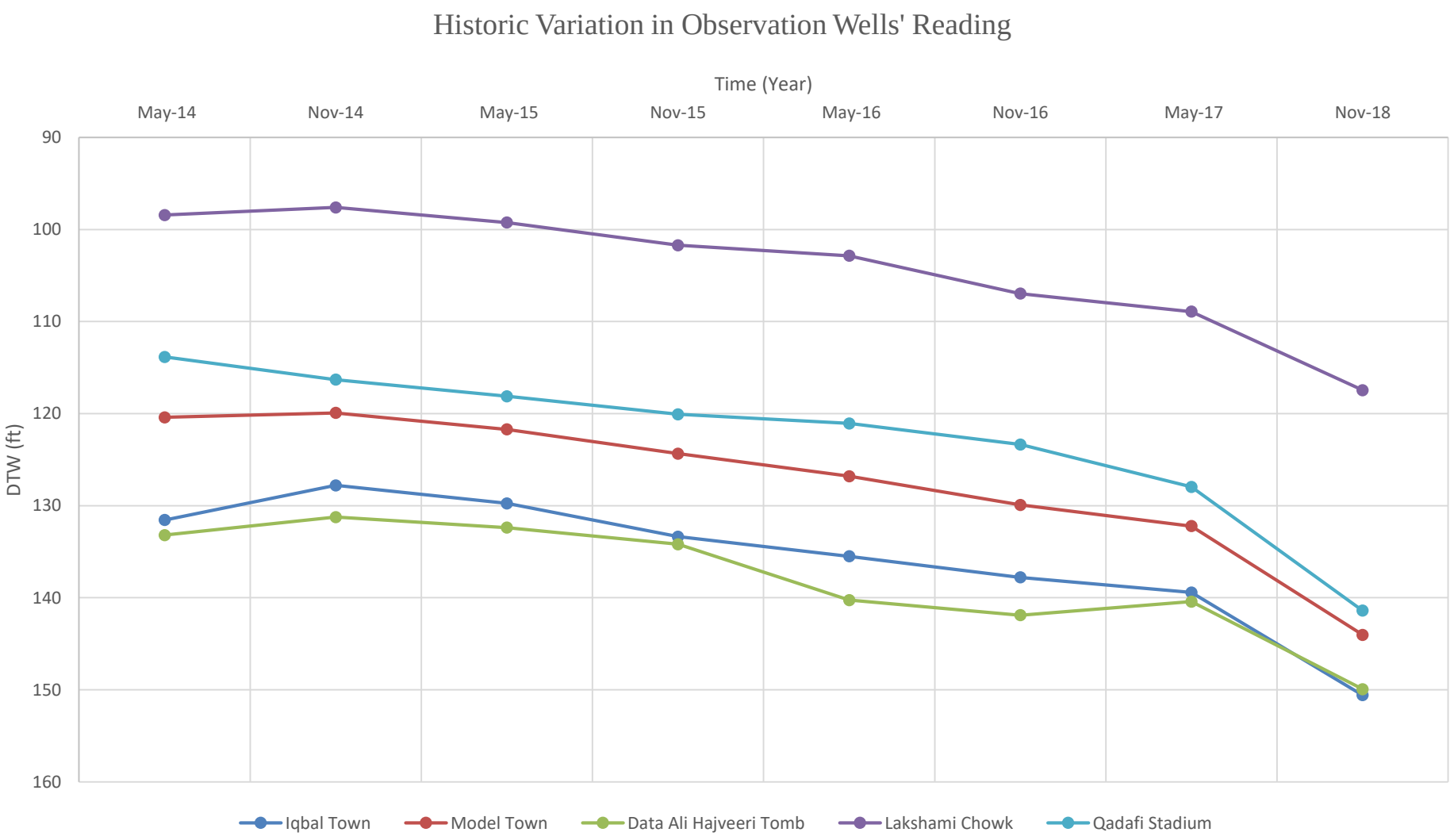
Groundwater Monitoring Network in Lahore

- SCARPs Monitoring Organization (SMO) is national level groundwater monitoring organization in Pakistan working under IWASRI, is having a country wide network of more than 6000 observation wells throughout the Indus Plain;
- Monitoring of GW depth and quality is carried out twice in a year (Pre & Post-Monsoon);
- In Lahore region there are more than hundred observation wells installed by SMO;
- Some of the wells have been dried due to groundwater subsidence;
- After monitoring of GW depth and quality, maps are produced and disbursed to other related organizations and universities.

