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SITUATIONAL ANALYSIS OF WATER RESOURCES OF SIALKOT

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LIST OF ABBREVIATIONS

BCM: Billion Cubic Meter

BRB: Bambanwala River Bedian

CDIA: Cities Development Initiatives for Asia

CPC: Cleaner Production Center

DPs: Dechlorane Plus

ET_{o}: Evapotranspiration

GDP: Gross Domestic Products

IBIS: Indus Basin Irrigation System

ILES: International Labor and Environmental Standards

J&K: Jammu and Kashmir

m: meter

MGD: Million Gallon per Day

MRL: Marala Ravi Link canal

OCPs: Organochlorine Phosphates

PBDEs: Polybrominated Diphenyl Ethers

PCBs: Polychlorinated biphenyls

PCNs: Polychlorinated Naphthalenes

PCRWR: Pakistan Council for Research in Water Resources

PEPA: The Punjab Environmental Protection Agency

PHED: Public Health Engineering Department

PKR: Pakistani Rupee

PMC: Pak Medical Centre

POPs: Persistent Organic Pollutants

PSQCA: Pakistan Standard Quality Control Authority

TMA: Tehsil Municipal Administration

UN: United Nations

WAPDA: Water and Power Development Authority

WASCOs: Water and Sanitation Community Organization

WBDs: Water Borne Diseases

WHO: World Health Organization

WWF-Pakistan: World Wide Fund for Nature Pakistan

EXECUTIVE SUMMARY

WWF-Pakistan, under its project entitled International Labour and Environmental Standards Application in Pakistan's SMEs (ILES), has undertaken a situational analysis study on water in Sialkot. The project aims to enhance cooperation in the water sector by promoting water resource management practices in Sialkot city and adjacent areas. The purpose of this study is to conduct an in-depth literature review followed by the implementation of an analytical approach to highlight issues hindering effective water resource management within Sialkot while proposing mitigation techniques and recommendations for strengthening policy and institutions.

Surface water resources in Sialkot city include nullah Aik and nullah Palkhu (stream is locally called *nullah*). River Chenab and River Tawi are also considered as resources of surface water which flow about 20 km of the north of Sialkot city.

Currently, 97 tube wells are present in Sialkot, out of which 95 tube wells are functional. Additionally, 15 Cantonment tube wells are operating to meet the urban water demand. Water discharge from each tube well is 1.5 cusec (42.5 l/sec or 153m^3/hr) (standard) with water extraction per capita per day of about 79.8 gallons. Total water extraction is 38.37 Million Gallons per Day (MGD) to meet the water demands of domestic (18.18 MGD), industrial (4.55 MGD), commercial (4.55 MGD) and institutional (3.03 MGD) sectors. The water demand in these sectors is expected to reach to 26.10, 6.52, 6.52 and 4.35 MGD respectively by 2035.

Besides Rivers Chenab and Tawi, nullahs Aik, Bhaid and Palkhu are the main sources of groundwater aquifer recharge in the city. Regrettably, 4.56 MGD of untreated wastewater and sewage is drained into these nullahs. Furthermore, rainfall (10-24 per cent of the annual rainfall) is also an important means of recharge for the water table.

In 2017, Pak Medical Centre (PMC), Sialkot conducted a study to investigate the drinking water quality of Sialkot. Notable amount of iron was detected in water samples collected from Cantt. and Model Town while other samples had lower iron content. Coliform bacteria were found in samples collected from Miana Pura, Mag Town, Cantt., Model Town, Neka Pura and Ugoki. Presence of coliform bacteria indicates that sewage

or municipal wastewater is contaminating the drinking water sources.

Wheat, rice, vegetables and fodder crops cultivated along the agricultural areas of these nullahs are directly irrigated with wastewater. Across the banks of these nullahs, hundreds of water pumping motors are installed by farmers, which release chemical laden water to crops. These food crops take up pollutants from the wastewater, and are later consumed by humans. However, eating such food may be extremely injurious to human health.

Natural water streams passing across the urban settlements experience outburst floods during monsoon season. There is no strategic plan or proper mechanism to treat the excess water and to utilize it for groundwater recharge.

Water scarcity is becoming a serious threat in the area due to over abstraction and less replenishment of groundwater. Water scarcity will pose tremendous impact on all business activities. Disturbance in water supply chain will destabilize industries and manufacturing units, where water is required for processing, irrigation, washing, cleaning, and cooling purposes. Moreover, over extraction of water will lead to a drought like condition, squeezing of cultivated land and deforestation.

Water scarcity needs to be addressed through collective action by all major stakeholders. One key solution to the problem of water scarcity in Sialkot can be through infrastructure repair and maintenance of water channels such as Bambanwala River Bedian (BRB) Canal, Marala Ravi Link Canal and Upper Chenab Canal. Leaking pipes and sewage systems normally lead to water wastage and contamination respectively. Groundwater should be protected from anthropogenic activities that are potentially polluting water. Disposal of untreated wastewater, solid waste and chemical waste to main surface water bodies should be prevented to protect the groundwater from contamination. Additionally, depression zones need to be identified, and declared, to minimize groundwater pumping across the city and flood water should be managed as a groundwater recharge source.

Under the Sustainable Development Goal-on Clean Water and Sanitation (SDG 6), Pakistan has committed to ensure availability of safe drinking water for all by 2030, by investing in sufficient water infrastructures, providing appropriate sanitation facilities and raising hygiene awareness at every level (local, regional and national). Thus, there is a need for a policy framework and effective administrative measures to ensure sustainable use of water resources in all cities of Pakistan.

1 INTRODUCTION

Sialkot District is well recognized for harboring the export-oriented industries of Pakistan. It is popularly known as the manufacturing hub of surgical instruments, sports and leather goods. One sector, especially worth mentioning in the district is the leather industry, which contributes to 5.4 per cent of Pakistan's GDP. The study presents the water accounting of Sialkot with a description of volumetric data of key water resources, water storage information, sink, discharge and water losses across the city. The scope of the study is to develop a water accounting profile; identify key present and future water risks at the city level to domestic and business sectors (and subsectors where appropriate), both in terms of water quantity and quality, including identification of key sources of pollution and a brief outline of the institutional and regulatory context of water and wastewater.

1.1 SPECIFIC OBJECTIVES

The specific objectives of the study are to collate key available information on water resources of Sialkot; to describe the physical water and institutional water management situation and risks (physical, reputational, regulatory and institutional risks) of Sialkot and to provide a robust evidence base to support the identification and implementation of water management activities.

1.2 METHODOLOGY

The study was conducted through mixed method approach by collecting secondary data. A wide range of stakeholders were engaged and their views, experiences and suggestions were incorporated in the report. An extensive literature review was conducted to gather water related data and to make assessments for the study. The methods and tools selection, including scale of its application, were guided by the study objectives and framework.

Results and analysis of the data provide information on water availability and management problems, for industrial, institutional and domestic users, probable hazardous risks and institutional/organizational water management scenarios. It is envisioned that the data presented in this report will be of value for government bodies, policy makers and other stakeholders.

1.3 LOCATION AND DEMOGRAPHY

Sialkot district of Punjab lies between 32°29′33″N and 74°31′52″E geographical coordinates at an elevation of 256 m above sea level with total area of 58 sq. km. On north it is bounded by Jammu, north-west by Gujrat, west by Gujranwala and south by Narowal. Sialkot district is divided into four tehsils i.e. Sialkot, Pasrur, Daska and Sambrial. Each of the tehsil has its own industrial importance e.g. Daska is famous for production of high-quality rice, wheat, potatoes and sugarcane. While Sialkot Dry Port located in Sambrial enhances export of quality products from Pakistan. Famous River Chenab flows on north of the district along with small seasonal streams. Sialkot shows seasonal streams in summer and winter. May, June and July are the hottest months while in winter the temperature may drop below zero. The soils are fertile, yielding maximum production of the cash crops due to plain topography. Annual average rainfall is approximately 1016 mm of which most of the rains are observed in the monsoon season in summer. Approximately 3229 industrial setups exist in the city with 270 leather tanneries.

Population of Sialkot district is 3,893,672 persons according to 2017 population census. Population density of 1,259 person/km^2 was reported in 2017 which indicated that Sialkot is a densely populated district. Among the above stated population, 29.4 per cent comprises of urban community while rest of 70.6 per cent is rural community, according to the (Pakistan Bureau of Statistics). Figure 1 shows the map of Sialkot city.

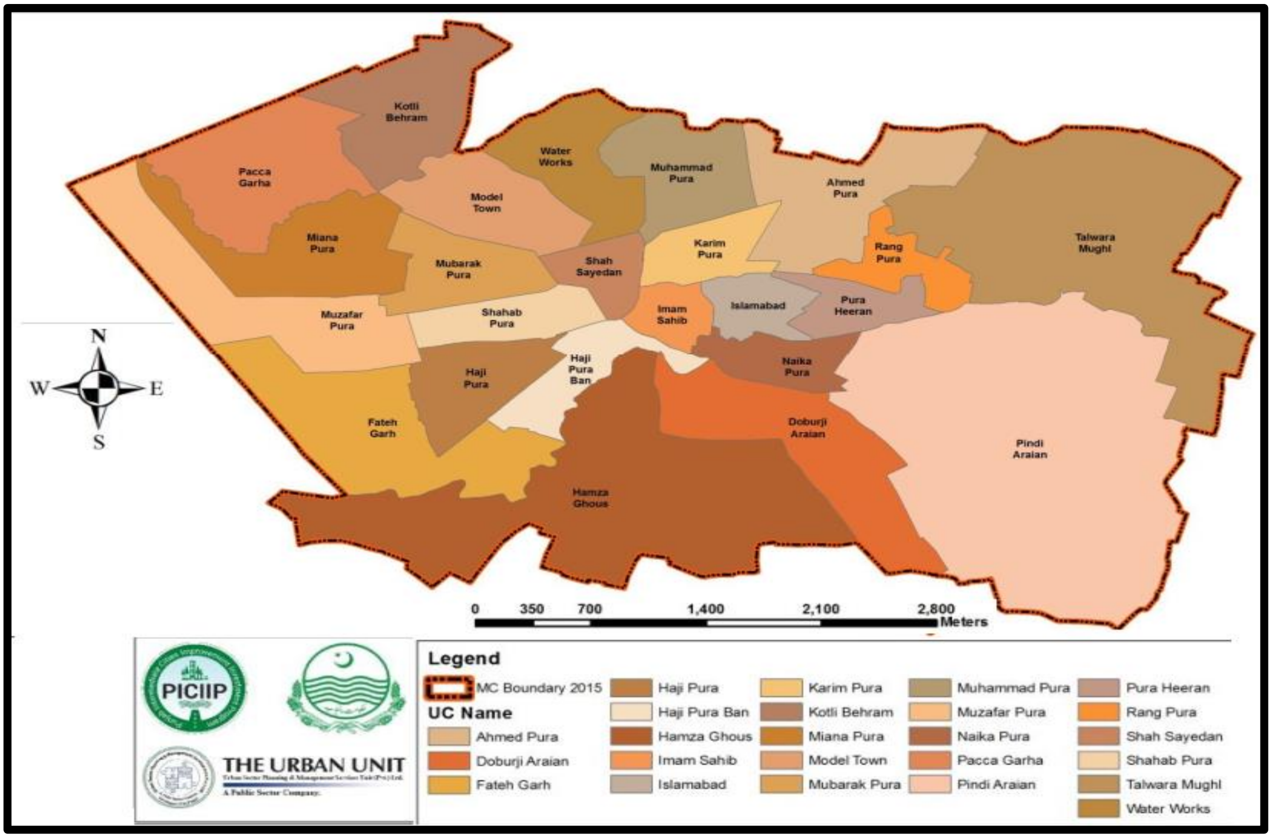


Figure 1: Map of City of Sialkot highlighting main Union Councils of the city (Source: Urban Planning in Sialkot; PICIIP, 2010)

2 WATER ACCOUNTING FOR SIALKOT CITY

2.1 SOURCES OF WATER

2.1.1 SURFACE WATER RESOURCES

Surface water sources in Sialkot city include nullah Aik and nullah Palkhu. River Chenab and River Tawi are also considered as surface water resources which flow about 20 km of the north of Sialkot city. River Chenab and River Tawi are the main recharge source for the aquifer for water table of the city.

Nullah Aik (32°63′N- 74°99′E and 32°45′N-74°69′E) and nullah Palkhu (32°69′N- 74°99′E and 32°37′N- 74°02′E) are the main surface water channels of the River Chenab. Catchment area across these nullahs is estimated to bear a population of 2.5 million people. These streams were the main source of drinking, domestic and irrigation water in the past. Land across nullahs Aik and Palkhu is alluvium deposits resulting from regular floods and is under cultivation since prehistoric times. These nullahs originate from Lesser Himalayas in Jammu and Kashmir (J&K) at an altitude of 530 m and 290 m (above sea level), respectively. Aik and Palkhu streams drain 1875 km^2 catchment area and discharge 315 cusecs and 288 cusecs water. Figure 2 describes the average stream water discharge of nullah Aik and Palkhu. Water sources of nullah Aik comprises of springs in eastern part of Jammu and Kashmir (J&K) and heavy rainfall in up-stream catchment areas.

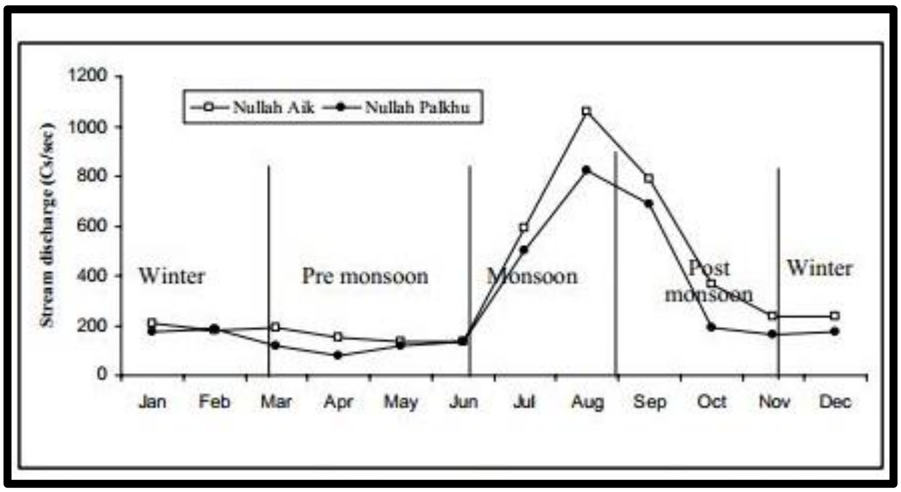


Figure 2: Average stream discharge of Nullah Aik and Palkhu (Source; Punjab Irrigation Department, 2007.)

At upstream, discharge level of nullah Aik is about 35000 cusecs which reduces towards its downstream and remains 5000 cusecs when it crosses Marala Ravi Link canal (MRL) near Khbranwala village and this reduced level reaches to 2000 cusecs at the small downstream headwork (Qadir, 2008). During monsoon season, heavy rainfall charges a large amount of water to these nullahs and sometimes they fail to retain rainwater that causes outflow of water to a large area. This flood water donates a large quantity of silt and new layer of soil which enhances soil fertility. This unique attribute of these nullahs encourages local community to use this land for cultivation purpose and is considered as the best source of irrigation (Mahmood et al., 2014). Currently, only one channel is active for irrigation purpose that originates from Marala headwork and is further divided into sub channels that irrigate croplands. Surplus water of this channel again recharges nullah Aik.

Currently, water quality of these surface water resources is deteriorated due to huge influx of solid waste and domestic and industrial effluents. This practice has influenced biological, chemical and physical properties of these nullahs making them unfit for any kind of human consumption. Sialkot generates 32 MGD of wastewater that drains in nullah Aik, Bhaid and Palkhu. It is important that no waste water treatment facility/plant has been established within the city.

Heavy volumes of urban sewage and industrial wastewater are considered a predominant hazard to the surface water bodies of this city. Due to deteriorated water quality, stream biotic life, specifically fishes and aquatic animals are facing severe impact of toxic pollutants. Reported fish species in these nullahs are *Heteropneustes fossilis, Channa punctata, Cirrhinus reba, Wallago attu, and Labeo rohita* which are consumed due to their edible nature (Qadir, 2008). It is reported via interviews from local communities that different fish species are still present in these nullahs but their number has been reduced significantly. Consumption of such kind of contaminated fish is a major threat to the population.

2.1.2 GROUNDWATER RESOURCES

Sialkot aquifer possesses Pleistocene alluvial deposition of soil with 200 m of thickness (Greenman et al., 1967). Soil is primarily alluvial with erratic textural classes like silt loam and clay while sandy loam and sandy clay loam is also present. Water table depth in Sialkot is normally 10-15 m which is polluted due to industrial and municipal wastewater leaching. Water level below 150 m (500 feet) depth is generally considered safe for consumption. (The Urban Unit; PCIIP, 2010). As mentioned earlier in section 2.1.1, groundwater aquifer is recharged by River Chenab and Tawi; water streams flowing from the city are seasonal; contain rainy water and are also responsible for recharge. These streams are highly polluted (details are provided in section 2.3) and in result of their recharge action they also contaminate the groundwater. Recharge of city water table with Aik and Palkhu streams resulted in considerable polluted ground water above 100 feet. Available data supports that groundwater table of 20-30 feet depth is polluted and unfit for consumption. (The Urban Unit; PCIIP, 2010).

