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Research Article

Investigation of potential sites for ground water recharge in urban areas (Faisalabad)

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Abstract

The increasing world population led to extensive agriculture and expansion of industries, thereby, putting greater demand on water. In the last few decades, an increasing awareness has thus been shown on the importance of occurrence and distribution of water on the earth. A great importance is now being given to hydrology all over the world in the development and management of water resources. The life on Earth is directly related to temperature, air and water. Salt water covers about 97% of the total water. Only 1% is available to living organisms. The quality of this 1% is continually being degraded. Some of it is contaminated and cannot support life. The scarcity of water has become an established factor now and the intensity of problem is increasing day by day. Human use of natural water particular of fresh water resources have increased steadily over the centuries. Ground water is used as main source of drinking water and about 30% of world's fresh water is stored as ground water. By realizing the importance of the problem, the issue of decreasing levels in the ground water has been addressed globally. Various countries are adopting different strategies and plan to cope with the alarming situation. Artificial recharge of ground water has become a common practice around the globe during the last few decades. The project and study primarily focuses on the artificial recharge method of ground water. The study is based on different techniques and their application in the Faisalabad region of Pakistan. Through these studies and suggestions, we can improve the situation and decreasing levels of ground water. The recharged aquifers then can be used to provide water for purposes like drinking etc. Further the conclusions are drawn related to existing situation and recommendations are made for the proper management and preservation of groundwater.

Keywords: *Groundwater; demand of water; water pollution; artificial recharge.*

Introduction

Groundwater is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table.

Per capita, water resource availability has diminished rapidly during the last four decades in the Central Asia. Especially groundwater has undergone dramatic changes in arid areas because of higher demand [1]. Here, groundwater is often the main source of both drinking and irrigation water, and thus rapidly decreasing groundwater levels calls for new methods to restore water availability [1].

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The groundwater recharge is the residual flow of water added to the vadose zone or water table resulting from the evaporative, transpirative and runoff losses of the rainfall. Thus groundwater recharge is a sensitive function of the climatic factors, local geological formation and topography, and land use types of the area under consideration. So, the Groundwater recharge is a phenomenon by which the ground water is recharge to preserve and maintain its level in the aquifers [2].

Groundwater can be recharged naturally by rainfalls, rivers, glaciers etc. But the demand is rapidly increasing from few decades [1]. So, there is a need to recharge it artificially to meet the increasing demand. Groundwater recharge can be differentiated into two main types:

1. Natural Recharge
2. Artificial Recharge

Natural Recharge

Groundwater is recharged naturally by rain and snow melt and to a smaller extent by surface water (rivers and lakes).

Through natural process it includes

- Precipitation
- River bed seepage
- Flooding
- Glaciers and Snow melts

Artificial Recharge

Artificial recharge includes the recharging of natural ground water aquifers using man made methods and developments. By using different methods, the level of groundwater in the aquifers are maintained to meet the supply demands and hence further this water is used for abstraction [3][1]. Its main objective is to balance and recover the groundwater resources through floodwater spreading systems and injection wells.

There are different methods which are adopted to recharge:

- Ditches and Furrows
- Spreading basins
- Stream augmentation
- Recharge wells

Nowadays there is an increasing necessity for taking suitable measures in order to meet the demands of fresh water because in near future there will be shortage and lack of access to cheap fresh water. It will severely affect the whole population. So, there is an immense need to plan and make proper alternatives; either harvest rain or waste water to increase the potential of groundwater [4].

Different methods are applied throughout the world to cater such problems. Some of which are discussed below.

El Paso Injection Recharge Project in Texas, United States

El Paso is an arid land with an annual rainfall averaging about 20 cm (8 inches). Water supplies are scarce. It obtains about 90 percent of its water supply from deep laying aquifer.

The El Paso, Texas, project is the first injection project in the United States where the sole intent of the project is to augment the potable water supply aquifer using reclaimed municipal wastewater. It is providing enough water to recharge the aquifer [5].

The El Paso recharge project is a 10-mgd (millions of gallons per day) direct-injection system. The overall recharge system consists of an advanced wastewater treatment plant, a pipeline system through the Hueco Bolson, and 10 injection wells. All sewage collected in the northeast of the city is pumped to the treatment plant. Following treatment [6][7][8], the wastewater is pumped to the injection system for injection across the freshwater section of the bolson aquifer between existing production wells. After injection, the water travels approximately 1.2 km through the aquifer to production wells for municipal water supply [7].