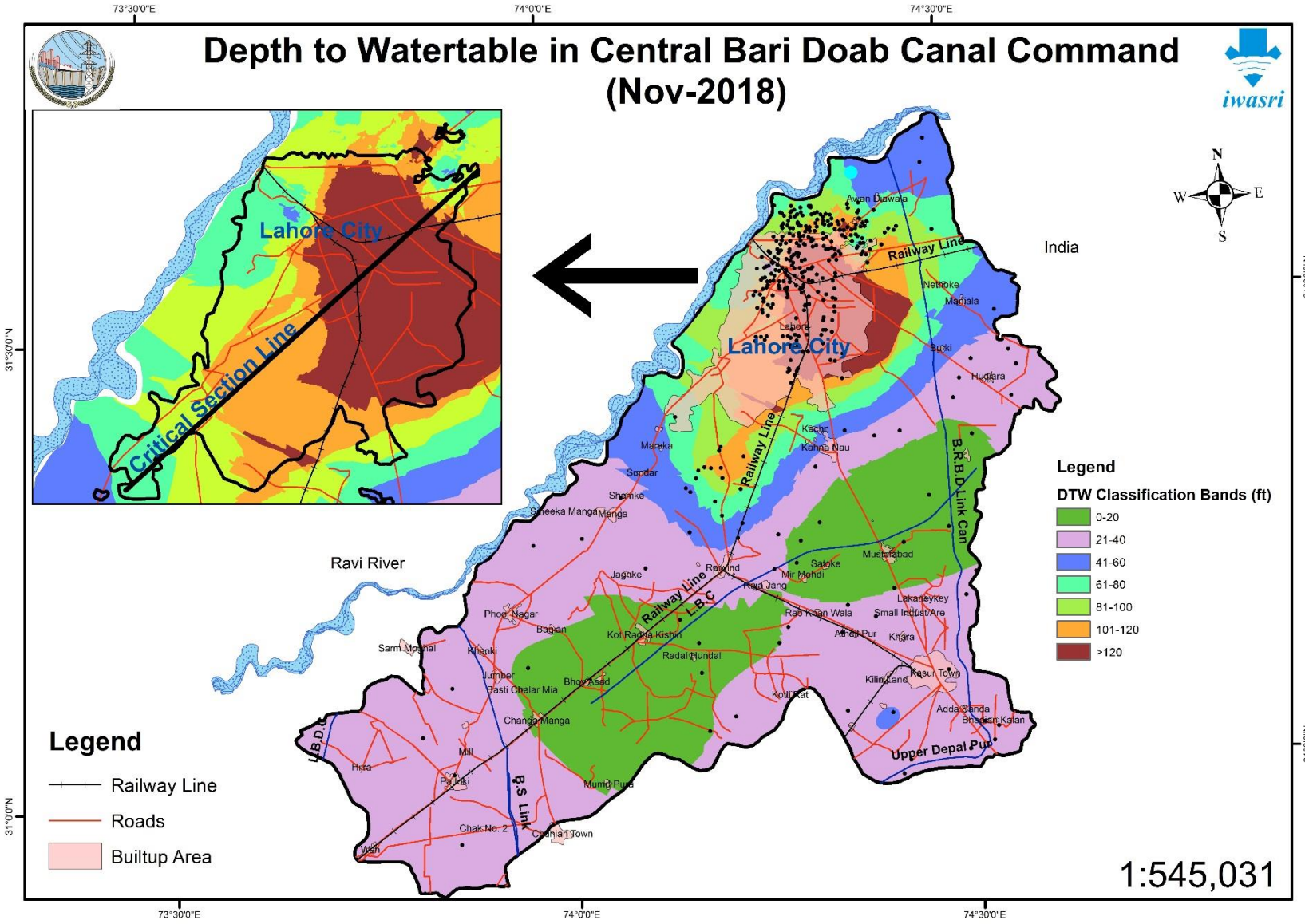
Groundwater Monitoring Network in Lahore