2.1.3 RAIN WATER

Graphs for average rainfall and temperature of the city are presented in Figure 3.

Sialkot bears heavy rainfall during monsoon period. In general, July and August are the months which face peak rainfall and average of 288.4 mm (July) and 259.1 mm (August) rainfall was recorded (2009-2017) while November was found to be the driest month (9 mm rainfall). Sialkot reaps an estimated average of 1016 mm/ year rainfall (based on data from Pakistan Meteorological Department)Rainy water from the catchment areas drains to nullahs Aik and Palkhu while some portion leaches in the soil and recharges the groundwater table. In the month of July, nullah Aik and Palkhu contain maximum water that flows towards River Chenab. Regrettably, there exists no recharge zone to conserve this rainwater.

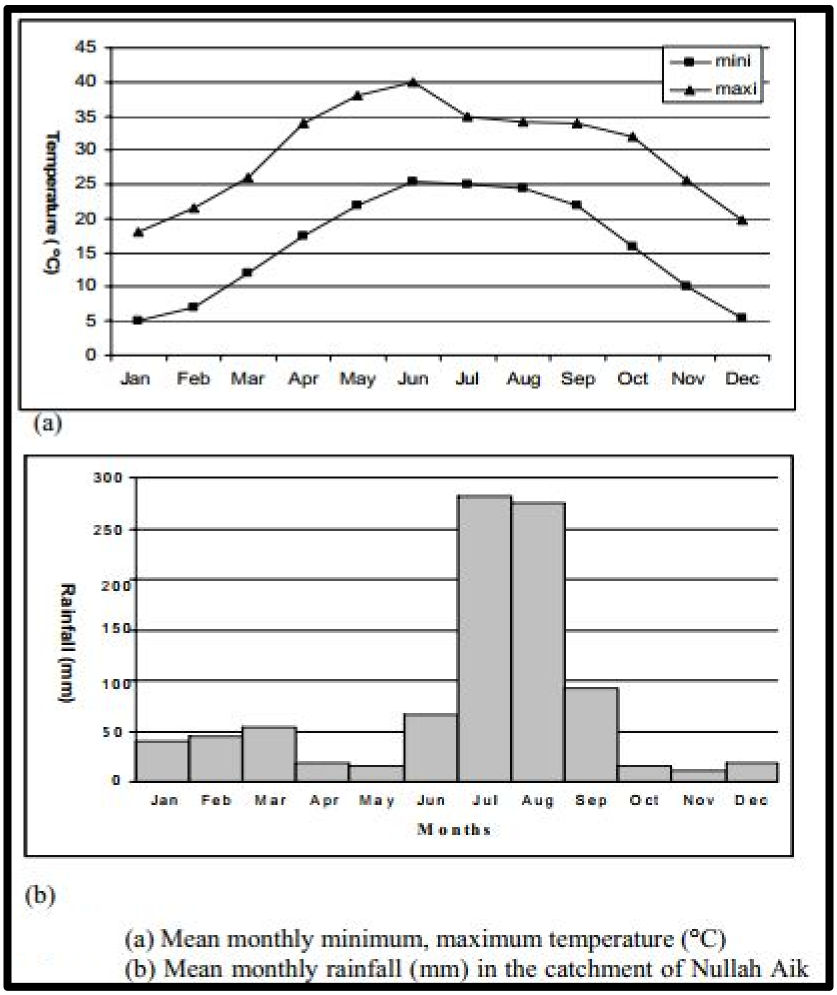


Figure 3: Temperature (a) and average rainfall (b) of Sialkot (Qadir et al., 2008)

2.2 SOURCES OF POLLUTION TO SURFACE AND GROUNDWATER

Sialkot is densely populated and houses a substantial number of industrial units in urban populated areas. Small and large industrial setups are scattered throughout the city which comprise of mainly leather, sports goods and surgical instruments manufacturing units. A total of 3229 industries are working in this city which comprise of 270 leather tanneries, 220 surgical equipment manufacturers and 900 sports goods factories (Qadir et al., 2008). Among above stated industries, leather tanneries are the major contributors in production of sewage sludge and wastewater. Effluents from tanneries is enriched with a variety of pollutants and salts such as metals (predominantly chromium), sodium and calcium, organic solvents and suspended solid materials. Mostly, industrial setups of the city discharge their effluents directly or indirectly into nullahs Aik and Palkhu. Wastewater after becoming the part of water bodies percolate to the surrounding soil through leaching and precipitation.

Cleaner Production Center (CPC) estimated that in this city, 297 tons of leather is produced per day with daily production of 9388 m^3 of tanneries' effluents. Each leather tannery unit produces 547- 814 m^3/day of wastewater (Qadir, 2008; Business Recorder, 2011). Surgical manufacturing units discharge effluents with toxic metals due to the production of acid containing wastewater, resulting from electroplating. It is important to note that the amount of effluents produced by surgical manufacturing units is much lower as compared to the leather tanneries. Sport goods and surgical goods manufactures are the least contributors of wastewater to natural water bodies.

Municipal sewage and sludge are another potential source of pollutants to the surface water bodies. Untreated water and raw sewage, along with the prominent quantity of organic matters plus human and animal excreta are directly or indirectly discharged to the surface water bodies of the city.

3 WATER USAGE AND CONSUMPTION IN SIALKOT CITY

3.1 GROUNDWATER AS DOMESTIC WATER USAGE

Water supply of groundwater in Sialkot through piped water system dates back to 1914. Water system was operated by a water tank located at elevated ground called Qila (fort) adjacent to the Tehsil Municipal Administration (TMA) offices. This tank was destroyed in the war of 1965. Water supply system in the city has been expanded at intervals since 1914 and currently caters to 65 per cent of Sialkot population of pre-2001 municipality region. Localities outside the municipal boundaries are considered as rural under 1993 uniform policy where Water and Sanitation Community Organizations (WASCOs) are responsible to supply water. In Sialkot city, currently 97 tube wells are present from which 95 tube wells are operational to meet the water demand of urban community (Figure 4). These 95 tube wells are operational only for urban settlement, excluding cantonment area; where 15 tube wells are working in addition to meet the water demand. Water discharge from each tube well is 1.5 cusec (42.5 l/sec or 153m^3/hr) (standard), however actual discharge depends upon the working conditions and life and health of the tube well. Every tube well discharges water for 12 hours/day and produces approximately 39 MGD water while per capita production is about 79.8 gallons per day. These production estimations are raw, as no proper monitoring and metering facility is available to acquire actual data. Depth of tube well bore ranges from 350 feet to 600 feet. TMA Sialkot is working to replace 350 feet depth tube wells with 600 feet depth tube wells, as it was determined that water table to 500 feet depth is polluted with industrial and sewage water. Currently 36 tube wells are reported to have been replaced from 350 feet bore to 600 feet bore (CDIA, 2015).

Water supply pipeline covers an area of 192 km with the main size of 75 mm to 900 mm. Old water supply system consisted of iron pipelines that have almost been replaced with asbestos-cement (AC) and PVC pipes (plastic **pipe** commonly used for **plumbing** and drainage). Pipes placed before the year 2000 are AC while after 2000 PVC pipes are being used for water supply while house connection is being provided through galvanized iron pipes. Throughout the city 12 hours/day water is supplied with exception of Model Town where 24/7 water supply continues by providing

160 gallons per person per day. There are 9 elevated reservoirs in the city but these are not used. The total capacity of these elevated reservoirs is about 2,600 m^3 (570000 gallons). This amounts to about 0.94-hour storage if demand plus unaccounted for water amounts to 50 gallons per person per day. If it is assumed that distribution system improvements reduce total water demand to 40 gallons per person per day, the available capacity will equate to 1.16-hour storage. The situation in the Cantonment is similar with all consumers being supplied by direct pumping rather than via elevated reservoirs. Many water consumers have water storage within their houses. It is possible that delivery to household tanks through open pipes with no float valves on the tanks is leading to high levels of wastage. TMA proposed that daily water demand of city is 33 gallons per capita per day and this demand was calculated based on the current population of the city. It is estimated by TMA that in 2035, these 33 gallons per capita per day water demand will increase to 48.51 gallon per capita per day (CDIA, 2015) (Table 1).

Table 1: Water abstraction, demand and losses (MGD) in different sectors of Sialkot City (Source: CDIA, 2015 and The Urban Unit)

Sources	Water Production	Current Water Demand	Projected water demand in 2035	Percentage of water usage
Domestic		18.18	26.10	47.38
Industrial		4.55	6.52	11.85
Institutional		3.03	4.35	7.89
Commercial		4.55	6.52	11.85
Water losses		12.12	8.70	31.58
Total	38.37	42.43	52.20	--

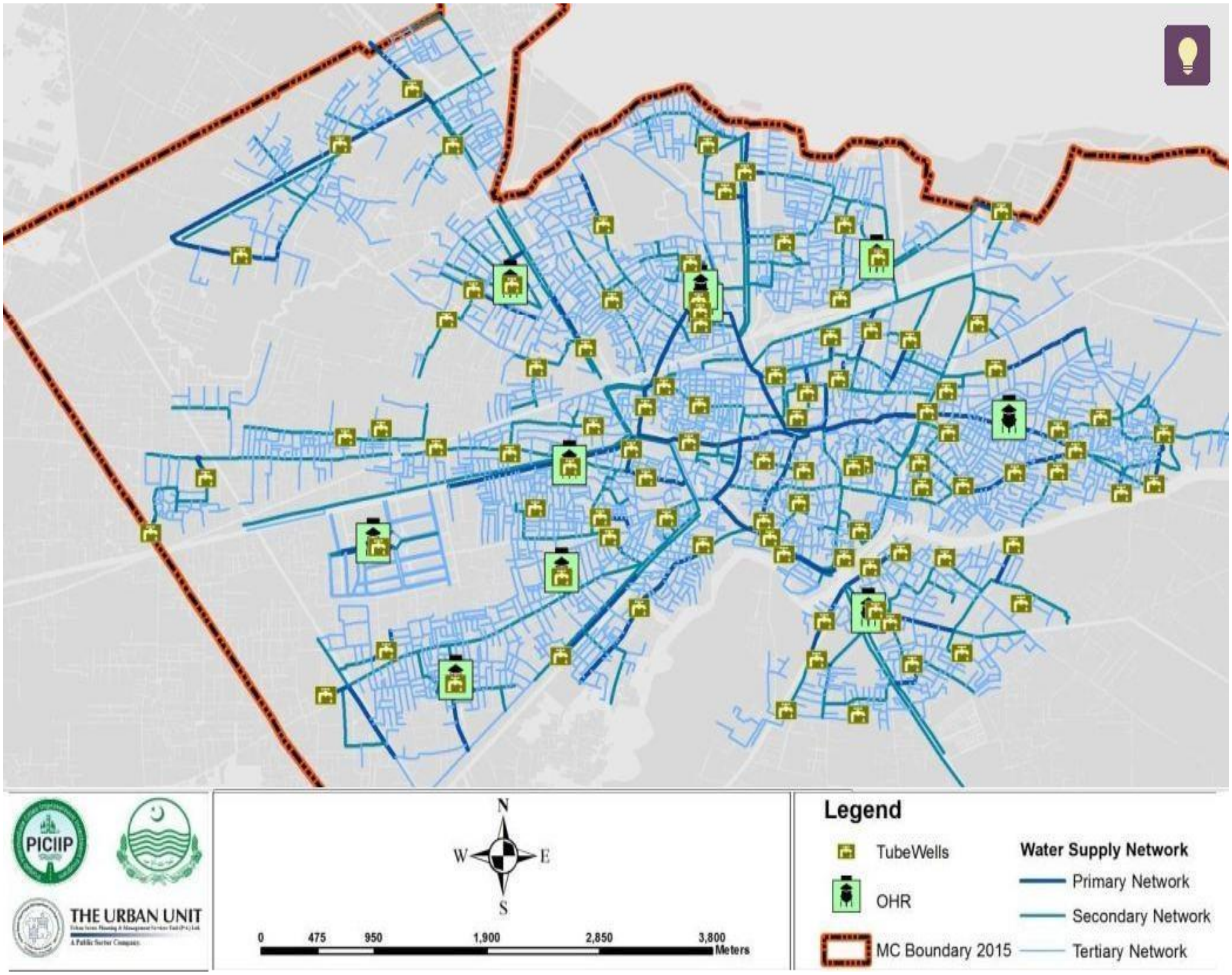


Figure 4: Water Supply system for all sectors in Sialkot (Source: CDIA, 2015 and The Urban Unit)

3.2 INDUSTRIAL WATER USAGE

It is estimated that industrial water demand in Sialkot accounts for 11.85 per cent of the total water consumption in the city. Industrial units mostly do not prefer water supply from TMA and it is assumed that most of the larger industrial setups install/their own private tube wells. Water demand by industrial sector is 4.55 million gallons per day (demand estimated according to water supply connection and supply amount), which is met by 228 water connections. It is estimated that this water demand will reach to 6.52 million gallons per day in 2035. Among industrial units, leather tanneries (largest industrial sector of the city) consume more than 70 per cent of total water supplied to the industrial sector (Table 1).

Actual water extraction by industries is not estimated nor available in literature because there is no system of accounting for this purpose.

3.3 COMMERCIAL AND INSTITUTIONAL WATER USAGE

Water demand of mosques, shopping centers, restaurants, public parks, bus stands, offices, railway stations, hospitals, educational institutes and other similar places is approximated to be 25 per cent of the total extraction of water. Total 2490 water connections have been installed in these sectors, which are about 6.3 per cent of the total water connections in the city. Commercial and institutional water usage in Sialkot city accounts 4.55 and 3.03 million gallons per day, respectively and it is estimated this demand will reach to 6.52 and 4.35 million gallons per day in 2035 (Table 1).

3.4 AGRICULTURAL WATER USAGE

Sialkot city is densely populated and urban expansion is at its peak, which has put enormous pressure on agricultural fields. In the urban boundaries there are almost no agricultural fields while the city is surrounded by extensive agricultural fields. Total agricultural area of Sialkot district is 221637 hectares. Major crops are wheat and rice which are irrigated by groundwater and surface water. Fields across the natural water streams are purely irrigated by surface water. Farmers have developed water channels to transport surface water to the far distance fields, which in turn provide economic benefits to farmers. However, this deteriorates the food crop quality, as surface water of Sialkot is reported to be contaminated and unsafe for irrigation purpose. Major irrigation mode is extensively pumped groundwater that is putting stress on the water table. Exact estimated data of water usage for agricultural purpose is not available for Sialkot district. However, it is observed that groundwater used for irrigation purposes is a serious threat to the water table of the city. (CDIA, 2015).

3.5 RECHARGE TO GROUNDWATER RESERVOIR

Ground water is the main source of drinking water in the city of Sialkot. Continuous usage of groundwater as drinking water source is a threat to water level if not recharged properly. Seepage from river, rainfall, water streams, lined and unlined channels and agricultural fields is vital to recharge the groundwater. It is complex to get exact estimation of water recharge from these bodies and there exists scarcity of studies and research field data on recharge of groundwater in the study area. Sialkot is a highly populated area and recharge to the urban areas is almost non-significant due to extensively developed infrastructure and urbanization without any efforts to establish recharge zones.

Multiple approaches are used to estimate the recharge of groundwater. In our country, seepage is prime parameter to calculate the percentage of available water quantity at the headwork of canals, tributaries, water reservoirs and agricultural fields. Water and Power Development Authority (WAPDA) has previously, in 2005 conducted a comprehensive study for the estimation of recharge to groundwater from different sources in order to develop Indus Basin Drainage Plan. Results of the study depicted that seepage loss out of total water flow is 15 per cent from main canals and 08 per cent from distributaries. This report also estimated that only 75 per cent of seepage losses contributes to recharge of the aquifer and the remaining 25 per cent is stored in soil profile.

A study "Assessment of aquifer intrinsic vulnerability using GIS based DRASTIC model in Sialkot area, Pakistan" published by Khan et al., in 2016 estimated the water recharge in Sialkot city along with the vulnerability of water. They calculated vulnerability by collecting data on net recharge, aquifer media, soil media topography, depth to water table, impact of vadose zone and hydraulic conductivity by consulting literature and different sources. Khan et al., 2016 estimated that Sialkot is dominated by medium to moderate zones in term of water vulnerability. Moderate zone covers an area of 446 km^2 and medium zone covers an area of 442 km^2 along with 09 km^2 area of least vulnerable zone. Sialkot city is located far from River Chenab and Tawi, which makes it a complex location in terms of recharge. Furthermore, this area is totally built up. (Figure 5 and 6, present the details of recharge zone, water table and related details).

Sialkot lies in upper Rachna doab area. River Chenab and Tawi along with the nullahs are the main recharge sources. Furthermore, rainfall also is an important factor in recharging the water table of the city. In Sialkot, the landscape is a hurdle for recharge that allows water to escape to nullahs and water drainages. (Basharat and Tariq, 2011). If conditions are favorable and ideal for rain water percolation, it is estimated the 250 mm (approximately one fourth) of rainwater from 1016 mm of annual rainfall can recharge the ground water of Sialkot. If open lands like parks, green belts, public places and water harvesting areas exist in the city, recharge rate may enhance to overcome the water level depletion and it is estimated to cause an increase of 0.70 mm in the water table. It has been reported that the groundwater has been exploited above its safe yield (up to 400 mm more) already and a slight water table drop has already been observed. Figure 5 presents groundwater table depth, soil types to support seepage of water, recharge assessment and material found in aquifer of Sialkot. Figure 6 presents topography, hydraulic conductivity, aquifer material and DRASTIC based vulnerability of water in Sialkot (Khan et al., 2016).