The injection wells are constructed so that water is recharged from the top of the saturated zone to the point where TDS levels approach 1,000 mg/l. This is generally in the interval from 107 to 290 m (350 to 960 ft.). The formation throughout the injection interval is fluvial in nature and contains gravel, silt, and clay lenses. [9] [21].

Ground water recharge operations are extending the lifetime of the Hueco Bolson aquifer. Water reclaimed from sewage is being injected with the intent of recovery for potable reuse with only chlorination. The construction cost for the treatment plant and recharge system was $33 million (in 1985) [10].

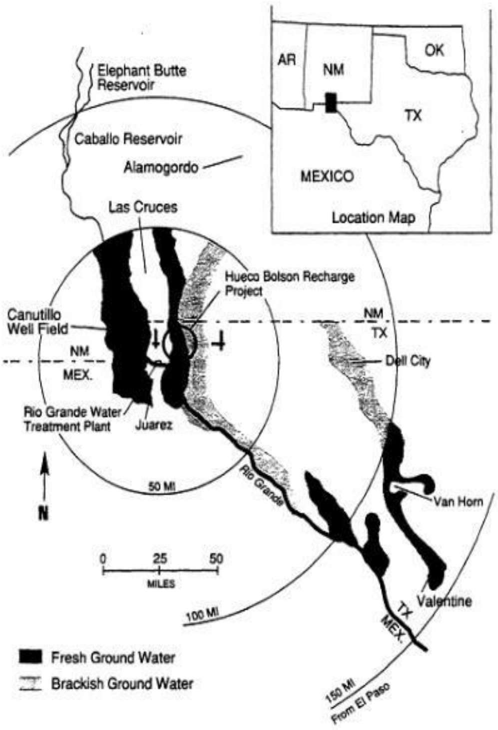

Figure 1 El Paso well field

The city of Faisalabad is an industrial city surrounded by agricultural land, is facing a number of public health issues due to lack of access to potable water. It has a poorly managed storm water management system. The monitoring and preservation of groundwater is totally neglected. This third major city of Pakistan is located within the center of the plain Punjab, equidistant from the Ravi and Chenab Rivers [23]. The city is having a flat terrain. A master plan was developed in 1992 but was not vigorously implemented to improve the infrastructure of the city.

Another reason is unplanned and unforeseen growth in residential, commercial and industrial sectors. Moreover, the administration is not giving enough importance to manage and balance the levels and quality of groundwater. Due to lack of pure drinking water, it becomes a root cause of many water borne and water related diseases [11] [12]. Therefore, the problems related to health are increasing day by day.

Hence proper studies should be done and plans should be carried out to deal with such issues. So that we can improve the quality and quantity of groundwater in this locality.

Ground Water

When rain falls to the ground, some of it flows along the land surface to streams, rivers or lakes, some moisturizes the ground. Part of this water is used by vegetation; some evaporates and returns to the atmosphere. Part of the water also seeps into the ground, flows through the unsaturated zone and reaches the water table, which is an imaginary surface from where the ground beneath is saturated [13].

Groundwater is contained in aquifers. An aquifer is a geological formation or part of it, consisting of permeable material capable to store/yield significant quantities of water. Aquifers can consist of different materials: unconsolidated sands and gravels, permeable sedimentary rocks such as sandstones or lime stones, fractured volcanic and crystalline rocks, etc. [14] [15].

Groundwater can be found almost everywhere. The water table may lie deep or shallow depending on several factors such as the physical characteristics of the region, the meteorological conditions and the recharge and exploitation rates. Heavy rains may increase recharge and cause the water table to rise. But on the other hand, an extended period of dry weather may cause the water table to fall [16].

Importance of Ground Water

Groundwater represents about 30% of world's fresh water. From the other 70%, nearly 69% is captured in the ice caps and mountain snow/glaciers and merely 1% is found in river and lakes. Groundwater counts in average for one third of the fresh water consumed by humans, but at some parts of the world, this percentage can reach up to 100% [17].

Ground Water Hydrology

Most groundwater comes from precipitation. Precipitation infiltrates below the ground surface into the soil zone. When the soil zone becomes saturated, water percolates downward. A zone of saturation occurs where all the interstices are filled with water [15]. There is also a zone of aeration where the interstices are occupied partially by water and partially by air. Groundwater continues to descend until, at some depth, it merges into a zone of dense rock [18].