Historical Trends of DTW in Observation Wells

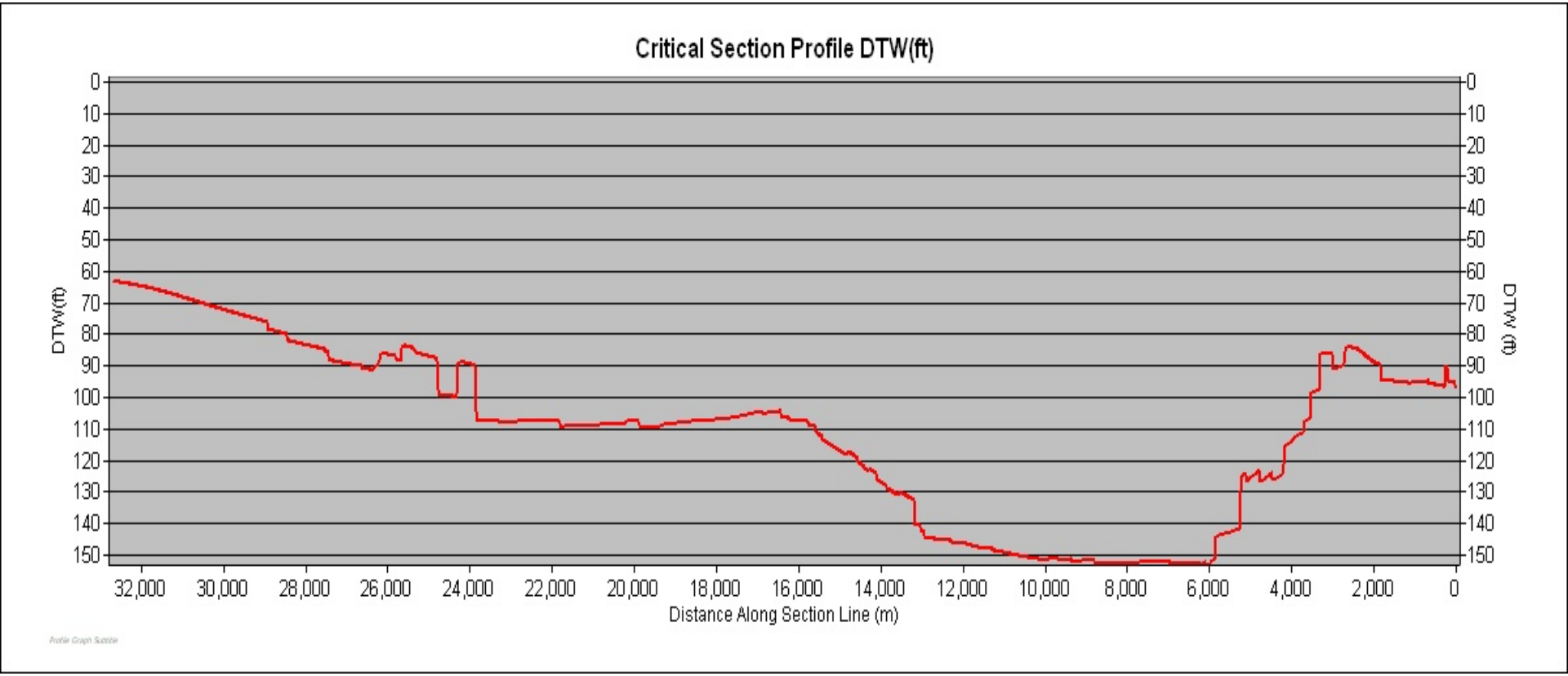


Current Status of Groundwater Depth in Lahore



Current Status of Groundwater Depth in Lahore

- Maximum Depth: 152 ft
- Minimum Depth: 60 ft



Statistics of Groundwater Depth in Lahore

- More than 70% of Lahore's GW is >70 ft deep

Sr. No.	DTW Bands (ft)	Area (sq.km)	Percentage
1	41-60	0	0
2	61-80	206	12
3	81-100	332	19
4	101-120	492	28
5	>120	738	42

The Wayout

- Each and every use of existing groundwater above 0.20 cusecs should be registered with all the allied information regarding his borehole and quantum of pumping;
- Each new user should be required to get a permit before installation of pumping equipment
- Building bye laws should be amended and enforced for private as well as public buildings for achieving maximum possible rainwater harvesting and recharge to groundwater.
- Monitoring of waste disposal at key points should be done to act as guiding tool for finding point sources of major pollution in the surface drains.
- At present about half of the WASA area and most of the housing societies are providing water to it residents at flat rates which is also one of the major reason for wasting the precious groundwater resources, the policy should be forced to change to metered water connections for reducing stress on the underground reservoir.
- Every user of groundwater should be charged with certain amount of groundwater development and management surcharge.
- Quantity and quality of waste water disposed off by government as well as private entrepreneurs should be monitored regularly.
- It is recommended that all sewerage being disposed in to the Ravi River should be conveyed in to a lined channel built along side the edge of the river bed. This can help reducing the pollution loads to the aquifer.

Any Questions

Thank you