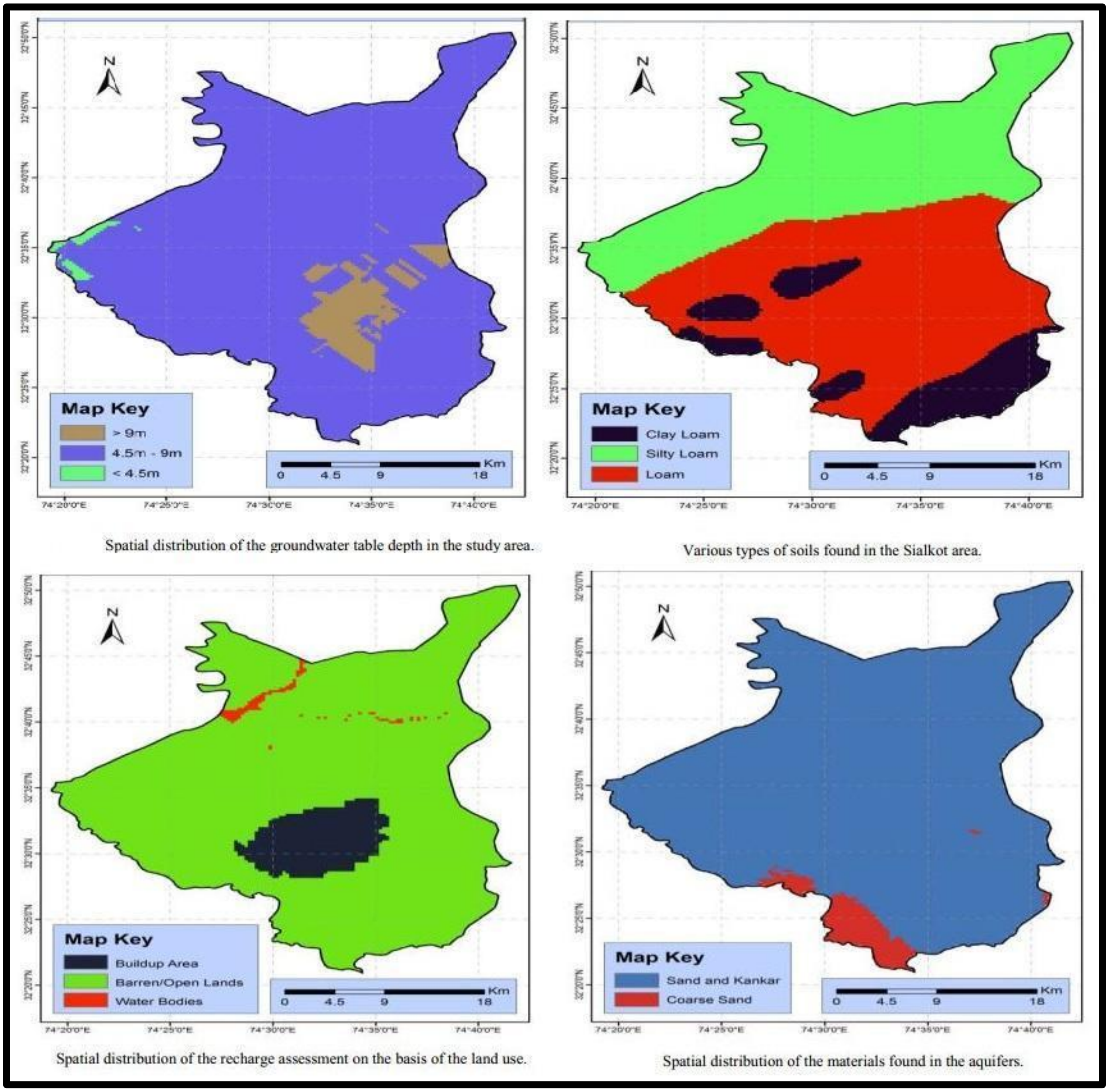
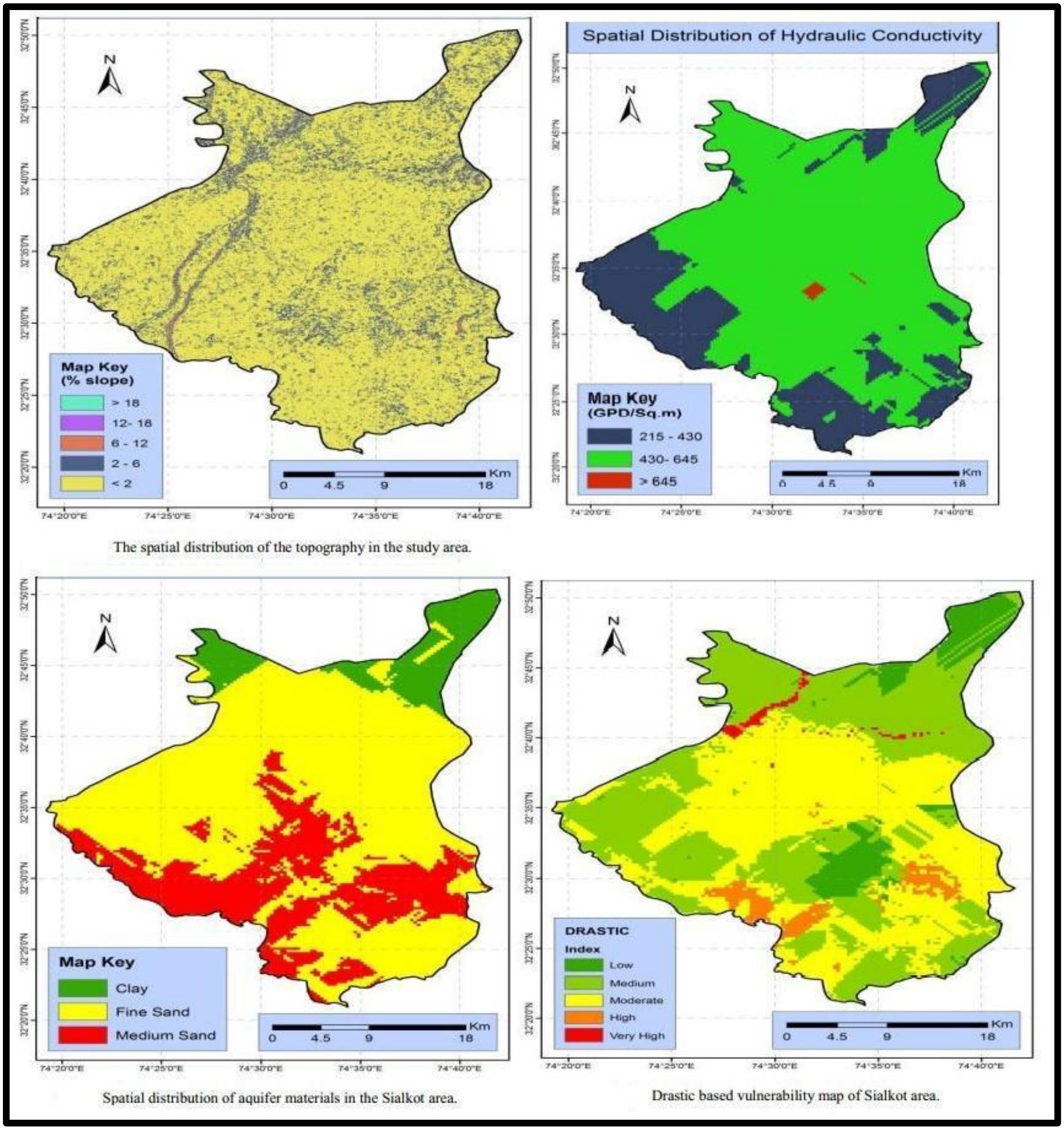


Figure 5: Groundwater table depth, soil types to support seepage of water, recharge assessment and material found in aquifer of Sialkot (Khan et al., 2016)



The spatial distribution of the topography in the study area.

Spatial distribution of aquifer materials in the Sialkot area.

Drastic based vulnerability map of Sialkot area.

Figure 6: Topography, hydraulic conductivity, aquifer material and DRASTIC based vulnerability of water in Sialkot (Khan et al., 2016)

3.6 EVAPO-TRANSPIRATION

Sialkot city is a well-developed urban area and approximately more than 92 per cent area is covered with concrete layer making the city unfavorable for evapo-transpiration. Figure 7 demonstrates that the city boundary area is comprised of buildings while rest of the rural and surrounding area of Sialkot is agricultural and forest covered. Figure 7 reveals that only source of evapo-transpiration within the city is water bodies and rainfall water plus minor fraction of vegetation. Ullah et al., 2001 conducted a study to calculate the evapotranspiration rate of Sialkot and average evapotranspiration rate in each month is provided in Table 2.

It is clear that evapotranspiration of Sialkot increases with the increase in temperature and is influenced by rainfall and crop growing pattern. Annual evapotranspiration (ET) is considerable when compared to the reference values of ET_o. Reference ET_o according to Penman Monteith method is 1497 and 1252 by Priestley and Taylor method. ET_o of Sialkot is 1210 mm/year (Ullah et al., 2001). Figure 8 shows the evapotranspiration of Sialkot with reference values by Penman Monteith and Hargeaves.

Table 2: Evapotranspiration (ETo: mm/day) of Sialkot (Ullah et al., 2001)

	Jan	Feb	March	April	May	June	July	Aug	Sept.	Oct	Nov	ET_o	Annual
ET_o	1.2	1.9	3.1	4.4	5.4	5.8	4.4	4.3	3.8	2.7	1.6	1.1	1210

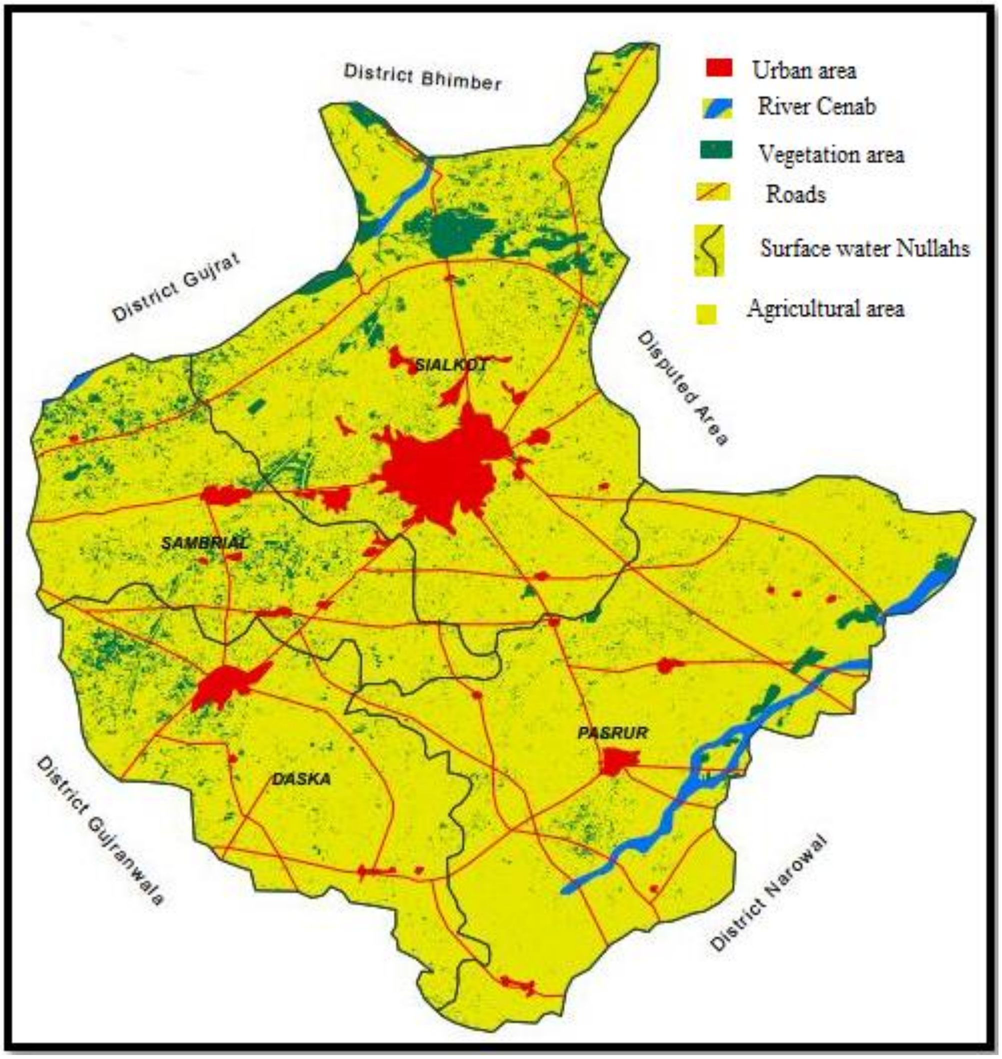


Figure 7: Land cover area of Sialkot depicting the evapo-transpiration concept (Khan et al., 2016)

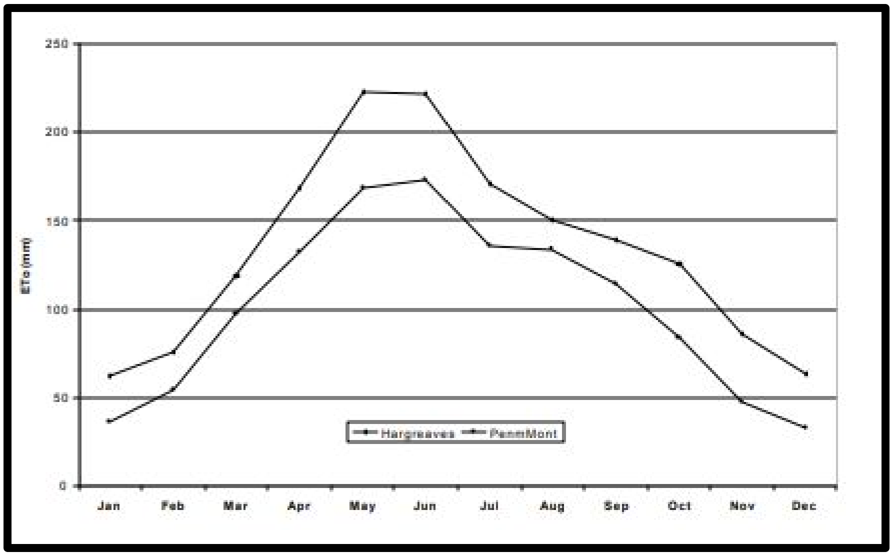


Figure 8: Reference evapo-transpiration for study area by Penman Monteith and Hrgreaves method (Ullah et al., 2001)

3.7 COLLECTION OF WASTEWATER

Sialkot is traversed by three surface water streams (nullahs), namely Aik, Palkhu and Bhaid. Nullah Aik drains the southern part of the city and nullah Bhaid joins nullah Palkhu which runs north of the Cantonment. Palkhu and Aik later join between Sodhra and Wazirabad before discharging into River Chenab. Wastewater from Sambrial discharges to a tributary of nullah Aik.

Bhaid is a small water channel that receives most of the city wastewater and municipal sewage water from many heavily polluting industries and urban settlement, respectively. Nullah Aik also receives huge amount of industrial and sewage wastewater from southern areas of the city while nullah Palkhu receives municipal sewage waste from few areas of Cantonment and industrial wastewater generated by industrial setup located north to the Puli area of Sialkot. All these nullahs ultimately drain into River Chenab. Plate 1, presents the visual demonstration of industrial waste water disposal to aforesaid nullahs. Diagrammatic expression of wastewater collection area from Sialkot is presented in Figure 9.

The total length of the sewerage network in Sialkot city is 178 km while overall coverage through sewerage network is approximately 49 per cent serving the remaining part of the city through covered or uncovered drains (CDIA, 2015 and The Urban Unit).