Water is contained in the pores of such rocks, but the pores are not connected and water will not migrate. The process of precipitation replenishing the groundwater supply is known as recharge. In general, recharge occurs only during the rainy season in tropical climates or during winter in temperate climates. Typically, 10 to 20 percent of the precipitation that falls to the Earth enters water-bearing strata (aquifers) [19].

Identification of Areas For Recharge

The first step in planning a recharge scheme is to demarcate the area of recharge. Such an area should, as far as possible, be a micro-watershed (2,000-4,000 ha) or a mini-watershed (40-50 ha) [20] [23]. The demarcation of area should be based on the following broad criteria:

- Where ground water levels are declining due to over-exploitation.
- Where substantial part of the aquifer has already been desaturated i.e. regeneration of water in wells and hand pumps is slow after some water has been drawn.
- Where ground water quality is poor and there is no alternative source of water.

Quality of Source Water

Chemicals and Salts

Problems which arise as a result of recharge to ground water are mainly related to the quality of raw waters that are available for recharge and which generally require some sort of treatment before being used in recharge installations. They are also related to the changes in the soil structure and the biological phenomena, which take place when infiltration begins, thereby causing environmental concerns [24]. The chemical and bacteriological analysis of source water and that of ground water is therefore essential [25].

Sediment Load

A major requirement for waters that are to be used in recharge projects is that they be silt free.

*Silt may be defined as the content of undissolved solid matter, usually measured in mg/l, which settles in stagnant water or in flowing water with velocities, which do not exceed 0.1 m/hr [26] [27] [28].

Ground Water Recharge

Ground water recharge includes recharge as a natural part of the hydrologic cycle and human-induced recharge, either directly through spreading basins or injection wells, or as a consequence of human activities such as irrigation and waste disposal [29][30]. Artificial recharge with excess surface water or reclaimed wastewater is increasing in many areas, thus becoming a more important component of the hydrologic cycle [31][32].

Groundwater is (naturally) recharged by rain water and snowmelt or from water that leaks through the bottom of some lakes and rivers. Groundwater also can be recharged when water supply systems leak and when crops are irrigated with more water than required [33].

Artificial Recharge Methods

A variety of methods have been developed to recharge groundwater artificially. The most widely practiced methods can be described as types of water spreading, vertical shafts, injection wells, percolation tanks etc [34].

Spreading Method

It is the releasing of water over the ground surface in order to increase the quantity of water infiltrating into the ground and then percolating to the water table. Although field studies of spreading have shown that many factors govern the rate at which water will enter the soil, from a quantitative standpoint, area of recharge and length of time that water is in contact with soil are most important [35].

Ditch and Furrow Method

In areas with irregular topography, shallow, flat-bottomed and closely spaced ditches or furrows provide maximum water contact area for recharge water from source stream or canal[36].

This technique requires less soil preparation than the recharge basins and is less sensitive to silting. Figure shows a typical plan or series of ditches originating from a supply ditch and trending down the topographic slope towards the stream. Generally, three patterns of ditch and furrow system are adopted [37][38].

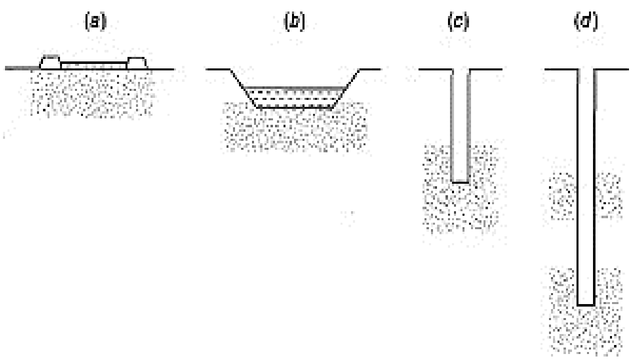

Figure 2 Recharge system for increasingly deep permeable materials.