PLATE 1: Disposal of Industrial and municipal wastewater to the surface water streams of Sialkot

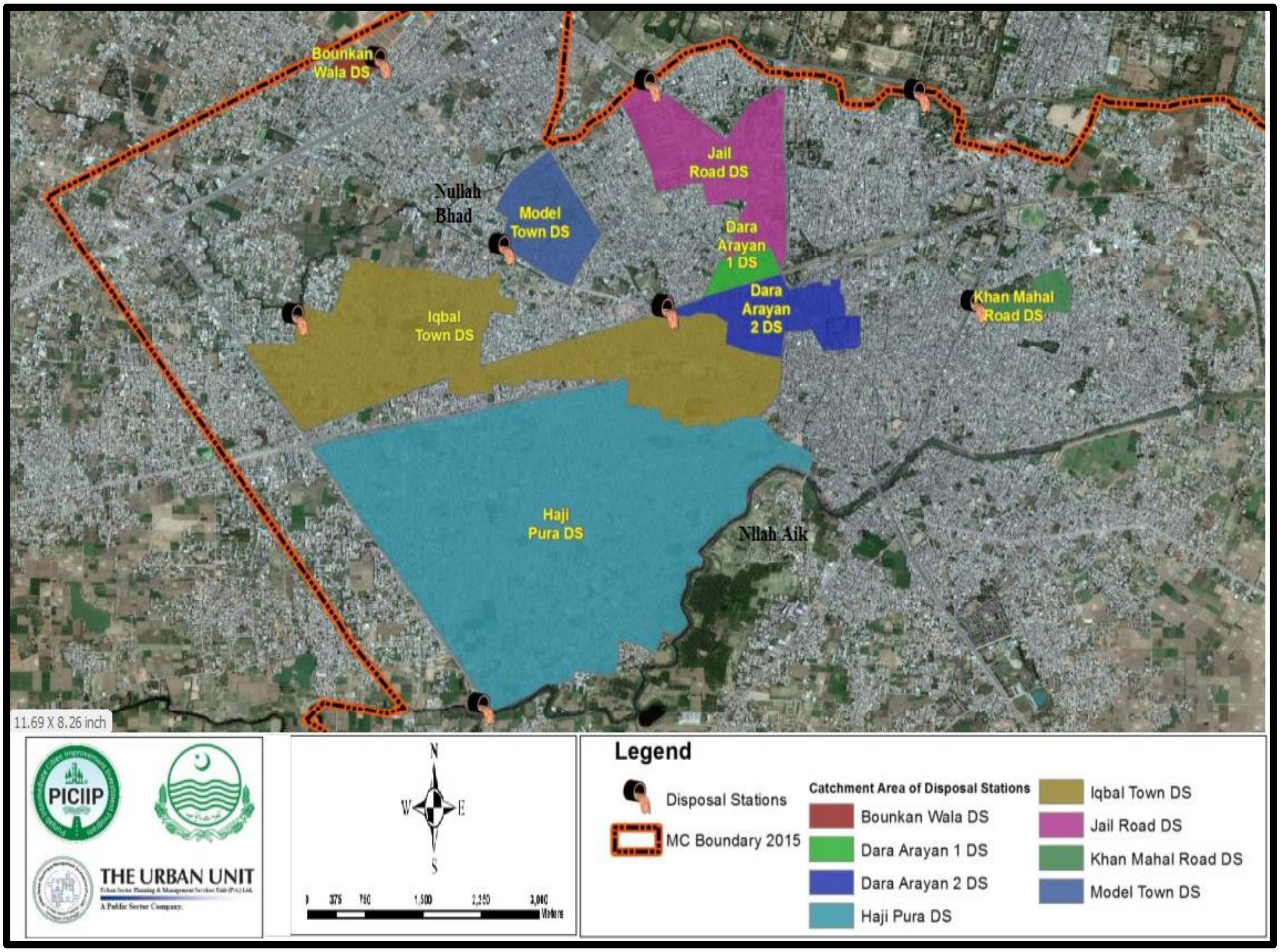


Figure 9: Catchment areas of disposal stations of Sialkot (Source: CDIA, 2015 and The Urban Unit)

3.8 WASTEWATER DISPOSAL

Wastewater is mainly drained into nullahs Aik, Bhaid and Palkhu. Total wastewater and sewage disposed to these nullahs is estimated to be 4.56 MGD. Catchment area of nullah Bhaid comprises of Iqbal Town (Dara Arayan 1 and Dara Arayan 2), Model Town, Jail Road, Commissioner Road and Khan Mahal Road while catchment area of nullah Aik comprises of Haji Pura, Rangpura and Pasrur Road.

Iqbal Town catchment area (Bhaid nullah) comprises of two pumping stations viz Dara Arayan 1 and Dara Arayan 2, and this catchment area is the largest catchment that receives sewage waste from central and western areas of the city and disposed to Bhaid Nullah at Iqbal Town Disposal Station. Dara Arayan 1 and 2 were designed to pump wastewater to a 54-inch diameter sewer that opens in Iqbal Town Disposal station. Currently 54-inch sewer line is blocked and Dara Arayan 1 and 2 directly dispose to nullah Bhaid. Model Town sewerage is disposed to nullah Bhaid via two out of three pumping units of Model Town disposal station. A small pumping station is working to dispose sewage from Ahmed Pura and eastern town of the city. Kutchahry road area, commissioner road adjacent area and northern areas of railway lines dispose its sewage directly to nullah Bhaid through open drains. Jail road pumping station operates in rainyseason to pump excess water while commissioner road disposal station is not functional.

Haji Pura disposal station is functional and pumps sewage from Shahab Pura, Haji Pura and Fateh Garh. This pumping station operates during the rainy season when water level in nullah Aik rises and does not support the direct disposal of wastewater from these areas. Sewage and wastewater from Rang Pura and its adjacent areas directly drains to nullah Aik while disposal station works in monsoon seasons.

Remaining part of the city (Naika Pura, Habib Pura and Doburji etc.) adjacent to Pasrur road drains directly to nullah Aik at chowk Naika Pura and there is no pumping station for wastewater disposal. Similarly, wastewater from northern areas of the city (Puli, Bhoth, Bharth and Khichian etc..) drain directly to nullah Palkhu and no pumping station is in operation for sewage disposal of these areas. Details of wastewater pumping stations in the city of Sialkot is provided in Table 3.

Table 4 presents the total wastewater production by Sialkot city currently and projected wastewater quantity in 2035 and Figure 10 presents the sewage network system of the city and Figure 11 presents a schematic diagram of wastewater collection and drainage system in Sialkot.

Table 3: Wastewater disposal stations and their pumping capacity (Source: CDIA, 2015 and The Urban Unit)

Sr. No	Name of Disposal Station	No. of Pumps	Ultimate Disposal	Total Capacity (MGD)	Total Discharge (MGD)
1	Dara Arayan Abbot Road	10	Through Gravity	1.62	0.342
2	Main Disposal Dara Arayan	10	--	5.17	0.8208
3	Model Town	10	Through Gravity	6.46	1.026
4	Iqbal town	10	Through Gravity	5.17	2.1888
5	Daska Road	06	Through Gravity	6.46	--
6	Rangpura	10	Through Gravity	10.34	--
7	Jail Road	10	Through Gravity	3.23	--
8	Khan Mahal Road	10	--	0.65	0.1824

Table 4: Wastewater generation of Sialkot City (Source: CDIA, 2015 and The Urban Unit)

Component	Wastewater Flow Excluding Cantonments (MGD)	
	Current Water Production	Projected water demand in 2035
Average Dry Weather Flow	32.08	45.92
Peak Dry Weather Flow	64.15	91.83
Infiltration	3.21	4.59
Strom Weather Infiltration	16.04	22.96
Peak Weather Flow	83.40	119.38

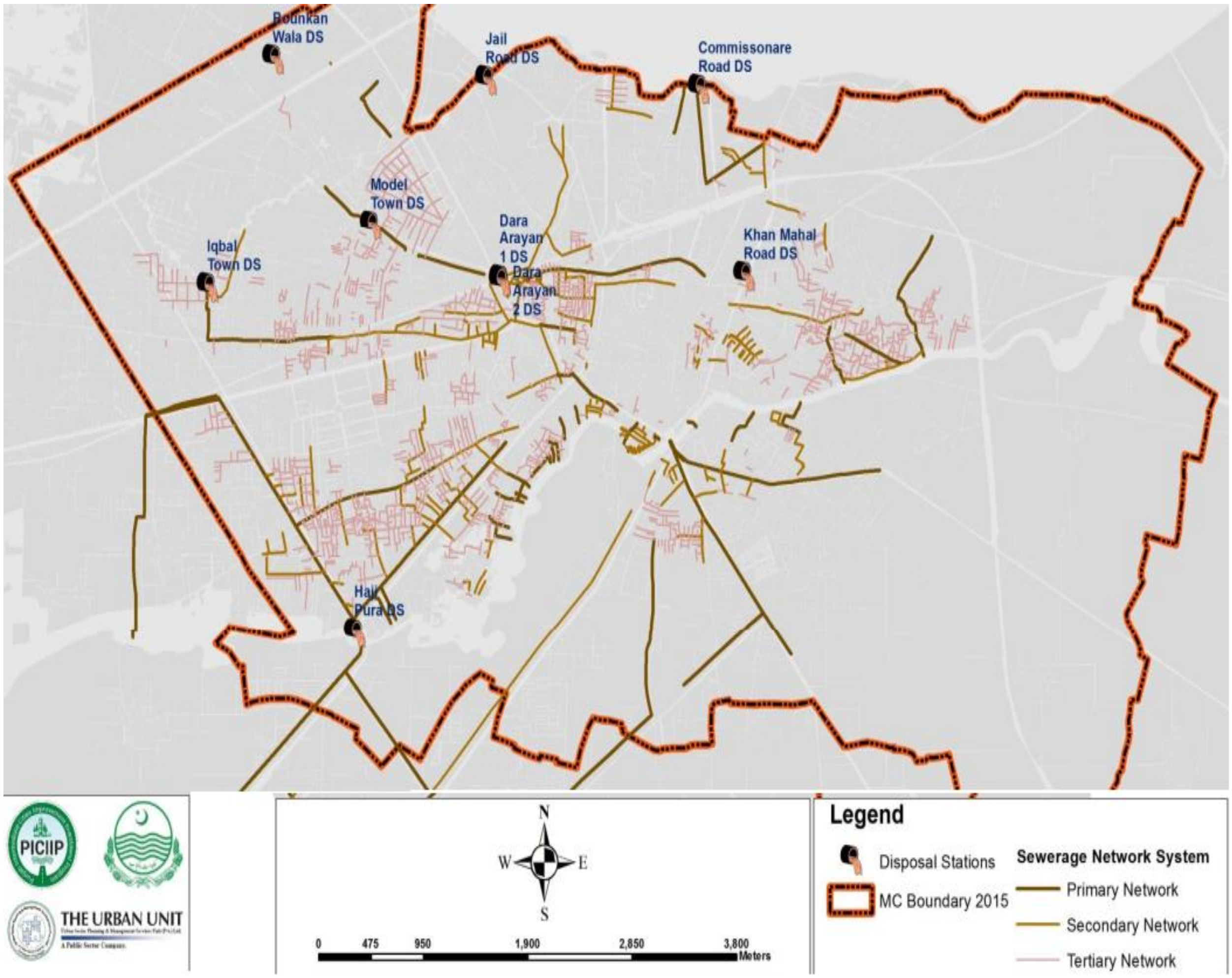


Figure 10: Sewerage network system of Sialkot (Source: CDIA, 2015 and The Urban Unit)

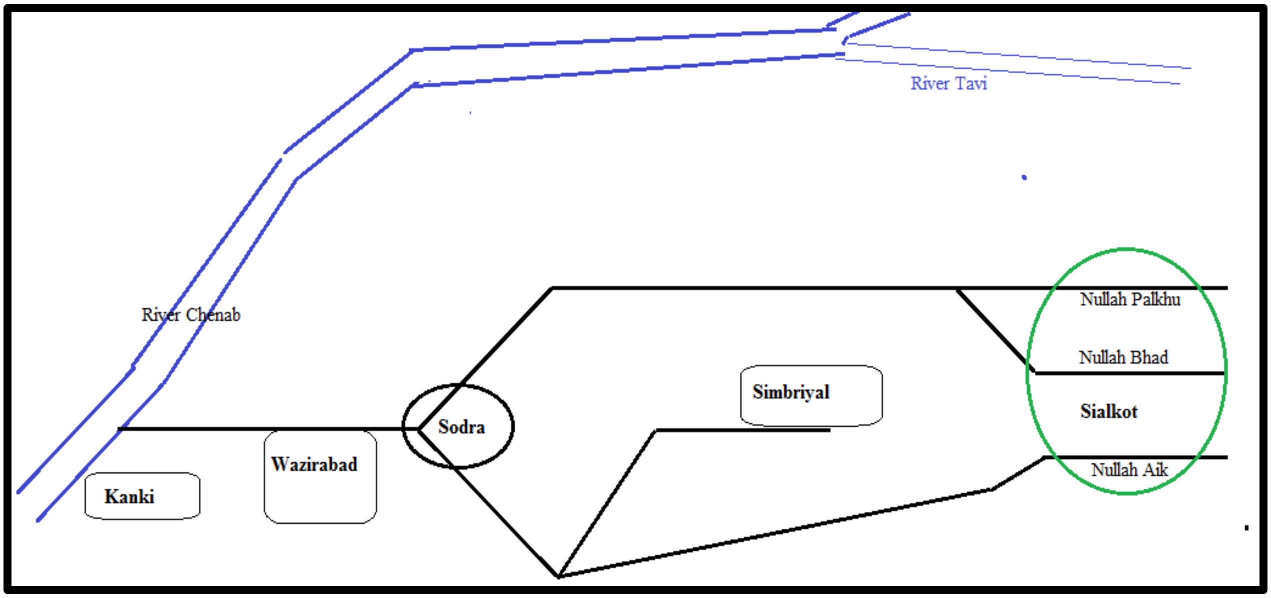


Figure 11: Wastewater collection and drainage system of Sialkot

3.9 WATER BALANCE

It can be analyzed from the discussion in previous sections that domestic, institutional and industrial sector of the city are dependent on ground water for their need. Agricultural sector is relying mainly on groundwater along with partial reliance on surface water. Groundwater extraction of the city is 38.37 MGD while the recharge rate has not been reported or calculated. Recharge rate from different sources viz, rainfall is 1016 mm/year and from evapo-transpiration is 1210 mm/year. Recharge data from River Chenab and surface water bodies is not available for the city. Figure 12 shows the estimated water balance of the city as derived from the data available. (CDIA, 2015).

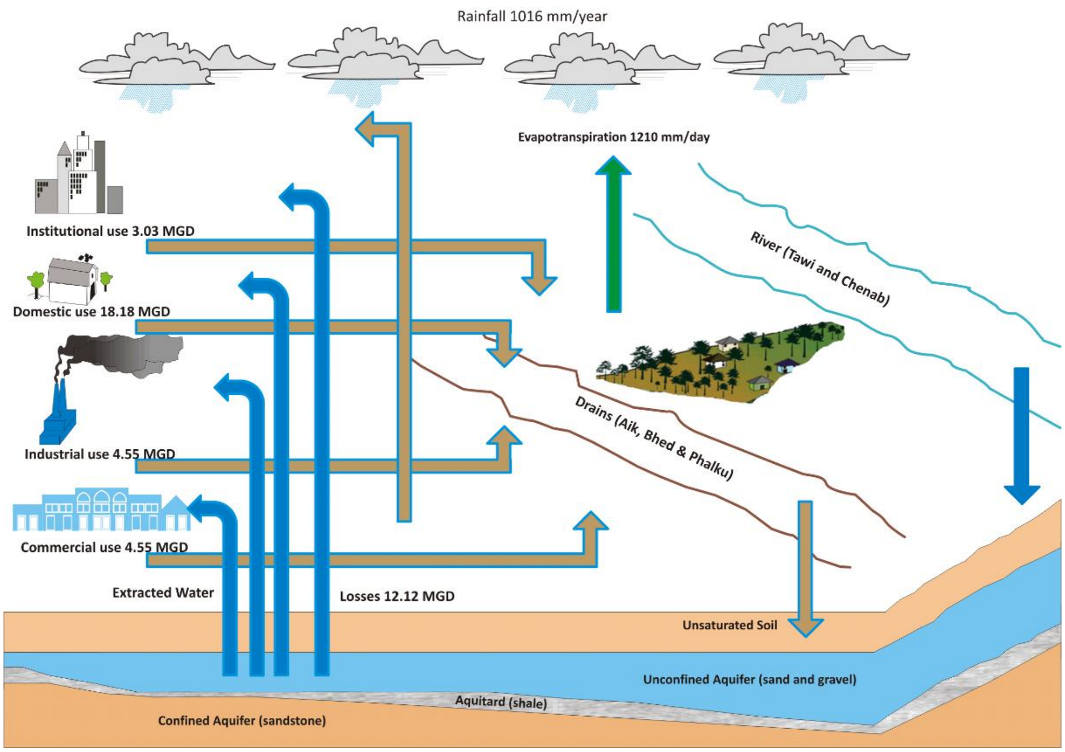


Figure 12: Schematic presentation of water balance of Sialkot

4 WATER QUALITY OF CITY SIALKOT

4.1 DRINKING WATER QUALITY

In 2017, Pak Medical Center (PMC), Sialkot conducted a study to investigate the drinking water quality of Sialkot. Results of the study are provided in Table 5. PMC collected 41 water samples across the city and 29 samples were purely collected from municipality of Sialkot city. Results of collected samples revealed presence of turbidity, phosphate, chloride and iron in few samples while coliform bacteria were present in some drinking water samples. Notable iron was detected in water samples collected from Cantt. and Model Town while other samples were found to have iron contents in lower amounts. Coliform bacteria were found in water samples collected from Miana Pura, Mag Town, Cantt., Model Town, Neka Pura and Ugoki. Presence of coliform bacteria revealed sewage or municipal waste water mixing in drinking water sources. All these samples which contained coliform were collected from 100-400 ft depth that showed the seepage level of waste water and recharge to ground water. Only Model Town sample was collected from 675 ft depth and it is assumed that there may be leakage in bore pipeline and mixing of sewage water to this sample.