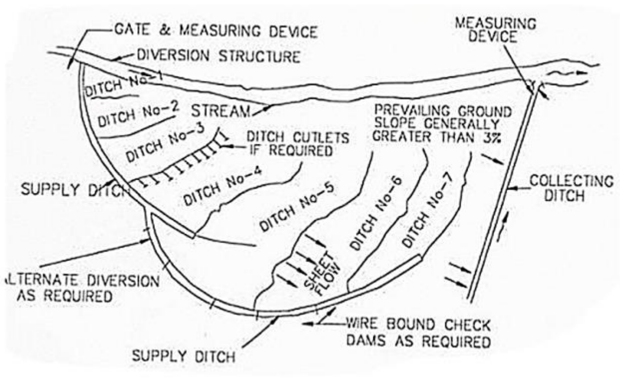

Figure 3 Ditch and Furrow Method

Recharge of dug wells and hand pumps

In alluvial as well as hard rock areas, there are thousands of dug wells, which have either gone dry, or the water levels have declined considerably. These dug wells can be used as structures to recharge the ground water reservoir [39].. Storm water, tank water, canal water etc. can be diverted into these structures to directly recharge the dried aquifer. By doing so the soil moisture losses during the normal process of artificial recharge, are reduced. The recharge water is guided through a pipe to the bottom of well, below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer. The quality of source water including the silt content should be such that the quality of ground water reservoir is not deteriorated[40]. Schematic diagrams of dug well recharge are given in Figure. In urban and rural areas, the roof top rainwater can be conserved and used for recharge of ground water. This approach requires connecting the outlet pipe from rooftop to divert the water to either existing wells / tube wells / bore wells or specially designed wells. The urban housing complexes or institutional buildings having large roof areas can be utilized for harvesting roof top rainwater for recharge purposes [30][36] [41].

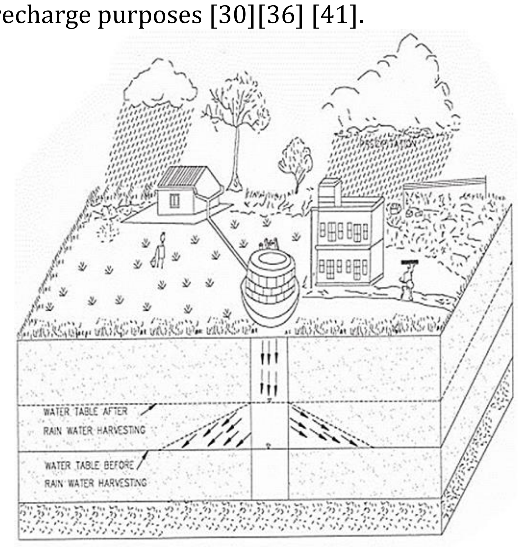

Figure 4 Recharge of Dug Wells through Roof Top Rain Water Harvesting

Vertical Recharge Shaft

The vertical recharge shaft can be provided with or without injection well at the bottom of the shaft.

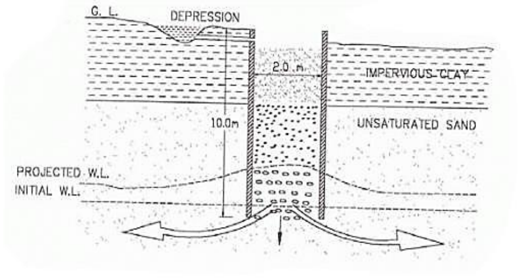

Figure 5 Vertical Recharge Shaft Without Injection Well

With Injection Well

In this technique an injection well of 100-150 mm diameter is constructed at the bottom of the shaft piercing through the layers of impermeable horizon to the potential aquifers to be reached about 3 to l5 m below the water level.

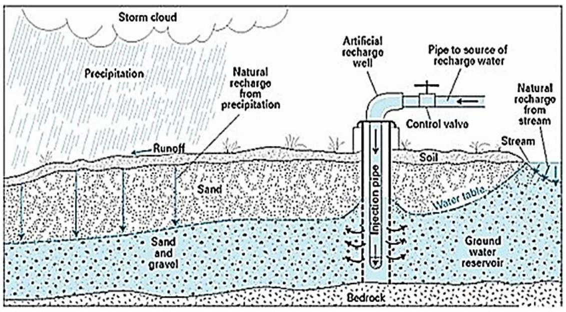

Figure 6 Vertical Recharge Shaft with Injection Well

Induced Recharge

It is an indirect method of artificial recharge involving pumping from aquifer, hydraulically connected with surface water, to induce recharge to the ground water reservoir. When the cone of depression intercepts river recharge boundary a hydraulic connection gets established with surface source, which starts providing part of the pumpage yield. In such methods, there is actually no artificial buildup of ground water storage but only passage of surface water to the pump through an aquifer. In this sense, it is more a pumpage augmentation rather than artificial recharge measure.