A research publication entitled "Assessment of groundwater contamination in an industrial city, Sialkot, Pakistan" published in African Journal of Environmental Science and Technology in 2009 showed a comprehensive profile of ground water quality of Sialkot. They collected water samples from 25 localities in the city for which the detailed sampling localities map is provided in Figure 13. Samples were screened for toxic metal presence and physico-chemical parameters including pH, Electric Conductivity (EC), Total Dissolved Solids (TDS), Salinity, Temperature, Turbidity, Sulfate (SO_4) Chloride (Cl), and Total Hardness. Results were verified by comparing standard values for safe drinking water by World Health Organization (WHO) and Pakistan Standard Quality Control Authority (PSQCA). Results (Table 6) revealed that groundwater of Sialkot city is not safe for consumption as 57 per cent of total collected samples were found turbid while iron (Fe) and lead (Pb) were found in quantities higher than the permissible limits defined by WHO, 1996. Fe level was found higher than WHO guidelines in 56 per cent sites and similar Fe related issue was also detected by PMC study. Along with Fe, Chromium (Cr) was also found in water samples of Sialkot. Cr contamination is directly correlated with leather tanneries which dominate the industrial units of the city. Different statistical techniques used in this research also confirmed that Fe and Cr are the main culprits of drinking water contamination in the study area. This 2009 report was eye opening for water quality issues that need to be considered by authorities for proper water quality management. There is dire need to check the sources of water contamination in the city and public awareness campaigns must be launched to combat this water pollution issue in the city.

Report on Water Quality status of Major Cities of Pakistan, 2015-16 published by Pakistan Council for Research in Water Resources (PCRWR), Ministry of Science and Technology presented the detailed status of drinking water quality of Sialkot. This report analyzed about 25 basic water quality parameters including Fe, Arsenic (As), Coliform and E. coli from ten water samples collected from tube wells. Results revealed that drinking water is safe for consumption except the water collected from Rorus Road tube well sample that contains considerable amount of coliform and E. coli.

Table 5: Results of drinking/domestic water quality analysis performed by Pak Medical Center (Source: Pak Medical Center; WWF, Site Office SKT)

Sample No	Location	Northing	Easting	Total Depth (ft)	Chlorine (mg/L)	Total Chromium (mg/L)	Flouride (mg/L)	Iron (mg/L)	Nitrate as N (mg/L)	pH Value	Phosphorus as Orthophosphate (mg/L)	TDS (mg/L)	Turbidity (NTU)	Conductivity (uS/cm)	Chloride (mg/L)	Calcium Hardness (mg/L)	Sulphate (mg/L)	Total Hardness as CaCO3 (mg/L)	Magnesium (mg/L)	TSS (mg/L)	Coliform
			WHO Standards		N.S	0.05	1.5	0.3	11	6.5-8.5	0.15	<1000	<5	N.S	250	N.S	250	N.S	N.S	N.S	A
1	Kotli Loharan	32° 34' 50"	74° 31' 40"	200	0.01	0.02	0.11	0.18	0.8	7.18	0.1	290	2.19	462	60	152	1	240	21.38	<10	A
2	Kotli Loharan - M	32° 34' 50"	74° 31' 40"		0.02	0.03	0.18	0.49	0.8	7.14	0.12	320	5.46	507	65	174	6	298	30.13	<10	A
3	Kotli Loharan - WS			400	<0.01	0.02	0.32	0.04	0.4	7.11	0.08	220	0.509	342	45	114	6	190	18.46	<10	A
4	Bhoth	32° 32' 0"	74° 34' 0"	80	0.01	0.01	0.57	0.06	3.1	7.2	0.09	570	0.118	921	90	206	58	410	49.57	<10	A
5	Bhoth - M	32° 32' 0"	74° 34' 0"	100	0.01	0.01	0.48	0.05	1	7.44	0.13	640	0.618	1040	140	114	59	3014	48.6	<10	A
6	Bhagowal	32° 41' 0"	74° 20' 0"	235	<0.01	0.01	0.2	0.02	0.5	7.6	0.06	310	0.109	491	50	86	1	170	20.41	<10	A
7	Bhagowal - M	32° 41' 0"	74° 20' 0"	250	<0.01	0.01	0.88	0.04	0.7	7.49	1.61	1920	0.251	3005	490	228	160	754	127.82	<10	A
8	Dheera Sandha	32° 27' 10"	74° 34' 35"		<0.01	0.01	1.04	<0.01	0.7	7.34	0.1	850	0.105	1338	180	172	69	314	34.51	<10	A
9	Dheera Sandha - M	32° 27' 10"	74° 34' 35"	100	0.01	0.01	0.4	0.02	0.6	7.37	0.11	520	0.476	815	110	168	28	340	41.8	<10	A
10	Dalowali	32° 31′ 26″	74° 36′ 19″	160	0.02	0.01	0.51	0.35	0.6	7.09	0.06	360	1.51	631	75	130	1	336	50.06	<10	A
11	Dalowali - M	32° 31′ 26″	74° 36′ 19″	150	<0.01	0.01	0.37	0.1	0.7	7.27	0.15	290	0.929	498	70	142	1	258	28.19	<10	P
12	Dalowali -WS				0.01	0.01	0.13	0.07	0.8	6.87	0.13	270	0.395	449	70	116	1	222	25.76	<10	P
13	Jaurian	32° 31' 0"	74° 27' 0"	150	0.03	0.02	0.24	0.03	4.1	7.06	0.25	770	0.175	1215	130	246	73	416	41.31	<10	A
14	Juarian II	32° 31' 0"	74° 27' 0"	200	0.01	0.02	0.18	0.04	1.4	7.12	0.45	960	0.639	1509	155	194	92	394	48.62	<10	A
15	Jable Noor	32°29'42.0"	74°29'10.6"	200	0.01	0.01	0.33	<0.01	5.9	6.94	0.16	940	0.083	1493	195	358	108	564	50.06	<10	A
16	Jable Noor - M	32°29'42.0"	74°29'10.6"	230	0.01	0.01	0.44	<0.01	3.1	7.06	0.08	1020	0.117	1587	235	414	120	630	52.49	<10	A
17	Haripur	32° 29' 0"	74° 36' 0"	150	0.17	0.01	0.45	0.04	0.9	6.94	0.12	300	0.274	466	55	158	6	242	20.41	<10	A
18	Haripur - M	32° 29' 0"	74° 36' 0"	100	0.05	0.01	0.59	0.17	0.6	7.42	0.12	290	1.13	455	55	138	9	248	26.73	<10	A
19	Ugoki	32°29'0	74°27'0	60	0.01	0.01	0.33	0.02	7.1	7.02	0.1	540	0.095	944	115	276	80	446	41.31	<10	A
20	Ugoki - M	32°29'1	74°27'0	500	0.02	0.01	0.42	0.04	0.8	7.29	0.1	280	0.263	478	55	156	4	232	18.46	<10	A
21	Ugpki - WS			500	0.01	0.01	0.23	0.05	0.9	7.16	0.07	270	0.152	455	50	156	1	236	19.44	<10	P
22	Model Town	31° 29' 4"	74° 19' 28"		0.02	0.01	0.26	0.03	3.6	6.82	0.15	440	0.132	737	85	232	53	328	23.33	<10	A
23	Model Town - M	31° 29' 4"	74° 19' 28"		0.02	0.01	0.21	0.02	0.8	7.12	0.6	286	0.136	472	60	130	3	238	26.24	<10	A
24	Model Town - WS			600	<0.01	0.01	0.22	0.01	1	7.36	0.13	285	0.182	470	60	106	3	246	34.02	<10	P
25	Model Town - M	32°30'12.1"	74°31'19.5"		0.03	0.02	0.18	0.41	0.7	7.08	0.02	520	5.17	813	70	132	78	326	47.14	<10	A
26	Neka Pura	32°29'6.71"	74°32'52.05	100	0.01	0.01	0.83	0.03	5.5	7.08	0.07	890	0.153	1623	210	284	119	656	90.4	<10	A
27	Neka Pura - M	32°29'6.71"	74°32'52.06	400	0.01	0.01	0.44	0.03	0.9	7.27	0.11	410	0.235	755	110	176	44	352	42.77	<10	P
28	Neka Pura - WS			675	0.03	0.01	0.12	0.17	0.08	7.3	0.11	290	0.872	496	75	142	11	230	2138	<10	P
29	Cantt Ward 4 - M	32°30'46.6"	74°33'32.3"	150	0.04	0.01	0.07	0.1	0.07	7.11	0.09	285	0.557	446	55	110	1	184	17.98	<10	A
30	Cantt Ward 4 - WS			400	0.09	<0.01	0.41	0.68	0.9	7.42	0.14	395	2.7	621	60	130	<1	298	40.82	<10	A
31	Cantt Ward 6	32°30'37.5	74°33'21.5"	125	0.02	0.01	0.24	0.01	0.9	7.3	0.13	335	0.252	526	60	128	<1	218	27.87	<10	P
32	Cantt Ward 6 - M	32°30'37.6	74°33'21.5"	100	0.11	<0.01	0.65	0.11	1.9	7.27	0.07	660	0.483	1027	105	188	47	260	17.49	<10	A
33	Cantt Ward 6 - WS			400	0.03	0.01	0.23	0.03	0.9	7.14	0.11	330	0.106	511	50	116	1	232	28.19	<10	A
34	Mag Town	32°30'01.8"	74°29'52.1"	100	0.03	0.01	0.47	0.04	1.7	7.03	0.08	280	0.832	459	60	158	30	236	18.95	<10	P
35	Mag Towin - M	32°30'01.8"	74°29'52.1"		0.01	<0.01	0.41	0.08	0.6	6.95	0.09	410	1.97	661	95	170	39	308	33.53	<10	A
36	Mag Town -WS			600	0.02	0.01	0.41	0.11	0.8	6.78	0.02	360	3.27	620	90	156	28	296	34.02	<10	A
37	SIE	32°29'19.0"	74°30'53.4"	80	0.03	0.02	0.31	0.05	6.7	6.98	0.06	660	0.353	1035	110	340	63	432	22.36	<10	A
38	SIE - M	32°29'19.0"	74°30'53.4"		0.03	0.02	0.39	0.11	1.7	7.28	0.06	665	1.97	1042	115	314	92	426	27.22	<10	A
39	SIE - WS			600	0.02	0.01	0.28	0.14	0.7	7.09	0.07	315	1.3	496	55	134	1	198	15.55	<10	A
40	Miana Pura	32° 29' 40"	74° 31' 5"		0.04	0.01	0.31	0.04	3	6.72	0.01	820	0.181	1291	145	306	98	476	41.31	<10	A
41	Miana Pura - M	32° 29' 40"	74° 31' 5"		0.02	0.03	0.36	0.01	6.4	6.96	0.03	840	0.162	1310	130	360	111	484	30.13	<10	P

Table 6: Water quality data from Sialkot (Ullah et al., 2009)

Parameter	Mean ± STD	Minimum	Maximum
pH	7.11±0.32	6.72	7.98
EC(us/cm)	555.28±248.69	171	1163
TDS(mg/L)	279.04±121.49	135.1	581
Salinity	0.84±0.66	0.08	2.64
Temperature	21.85±0.47	21.3	22.7
Turbidity (NTU)	25.85±48.70	0.47	197
SO4(mg/L)	67.40±79.02	18	315
Cl(mg/L)	21.17±40.77	4.1	195
Total Hardness(mg/L)	200.80±65.09	72	335
Iodides(mg/L)	0.04±0.14	0	0.5
Fluoride(mg/L)	0.68±0.16	0.41	0.99
Fe+3(mg/L)	0.13±0.10	0.01	0.35
NO3(mg/L)	3.96±3.93	0	9.9
Mn(mg/L)	0.03±0.03	0	0.09
Total Chlorine(mg/L)	0.02±0.04	0	0.14
Alkalinity	207.64±84.44	116	318
Zn(mg/L)	0.16±0.20	0	0.81
Pb(mg/L)	0.49±0.21	0.11	0.81
Fe(mg/L)	0.30±0.24	0	0.83
Cu(mg/L)	0.06±0.04	0.01	0.17
Ni(mg/L)	0.10±0.07	0.01	0.22
Cr(mg/L)	0.03±0.07	0	0.3

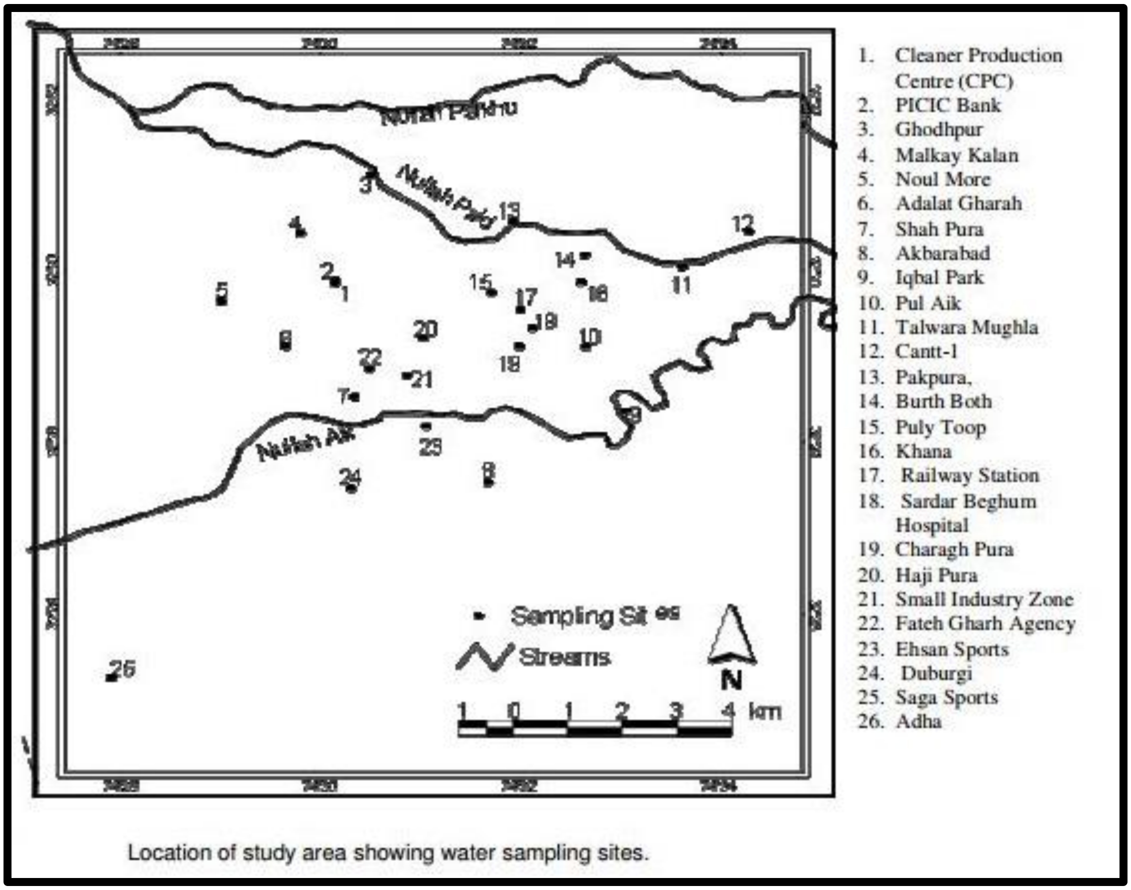


Figure 13: Location map of sampling sites for comprehensive water quality analysis of Sialkot (Ullah et al., 2009)

4.2 SURFACE WATER QUALITY

Nullahs Aik, Palkhu and Bhaid are reported to be highly contaminated by various researchers (Mahmood et al., 2014; Mahmood et al., 2015, Qadir et al., 2013; Khan et al., 2015). In past decades, the water of these nullahs was clean and had been used for domestic purposes. (Qadir et al., 2008). Qadir et al., 2013 conducted research on surface water quality of Sialkot and collected samples from nine sites across nullah Aik, Palkhu and Bhaid. Detailed results are presented in Table 7. Results of water samples collected from the sites located across the city of Sialkot revealed that 22 screened basic water quality parameters were not in safe limits which makes water highly contaminated and unfit for any kind of human consumption. Mahmood et al., 2015 conducted a detailed study on wastewater irrigation to food crops and its hazardous impact on human and animal health. Surface water quality was one part of this study.

Authors investigated organochlorine phosphates (OCPs), polychlorinated biphenyl (PCBs), polychlorinated naphthalenes (PCNs), Polybrominated diphenyl ether (PBDEs) and dechlorane plus (DPs). These chemicals are known as Persistent Organic Pollutants (POPs) and have severe toxic effect on living organisms. Minor exposures to such chemicals can have severe negative health implications for humans. (Mahmood et al., 2014). Results of these previously published reports depicted the presence of above-mentioned POPs in surface water of Sialkot. It is important to note that surface water of above said streams is directly being used to irrigate food crops and fodders that in turn contaminate the entire food chain. Direct discharge of industrial and municipal wastewater to these streams is the possible source of this contamination.

Table 7: Concentration levels of water quality parameters of surface water samples from Sialkot (Qadir et al., 2013)

Means ± S.D of water quality parameters in stream water at various sampling sites located on Nullah Aik

SITES	1 Mean ± SD	2 Mean ± SD	3 Mean ± SD	4 Mean ± SD	5 Mean ± SD	6 Mean ± SD	7 Mean ± SD	8 Mean ± SD	9 Mean ± SD
Temperature(°C)	21.21±5.88	21.33±6.02	21.33±6.00	21.21±5.89	21.21±5.88	21.33±6.02	21.21±5.88	21.83±17.00	21.00±6.107
pH	8.04±1.40	8.01±0.29	7.72±0.60	7.76±0.43	7.69±0.37	7.91±0.56	7.89±0.41	7.55±3.25	21.17±0.472
DO mg/L	6.01±1.45	6.20±1.03	1.18±0.82	0.97±0.58	1.14±0.56	4.44±0.89	3.32±1.59	3.02±0.24	8.01±1.298
COD	33.39±16.79	58.39±58.20	317.3±278.48	312.09±177.9	271.5±207.7	65.91±21.83	89.88±61.42	78.90±1.38	3.06±76.713
EC us/cm	575.9±108.1	558.2±103.6	1022.8±411.1	1076.8±256.4	953.5±280.1	779.3±249.8	723.2±219.3	732.78±64.3	131.7±228.2
TDS mg/L	389.9±97.42	362.0±104.3	603.45±256.1	673.28±127.7	585.8±126.5	463.5±104.0	407.1±112.3	485.8±216.3	918.7±130.8
Turbidity	37.39±48.12	40.99±49.25	102.47±162.6	140.64±97.61	255.1±518.8	82.2±116.75	70.31±52.56	81.0±130.84	564.6±208.2
NO_3 mg/L	2.72±1.78	4.44±2.83	0.82±0.52	2.39±2.92	0.73±0.39	0.70±0.21	0.81±0.49	1.89±34.89	135.49±0.65
PO_4 mg/L	1.15±1.19	1.03±0.96	2.29±1.77	5.23±4.18	5.03±4.77	1.64±0.64	1.24±1.53	1.15±1.29	1.24±0.98
Cl mg/L	49.47±28.54	41.51±31.43	275.65±740.6	117.46±73.35	103.61±54.7	90.61±48.89	182.0±247.1	41.02±0.45	1.12±40.28
Sulfides mg/L	0.01±0.01	0.01±0.01	0.40±0.33	0.74±1.10	0.49±0.45	0.39±0.45	0.13±0.11	0.04±23.25	87.54±0.11
Na mg/L	51.48±27.43	49.03±23.51	67.44±31.21	79.09±46.87	84.63±58.67	67.32±32.07	54.10±35.64	39.41±0.02	0.11±37.13
K mg/L	10.05±8.13	10.56±7.98	20.51±12.75	18.16±8.69	16.08±7.65	18.44±15.89	9.81±6.50	2.58±15.73	71.41±6.58
Ca mg/L	58.34±23.08	56.92±24.74	87.25±51.31	65.07±18.46	62.39±18.12	59.50±19.22	50.63±17.00	47.45±2.60	10.39±22.22
Mg mg/L	12.37±7.28	10.67±7.14	24.40±21.23	25.86±13.99	22.09±12.71	25.63±14.45	14.89±8.57	8.86±5.88	53.60±22.94
Fe mg/L	0.32±0.58	0.55±0.68	0.68±0.51	0.67±0.70	0.79±0.60	0.45±0.49	0.38±0.60	0.82±3.08	20.93±0.430
Pb mg/L	0.13±0.17	0.29±0.64	0.29±0.29	0.27±0.27	0.30±0.31	0.24±0.21	0.13±0.10	0.21±0.78	0.33±0.19
Cd mg/L	0.02±0.03	0.02±0.03	0.03±0.04	0.02±0.03	0.02±0.03	0.02±0.03	0.02±0.03	0.07±0.06	0.20±0.03
Cr mg/L	0.04±0.02	0.10±0.24	0.32±0.35	0.26±0.31	0.24±0.27	0.21±0.26	0.17±0.21	0.03±0.07	0.02±0.34
Ni mg/L	0.08±0.10	0.07±0.11	0.07±0.08	0.07±0.07	0.10±0.11	0.11±0.13	0.11±0.37	0.07±0.02	0.27±0.26
Cu mg/L	0.04±0.13	0.03±0.09	0.03±0.06	0.03±0.05	0.03±0.06	0.03±0.06	0.02±0.06	0.11±0.09	0.13±0.07
Zn mg/L	0.04±0.03	0.04±0.03	0.07±0.06	0.09±0.08	0.11±0.11	0.09±0.12	0.08±0.06	0.02±0.11	0.03±0.072

4.3 WASTEWATER IRRIGATION TO FOOD CROPS

Wastewater in Sialkot comprises of effluents from leather tanneries, chemicals, surgical and electroplating industries, transformer repairing workshops as well as municipal waste that contains toxic metals and different compounds of POPs (Daily Dawn, 2006). Few stockpiles, holding thousands kilogram of organochlorine pesticides, are located in the catchment area of nullahs Aik and Palkhu (Malik et al., 2011).

Nullahs Aik, Palkhu and Bhaid; the prime surface water resources of Sialkot are under venomous threat of toxic pollutants coming from industries and municipal effluents. As described in section 2.1.1, these water tributaries have been used as a resource for domestic and drinking water in the past (Qadir et al., 2008). However, currently these water resources are gradually turning to industrial water drains due to uncontrolled and untreated wastewater disposal into these streams.

Sialkot is a major producer of rice in the country. Wheat and rice are the major cereal crops cultivated across the rural and agricultural areas of Sialkot. Wheat and rice cultivated along the catchment agricultural areas of these nullahs are directly irrigated with wastewater. Wastewater of aforesaid nullahs is directly pumped out via heavy motors and discharged to the cultivated crops without any pre-treatment. Across the banks of these nullahs, hundreds of water pumping motors are installed by farmers and contribute chemicals to food crops (Plate 2). Wheat and rice are staple foods of the city and used as daily food commodities. People who consume such food crops may be highly vulnerable to the toxic effects of pollutants.

Despite wheat and rice cultivation with wastewater, it has been observed that a number of local farmers across the streams use surface water of nullah Aik, Palkhu and Bhaid to irrigate their agricultural fields cultivating fodder and vegetables (Mahmood et al., 2015). Generally grown vegetables by wastewater in Sialkot are Spinach (*Spinacia oleracea* L), Radish (*Raphanus sativus*), Tomato (*Lycopersicon esculentum*), Cress (*Lepidium sativum*), Dill (*Peucedanum graveolens*), Coriander (*Coriandrum sativum*), Chili (*Capsicum annum*), Cabbage (*Brassica oleracea* var. *capitata*), Brinjal (*Solanum melongena*) and Okra (*Hibiscus esculentus*). Large quantity of various food crops are sold in supply market of the nearby settlements. It has been reported that serious health problems can develop as a result of accumulation of dietary heavy metal uptake through food crops irrigated with contaminated wastewater. Earlier studies on River Chenab and its associated tributaries such as nullah Aik and Palkhu indicated heavy metal pollution in surface water and fish species. These studies only provided baseline information of heavy metal pollution, and no information on mobility of heavy metal along the food chain and the possible health risks due to consumption of contaminated food crops if irrigated with polluted wastewater is available. However, there is limited empirical information from the study area for heavy metals, POPs and other pollutant contents in soil and irrigation water and its accumulation and translocation to crop plants especially in vegetables. The edible plants produced from such soils could expose consumers to the risk of ingesting high doses of metals that exceed the standards in the long-term which could cause cases of sub-acute or chronic toxicity (Salvatore et al., 2009).

PLATE 2: Wastewater pumping and irrigation to vegetables and crops in City of Sialkot

4.4 TOXICOLOGICAL IMPACT ON HUMAN HEALTH BY CONTAMINATED SURFACE WATER IRRIGATION TO FOOD CROPS

Wastewater released from industries and urban areas is used for irrigation in urban and suburban areas. Although this may provide economic benefits to support livelihoods for poor farmers but it significantly deteriorates the quality and ecological integrity of water bodies (Marshall et al., 2007). Wastewater irrigation is extensively practiced throughout the world and in recent times a number of research reports have been published on wastewater-irrigated food crops contaminated with heavy metals and their damaging effects on DNA due to oxidative stress by hyper accumulation of heavy metals in plants (Mapanda et al., 2005). Continuous irrigation of soil with contaminated water reduces the capacity of soil to retain heavy metals, persistent organic pollutants (POPs) and other pollutants, which percolate into the ground water or soil minerals that are available for plant uptake. (Chary et al., 2008). Such toxic pollutants are not removed even after the treatment of wastewater at sewage and industrial effluent treatment plants, thus cause risk of heavy metals and POPs contamination of the soils and subsequently the food chain. Toxic pollutants originating from soil irrigated with wastewater are potentially toxic to vegetables, and crops production. Heavy metals and POPs have tendency to bio-accumulate in different parts and tissue of animals and human body when consumed through contaminated water and food plants (Cambra et al., 1999). A report "Health Risk Assessment of Consumption of Heavy Metals in Market Food Crops from Sialkot and Gujranwala Districts, Pakistan" published in Human and Ecological Risk Assessment: An International Journal, depicted that levels of toxic metals like Pb, Cd and Cr is exceeding the safe limits of Food and Agriculture as well as World Health Organization (WHO). The author investigated that food crops (vegetables and wheat) irrigated by contaminated surface water in Sialkot are hazardous for human health and may cause cancer if consumed for long term. It was suggested to stop the disposal of industrial wastewater to natural water streams (Khan et al., 2013). During this study, a field visit revealed that wastewater irrigation to food crops is still being practiced in the surrounding of Sialkot city (Plate 3).

Toxic pollutants can easily biomagnify in the food chain through bioaccumulation inhuman and animal tissues. Concerns exists regarding the bioaccumulation of such pollutants in living organisms, as recently various metabolites of POPs and toxic metal were reported to be hormone disruptors and can modify the operation of endocrine and reproductive system in wildlife and humans. Persistent nature of such pollutants makes them stay in fatty tissues for years, resulting in chronic problems such as, stunted growth and permanent impairment of brain function, birth defects, learning disabilities, reduced ability to cope with diseases, respiratory problems like asthma, cancer, and neurological, immunological, behavioral, and reproductive discrepancies in animals and humans. (Harrison et al., 1995). Newly born babies and children are more vulnerable to pollutants. Reduced immunity, neurobehavioral impairment, infections and tumor development in children are reported due to chemical pollutants exposure. (Bouwman, 2003).

PLATE 3: Wastewater irrigation to fodder crops

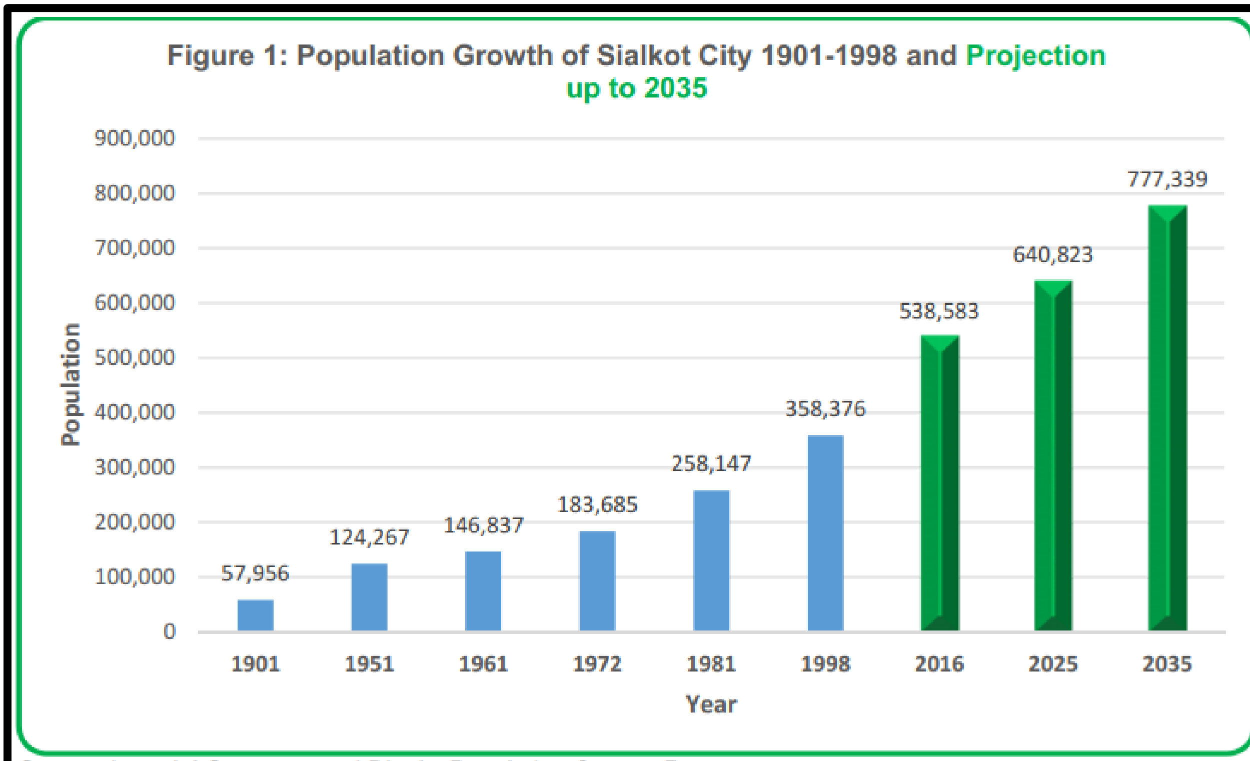
5 IDENTIFICATION OF KEY PRESENT AND FUTURE WATER RISKS OF SIALKOT CITY

5.1 DEMOGRAPHIC AND SOCIO-ECONOMIC RISKS

The world population increased during 1950 to 2000 from 2.5 billion to 6.1 billion and by the year 2050 it is estimated to be at 9.1 billion. The world population doubled in the past fifty years (1950 – 2000) and perhaps will grow less in fifty years from 2000 to 2050. World population is increasing annually by 1.2 per cent (77 million people per year) and six countries contribute to half of this annual increase: China, India, Pakistan, Indonesia, Nigeria and Bangladesh. Increasing population has led to an increase in water demand globally. Pakistan has experienced massive population expansion in previous decades which has put a burden on urban areas and open lands. According to 1981-1998 census of Pakistan, the average urban expansion rate is 3.4 per cent. It is estimated that the urban expansion in Pakistan will continue and be more rapid in next 25 years. Pakistan is facing rapid population growth since 1961, whereas average annual population growth rate in 1951 was 1.8 per cent which increased to 2.4 per cent in 1961 and touched its peak in 1976 with 3.6 per cent. This population growth rate declined in 1981 to 3.1 per cent and further in 1998 to 2.69 per cent. Currently, the estimated population growth rate is 1.89 per cent (Economic Survey of Pakistan).

Sialkot is home of 2nd largest industrial complex in the country and it is estimated that industrial growth will continue to flourish in next 20-25 years by contributing a significant impact on economic values of the city as well as the country. Population of Sialkot district was 1,509,424 persons according to 1972 population census followed by 1,802,505 persons according to 1981 population census, 2,723,481 persons according to 1998 population census and 3,893,672 persons according to 2017 population census. Population density of 903 person/km^2 was reported in 2011 by population and census organization that increased to 1,259/km^2 in 2017 and revealed +1.90 per cent/year change in population density from 1998-2017 which indicates that Sialkot is a densely populated district. Among the above stated population figures, 29.4 per cent (1,143,362 persons) comprises of urban community while rest of 70.6 per cent (2,750,310 persons) is rural community (Pakistan Bureau of Statistics). Population of Sialkot city was 358376 in 1998 which increased to 538,583 persons according in 2016. It is estimated that population of Sialkot city will reach to 640,823 persons in 2025 and further projected to reach 777,339 in 2035 (Figure 14).

Sialkot has diversified economic activities and is supporting its population by manufacturing activities since several years. Small- and large-scale industrial units are scattered throughout the city which facilitate its population to meet their economic needs.



Source: Imperial Gazetteer and District Population Census Reports

Figure 14: Year wise census data till 2035 of Sialkot

5.2 GROUNDWATER AVAILABILITY AND QUALITY CHALLENGES

Though, the Rivers Chenab and Tawi are the key sources of water table recharge, the magnitude of recharge does not remain similar throughout the year. During monsoon season, recharge is at peak while during rest of the period quantum of recharge decreases to the normal range. There exists scarcity of validated reports and data which reflect the actual picture of water table of the city. Due to increase in population, water demand in the next 25 years will also increase, that will in turn put pressure on the water table and counter strategies must be made to overcome this issue by enhancing groundwater recharge. Water level of natural water streams of the city (nullah Aik, Palkhu and Bhaid) have decreased to a considerable level and have been polluted to maximum extent (Qadir et al., 2008). Decrease in water level of natural water streams can affect the recharge to the water table. Pollution load of surface water (being the main source of ground water recharge) reported in previously published articles (Qadir et al., 2008; Ullah et al., 2013; Mahmood et al., 2015) revealed the contamination of groundwater. In Sialkot ground water pollution is a major issue and according to few reports water from 600 feet depth has been reported as safe for drinking purpose. Extraction of water from tremendous depth puts a serious burden on water supply department in terms of money. In Pakistan, the estimated cost of ground water extraction including energy and installation up to 20-meter depth is about 2800 PKR (USD 20)/ 1000 m^3. Further, for a water table depth of 40 meters, cost goes up to 7000 PKR (USD 50)/1000 m^3. If the water table depth is more than 70 meters, this cost is doubled (PKR 14000 or USD 100/1000 m^3) (Qureshi et al., 2008). It is also important to note that more depth of groundwater pumping will increase the risk of saline water intrusion from surrounding areas that would in turn intensify the water quality problems.

Natural water bodies are being contaminated with industrial as well as municipal water disposal to streams directly without any treatment. Plate 4 below shows the discharge of pure industrial wastewater to nullah Aik at Marala Road near Malky Kalan. Such practices are very common throughout Sialkot and increasing day by day. Disposal of industrial waste water to natural water streams not only contaminates the surface water directly, but also puts enormous negative impact on groundwater quality. Reported groundwater pollution issue is becoming serious day by day but no action is being taken on waste water disposal to water streams. Water contamination needs to be controlled by installing water treatment plants and by constructing wetlands to reduce pollution load of industrial wastewater before its disposal to natural surface water bodies.

PLATE 4: Direct disposal of tannery wastewater contaminated with chromium without prior treatment to nullah Bhaid

5.3 LOCAL AND REGIONAL CLIMATE CHANGE SCENARIOS AND THEIR LIKELY IMPACT ON WATER RESOURCES

Urban settlements provide residence to more than 50 per cent of the total global population. Small and medium sized cities in developing countries are more vulnerable to climate change issues.

Pakistan is ranked 12th most vulnerable country to climate change across the globe. Unusual and heavy monsoon rains and storms cause flooding which has been the main climate tragedy, contributing severe damages to the economy of that region (Khan et al., 2010). In 2010 Pakistan has faced severe floods when 2000 people died, 1.6 million houses were damaged, 20 million people were affected, and economy had to bear a loss of USD 43 billion (Annual Flood Report of Federal Flood Commission, 2013, Islamabad). Total costs by climate allied calamities are similar to losing at least 5 per cent GDP (Gross Domestic Products) each year. When broader hazards are considered, this damage may rise to 20 per cent of GDP (Khan et al., 2010). Further, climate change risks and impacts put local ecosystem and natural environment in danger. Decline in water table across the globe resulted in the worst drought in history at the turn of this century, severely degrading ecosystems and drying up wetlands.

Sialkot city has humid subtropical climate. During every monsoon season, the nullahs Aik, Palkhu and Bhaid experience outburst flooding and are responsible for deluging the surrounding areas. If the predicted climate change scenarios are realized, Sialkot will experience more torrential rains and flooding is expected to worsen.

Riverine system of Pakistan is dependent on northern glaciers, which are melting continuously due to drastic climatic changes. It is estimated that water flow in rivers will increase considerably in future, but ultimately will lead to the decrease of water flow due to the reduction in glacier volume at north of the country. There exists no proper mechanism or strategic plan to treat excess of water and to control or use the water for groundwater recharge. Pakistan has to prepare itself to address the probable water issues due to climate change in future. Present water management strategies are not well enough to cope with the impact of climatic changes on water, public health, agriculture, energy generation and aquatic ecosystem.

5.4 WATER MANAGEMENT INFRASTRUCTURE

Water shortage is one of the prime issues in Indus Basin Irrigation System (IBIS). In Pakistan, canal system was designed in 19^{th} century to meet the water demands of about 70 per cent cultivation while currently cultivation across IBIS is about 120 per cent. This boost in crop production is mainly due to the use of groundwater in areas where no irrigation system exists. Sandy or clay canals system and disorganized irrigation application results in salinity and water logging. By the end of 1979, total area around IBIS affected by water logging was 42 per cent (WAPDA, 1979). Currently, over a million tube wells are present in Punjab extracting around 50 MAF (GOP, 2019).

Across the Indus basin, seepage from surface water contributed to enhance the ground water quality at 120 meters to 150 meters depth. However, the depth ranges from less than 60 meters to 30 meters or less in some areas along the margins and center of Doabs. According to an estimate, around 2000 billion m^3 groundwater is salty (Ahmad et al., 2001). Concerns about quality of groundwater are gaining attention due to population growth, industrial expansion and accelerated agriculture. Groundwater quality is essential for better public health and crop production. Over pumping of groundwater puts tremendous pressure on quality and water table mainly in Punjab.

Salinity level increase is projected to decrease the useable aquifer up to 57 per cent by the year 2025. Furthermore, currently we have around 145 MAF of surface water and around 50 MAF is extracted annually. Current water storage capacity needs to be at least doubled. In comparison with other arid countries, Pakistan has only 15 per cent of annual rainfall water storage capacity which is less. Further, this country can hardly store water for only 30 days in Indus basin. It is assumed that water demand will increase by 12 per cent in next ten years and the situation will worsen if no water storage reservoir is built in the future. Projected water demand in 2025 is 165 BCM that will need urgent attention to increase the water storage capacity to 22 BCM (~17.9 MAF) until 2025 to meet this demand.

5.5 WATER RELATED ISSUES FOR INDUSTRIES

Water quality and climate change will be the prime challenges for business and industrial sector. The era of cheap and easy freshwater access has almost passed. Its impact on industries and human survival are obvious, as no substitute exists for industrial processes where water is required at every step. Sialkot is the main hub of industrial setups and leather sector is dominating over other industries. Leather tanning process is mainly dependent on water at every step until the final processed product. Pumping rate of groundwater for industrial and municipal demand is alarming in Sialkot. Across Sialkot, agricultural activities are dependent on groundwater irrigation sources due to the depletion or pollution load in surface water resources. This boost in groundwater usage for agriculture poses a serious threat to the sustainability of agriculture sector and the groundwater resources in Sialkot. Meanwhile, municipal services are also mainly dependent on groundwater and this demand is increasing continuously. In Sialkot, leather sector uses maximum water during processing and this industry is at peak level of water risk in the future.

5.5.1 PHYSICAL RISKS

Physical scarcity of water will pose tremendous impact on business activities, production and supply of raw material, midway supply restrains, and usage of yield in a number of ways. Disturbance in water supply chain will destabilize industries and manufacturing units, where water is required for processing, irrigation, washing, cleaning, and cooling purposes. Furthermore, decline in water quality will also impact the industries, as water is required for industrial processes in acceptable quality. Substandard quality water needs more investments to meet the water quality standards according to guidelines, before using water for specific manufacturing processing. If the industrialists do not have access to clean and quality water, they need to invest for pre-treatment of water. In case water treatment technologies are not financially and physically feasible, industry needs to be shut down or shifted to those areas where water is available in easy and cheap manner, which in turn is also a financial burden on industrialists.

5.5.2 ENVIRONMENTAL RISKS

Industries are responsible for degrading the water quality by emitting wastewater directly to surface water bodies of the city. Surface water has its own physical and chemical parameters, which are responsible to support biotic and a biotic components of environment. Deterioration of water quality badly damages the environment. Moreover, polluted surface water used for irrigation purpose also poses negative impact on food crops and animals. Additionally, air-water exchange mechanism of contaminants also pollutes the atmosphere.

Scarcity of water will also lead to the depletion of water resources that in turn will deprive the irrigation water quantity, leading to drought like condition, squeezing of cultivated land and deforestation. Evapotranspiration process will be affected which ultimately impacts the rainfall system in the country, resulting in barren and dry land with an increase in earth temperature.

5.5.3 REGULATORY RISKS

Industrial, physical, institutional and environmental risks of water quality and availability demand more strict water policies. Policymakers must address water pumping without permits and stringent water quality standards need to be observed. Water users especially industries should be encouraged to adopt water conservation practices and improve their environmental management to avoid the water related risks translate into tangible business risks. Additionally, water quality should be monitored regularly.

5.6 WATER RELATED ENVIRONMENTAL AND HEALTH ISSUES

Sialkot is facing serious water issues which are harmful for environment. Water table quality is depleting at a high rate, as water drilling from 600 ft is the recommended depth of fresh water boring in the city. This alarming situation is further aggravated as the ground water table is being contaminated rapidly and no preventive, remedial measures are being adopted. Increase in reports of hepatitis patients is due to poor water quality in the city. Usage of contaminated water is responsible for water related diseases like hepatitis, typhoid, cholera, dysentery and diarrhea which are responsible for one third of all deaths (World Bank, 2006).

Sialkot district health authority and public health engineering department reported that domestic water supply by Municipal Corporation is contaminated and declared it as unhygienic (The Nation, 2018). Health officials reported that people are becoming victims of waterborne diseases (WBDs) and their number is increasing day by day due to usage of unhygienic drinking water (The Nation, 2018).

Vegetables (variety of species e.g. spinach, carrot, potato, tomato, cabbage, pepper, garlic, turnip, etc.), wheat and rice collected from Sialkot, irrigated by surface water and ground water of Sialkot were investigated for different toxic pollutants. Results concluded that most of the vegetables are not purely healthy for consumption and possibly the use of such contaminated food commodities will lead to chronic diseases in human well-being in near future if no preventive measure will be taken on this practice (Khan et al., 2013; Mahmood et al., 2015)

PEPA (The Punjab Environmental Protection Agency) has also shown grave anxiety on the issue of mounting pollution load in water bodies highlighted in recent months by water and sanitation agency, and tehsil municipal administrations. PEPA has also intimated the local farmers not to use wastewater for irrigation purpose, but it is still in practice (The Nation, 2018).

5.7 WATER RELATED CHALLENGES FOR ORGANIZATIONAL INSTITUTES

Groundwater usage by water supply to domestic consumers is managed by Municipal Corporation for urban settlement. There are total 39,274 domestic users and 2,269 commercial users via 372 km water supply pipe lines. Water supply pipe lines are reported to be 60 years old, which are severely damaged from various points and badly attacked by rust (The Nation, 2018). Seepage of sewage and municipal waste water gets mixed with these damaged pipelines and contaminates drinking water. Municipal Corporation has no proper mechanism for leakage detection to recover affected part of pipelines to avoid WBDs. Further, no procedure exists for replacement of damaged pipes. In case of severe leakage, affected part is repaired need based. Figure 15 presents the details of damaged pipelines in city of Sialkot and water loss and contamination load can be imagined by visual representation of current situation of water supply pipelines system.

Due to lack of metering, water is wasted at significant level owing to unbalanced control of household hose and private water storage tanks. Water is supplied at constant rate and people are not conscious about wasting water and do not make efforts to conserve it either.

Fixed water tariff is another hurdle in conserving water at domestic level. TMA needs to fix water tariff based on water discharged from household hose and this is very easy to monitor by installing water meters to household, commercial and industrial connections. 12-hour water supply per day needs revision and urban community should focus to save water at household level.

It is further observed that there is no proper quality assessment mechanism for groundwater and surface water of the city, even though water quality laws and guidelines exist in the country. The Pakistan Environmental Protection Act (PEPA), 1997 places emphasis on conservation, protection, rehabilitation, and betterment of the environment, pollution control and prevention strategies, and sustainable development of natural resources. In Pakistan, now the National Water Policy along with NEQS (National Environmental Quality Standards) and National Environmental Policy exist but regulatory mechanism and implementation of law is very poor (Hashmi et al., 2011). There is no proper checkup for industrial effluent discharge to surface water bodies without prior treatment

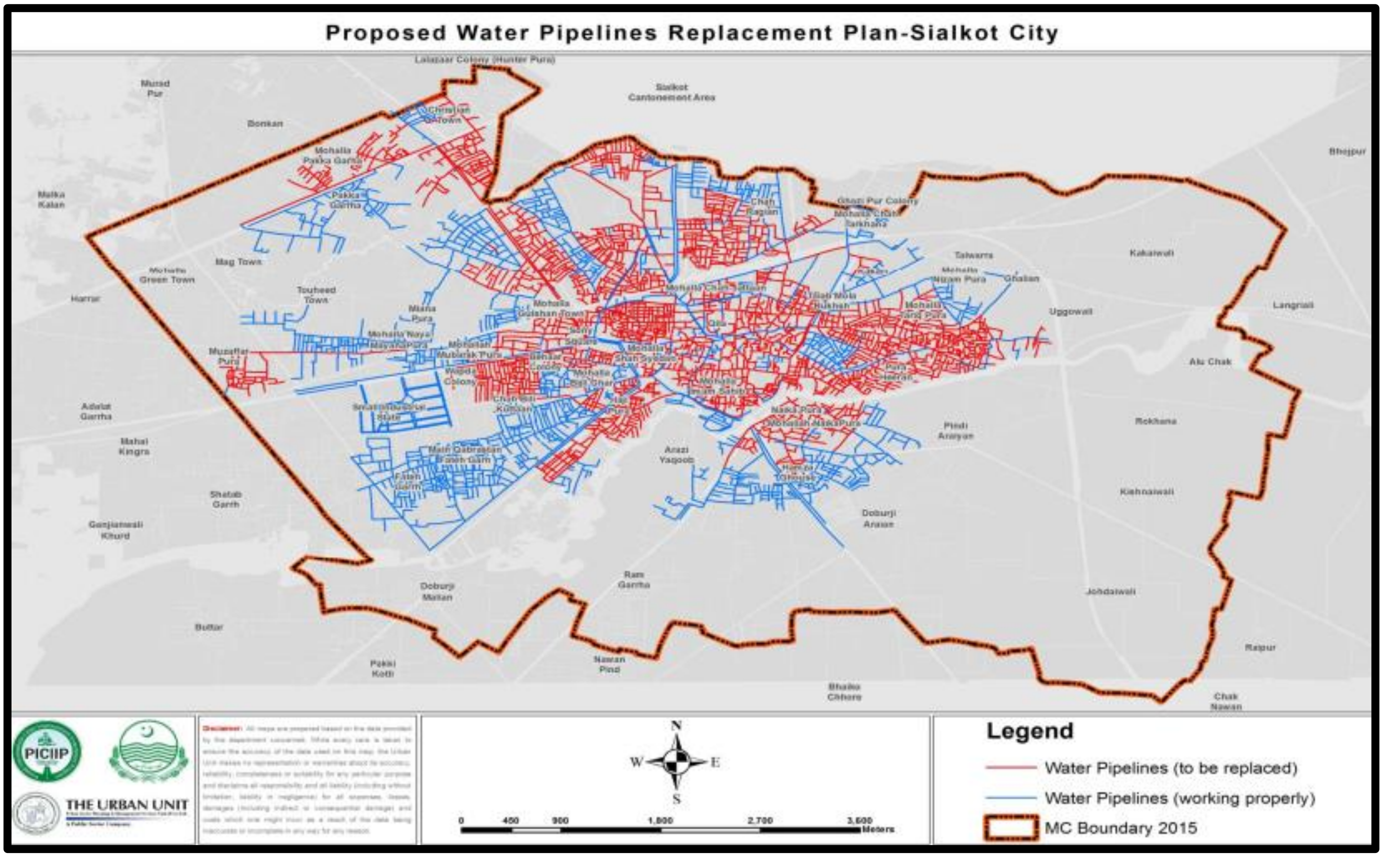


Figure 15: Damaged water supply pipelines in Sialkot result in huge volumetric water loss (Source: CDIA, 2015 and The Urban Unit)

5.8 WATER RELATED RISKS FOR COMMUNITY

Situational analysis of water resources of Sialkot identified following water related general risks for the community, as detail has already been described in previous headings of the current chapter.

- Continuous ground water availability will suffer in future.
- Water scarcity is projected for community.
- Quality of domestic and drinking water will degrade in the future.
- Industries are putting pollution stress on surface water bodies.
- Surface water bodies will be completely unfit for consumption in any way in near future.
- Cultivation of food crops and vegetable by surface water irrigation will pose serious health hazards to community.
- Uncontrolled banks of nullah Aik, Palkhu and Bhaid may result in serious flooding to urban areas due to climatic changes.
- Increased susceptibility to waterborne diseases.

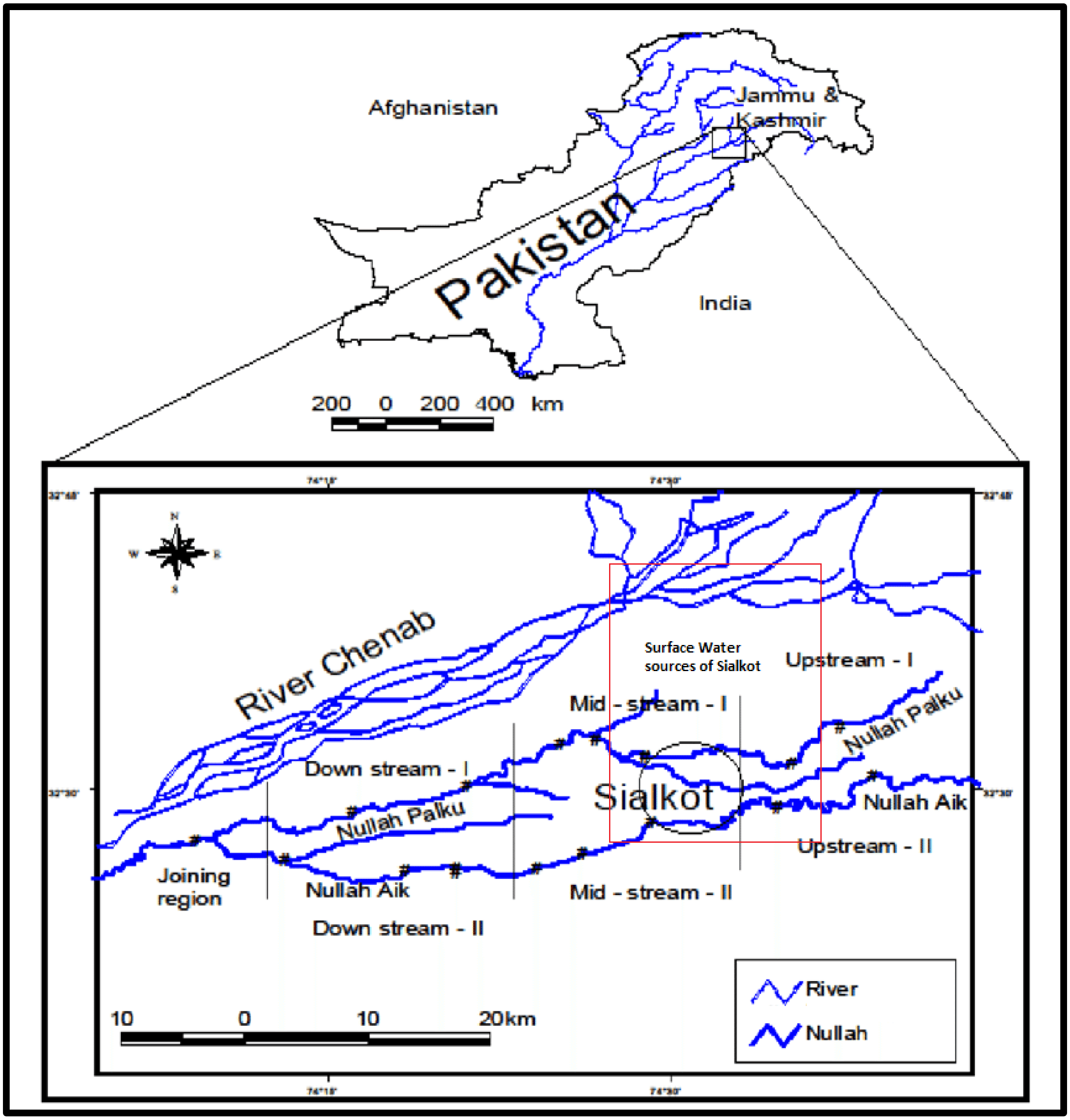


Figure 16: Surface water resources of Sialkot City and their flow towards disposal/drain points (Qadir, 2008)

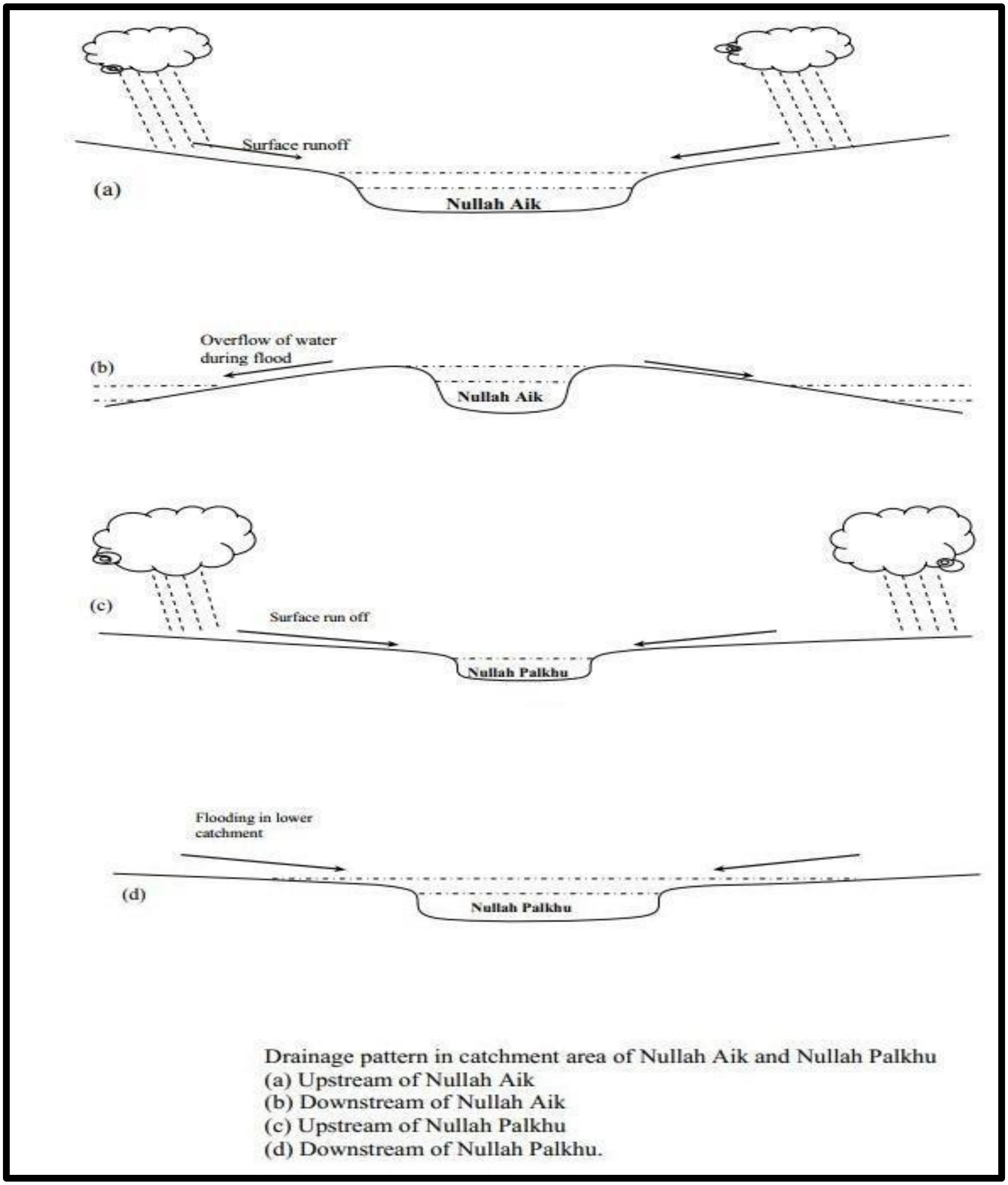


Figure 17: Drainage pattern in the catchment areas of surface water bodies of Sialkot (Source: Qadir, 2008)

6 STRATEGIES AND REMEDIAL MEASURES FOR WATER MANAGEMENT IN SIALKOT

Several strategies and remedial measures for water and wastewater management in Sialkot are given under five main domains, i.e. Education, Management, Policy, Resources and Technologies.

6.1 MANAGEMENT

6.1.1 INFRASTRUCTURE REPAIR AND MAINTENANCE

One of the key ways of solving the problem of water scarcity in Sialkot can be through infrastructure repair and maintenance of water channels such as Bambanwala River Bedian (BRB) canal, Marala Ravi Link Canal and Upper Chenab Canal. The three natural streams in Sialkot i.e. nullahs Aik, Palkhu and Bhaid must also be maintained properly to prevent water losses. Leaking pipes and sewage systems normally lead to water wastage and contamination respectively. If these infrastructures are left unattended over time, the cumulative effects can create water shortages. Millions of liters of water are lost yearly in various regions of the world owing to leakages and sewer contamination thus creating water shortages.

6.1.2 GROUNDWATER PROTECTION

Groundwater should be protected from anthropogenic activities that are potentially polluting. Disposal of solid waste and wastewater to main surface water bodies without pre-treatment should be prevented. Depression zones need to be identified accurately to minimize the groundwater pumping across the city. Results of the present study revealed the center and core area of the city of Sialkot as depression zones due to minimum recharge and extensive water pumping. Depression zone should be declared as groundwater protection zone. The public should be made aware through information campaigns to conserve water from such areas. Water recharge units such as rain water reservoirs should be designed for open areas in such zones. Detailed investigation is required to identify more groundwater depression zones in the city.

Industrial and agricultural sector is mainly dependent on groundwater to fulfill their major water needs. These sectors must try to incorporate the impact of climate change to groundwater resources. Many developed countries like Japan have provided access to industries to use surface water to meet their needs and to reduce the dependence on groundwater. In view of current groundwater situation in Pakistan, industrial sector may be given surface water rights to minimize the groundwater pumping practice. It is further suggested that industries need to control the water quality by adopting treatment facilities along with the groundwater recharge.

Public community considers groundwater as an unlimited resource and uses it abundantly. It is important to educate all water users and stakeholders about groundwater importance. Trainings and education series need to be launched for the public about rainwater and runoff water harvesting for domestic and agricultural use and as a recharge option for groundwater.

6.1.3 INSTALLATION OF WATER METER

Old infrastructure of water supply, damaged pipes, leaks at joints and hose waste considerable quantity of water. A dripping water tap can leak 300 liters of water in a year. In our country fresh water is supplied continuously for constant time with fixed tariff. Water must be supplied through water meter and tariff needs to be fixed on volumetric basis of (in gallons) water consumption at household level. This practice will instigate consumers to stop the wastage of water and water conservation can be achieved in easy manner same like the gas and electricity.

6.2 RESOURCES

6.2.1 RECHARGING AQUIFERS

According to a 2012 UN report on *The World's Water,* groundwater retraction has tripled in the past five decades because of industrial and agricultural uses. For this reason, governments and organizations of Sialkot can undertake measures to recharge aquifers or groundwater by undertaking projects aimed at infiltrating or injecting excess surface water into the underground aquifers. This may include aspects such as construction of watersheds and wetlands and the practice of green infrastructure which aims at reducing impervious surfaces.

6.2.2 WATER CONSERVATION

Water conservation is one of the leading ways to grow out of water scarcity. It is an indirect approach to reducing water demands and is usually critical in maintaining the supply-demand balance. During droughts and in densely populated regions, for instance, water conservation efforts ensure there is a supply-demand balance. The approaches can easily be implemented in Sialkot as they involve simple ways of saving water. For water conservation to be effective enough, it has to work hand in hand with water management policies.

6.2.3 RAINWATER HARVESTING

To increase recharge to groundwater, rainwater harvesting should be encouraged in all new schemes and in TMA jurisdiction areas. Special recharge zones need to be developed where rainwater can be collected and then used to recharge groundwater using different recharge technologies. However, while doing so the rights of downstream users must be protected. According to the field survey and situation analysis water recharge zone is proposed at Latitude 32°35.458´N and Longitude 074°32.725´E. Open depressed land near Shadiwal village shown in Plate 5 can be designed to harvest the rain water, which can be a potential rainwater harvesting site that may remain charged with water throughout the year.

PLATE 5: Proposed site for rainwater harvesting and water recharge zone

6.2.4 CLIMATE CHANGE AND FLOOD MANAGEMENT

Climate change is responsible for heat waves and droughts throughout the world, on the other hand contributing to floods and rise in sea water level. More frequent flooding in recent years is a possible result of climate change that is a continuous threat to urban population of the city and agriculture. City can be protected by creating small reservoirs to store flood water that will save cities from destruction.

i) As a result of this study, one possible location is proposed for a small water reservoir; an elevated depression site near cricket ground of Kharota Sayadan village (Latitude 32° 32.258´N and Longitude 74° 32.432´E). If this site is utilized, flood water can be better managed during the monsoons and groundwater recharge will also be achieved simultaneously. This site has already been serving as a natural water harvesting site. If a slight diversion in water flow of nullah Palkhu is created, water will flow into this depression zone.

PLATE 6: Proposed site for small water reservoir

6.3 POLICY:

6.3.1 WATER MANAGEMENT BY USING REGULATIONS AND POLICIES

In Sialkot, water management by the use of regulations and policies can help reduce water scarcity. The regulations and policies can address water-related problems such as water reuse, water resource management, water rights, industrial water use, wetland restoration, domestic water supplies, water pollution, and others. In precise, water management has the capability of addressing human interventions and the various natural events.

6.3.2 SUPPORT CLEAN WATER INITIATIVES

There are organizations located all over the world that are looking to bring clean water to areas that do not have it. Some private and public organizations of Sialkot should be motivated to bring clean water initiatives in remote areas.

6.4 TECHNOLOGIES:

6.4.1 WATER REUSE AND EFFECTIVE WATER TREATMENT TECHNOLOGIES

Water reuse strategies can help alleviate water scarcity in Sialkot. The main strategies recommended for Sialkot include reuse and recycling and the use of zero-liquid discharge systems. Zero-liquid discharge system is whereby the water within a facility is constantly treated, used and reused again and again without being discharged into the sewer or other external water systems.

The non-potable water (grey water) can be used for washing cars, irrigating landscape, industrial processing and flushing the toilets. Such a system allows waste water that would have been discarded to become a helpful resource. There are plenty of technologies out there that allow one to recycle rainwater and other water that one may be using at household level. Not only does it help to prevent scarcity, but it can save some money as well. Such recycling technologies must be promoted in Sialkot.

6.4.2 CONSTRUCTION OF RESERVOIRS AT RACHNA DOAB OF SIALKOT

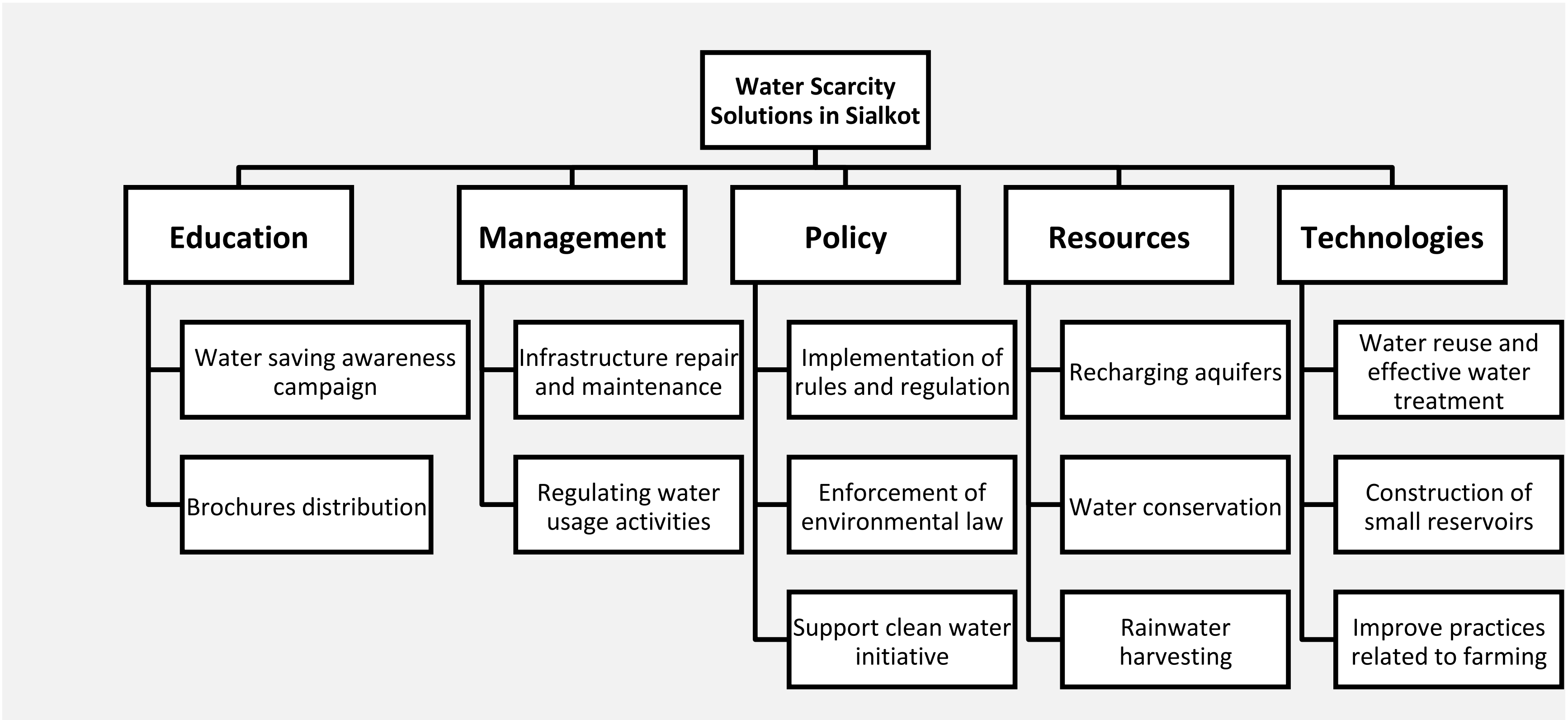
Reservoirs can provide the following functions:

- Serve as storage for drinking water in areas where there is acute shortage
- Use for irrigation and as source of water for livestock
- Water security in far flung areas
- In higher reaches there is some hydropower potential
- Fish production and recreation

Reservoirs are often promoted as low-cost solutions. These can be constructed in a short period of time and communities can benefit from them.

6.4.3 IMPROVE PRACTICES RELATED TO FARMING

Farming and irrigation are often huge culprits when it comes to water scarcity. Because of that, we need to improve practices so that we don’t use as much water and those who are using water are using it to its fullest potential. In Sialkot, water efficient technology should be used in farming and agriculture practices to save the water. Furthermore, irrigation through wastewater should be immediately stopped.


Water Scarcity Solutions in Sialkot
Education
Management
Policy
Resources
Technologies
Water saving awareness campaign
Brochures distribution
Infrastructure repair and maintenance
Regulating water usage activities
Implementation of rules and regulation
Enforcement of environmental law
Support clean water initiative
Recharging aquifers
Water conservation
Rainwater harvesting
Water reuse and effective water treatment
Construction of small reservoirs
Improve practices related to farming

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