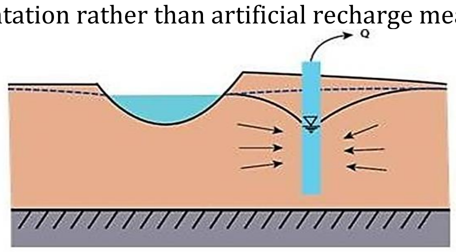

Figure 7 Induced Recharge

Distribution of Water

The distribution of water on the Earth's surface is extremely uneven. Only 3% of water on the surface is fresh; the remaining 97% resides in the ocean. Of freshwater, 69% resides in glaciers, 30% underground, and less than 1% is located in lakes, rivers, and swamps. Looked at another way, only one percent of the water on the Earth's surface is usable by humans, and 99% of the usable quantity is situated underground.

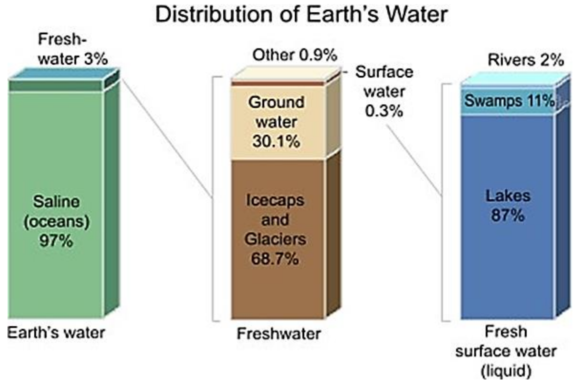

Figure 8 Distribution of Water

Case study and analysis

Water management is very critical for the growth and development of any economy, more so in a developing country like Pakistan which is endowed with many water resources that need to be conserved, better managed, recharged and channelized for meeting the ever increasing requirements of present trend of urban growth of Pakistan which is one of the highest in South Asia region. Groundwater is a reliable resource for drinking and production both in terms of quantity and quality.

However, the resource is now under severe stress in Pakistan, because of the excessive groundwater abstraction in the course of socioeconomic development. The consequences of these over exploitation of groundwater are either irreversible in nature or require extended periods to abate. Therefore, it's a need to consider how to conserve this precious resource while taking full advantage of it for the development purposes.

Study Area

Faisalabad is the third largest city of Pakistan with approximately a population of about 3.2 million. It is centrally located on the flat alluvial plain of Punjab Province, shown in figure 9 The river Chenab is located about 30 km to North West and the river Ravi about 40 km to South East. In 1900, the city was established as Agricultural Market Town and was an attraction to the agricultural business from the surrounding area.

In more recent years, the industrial activities have been developed, in particular agro based production i.e. mostly cotton etc. The city is suffering from the crisis of mixed development pattern. As a result of lack of planning, city contains agricultural lands and livestock farms within the residential colonies.

The jurisdictions of FDA city along with the area of Faisalabad city where services are provided by WASA are shown in Figure. Further a GIS image is also being used for the location of infrastructure.

Figure 9 Location of Faisalabad in Pakistan

Temperature

Average daily temperature varies between 19-41°C, whereas the maximum daily temperature varies from 4 to 28 degree Celsius. The maximum and minimum temperatures ever recorded in Faisalabad are 48 and -4°C respectively. These calculations are based on average values taken from the 38-year record. As shown in Table 1.

Rainfall

The annual rainfall varies between 198mm & 615mm. The heaviest average daily rainfall recorded is 264mm. The total monthly rainfall data based for the last 40 years is shown in table 1.

Evaporation

The monthly pan evaporation varies from 46mm to 293mm. As humidity increases, in August, the evaporation rate declines rapidly. The evaporation records for the last 40 years, on monthly basis, are shown in the Table 1.

Wind

4Average wind velocities vary from 2 to 7 knots (1-3.6m/s) with highest daily records prior to Monsoon (June-July) period. The prominent wind direction during the summer month is from South to South east and during winter from North to North West. The velocities are generally moderate and rarely exceed 5.1 m/s.

Table 1 Table mentioning the monthly variation of temperature, rainfall and evaporation characteristics of Faisalabad City

Month	Max. Temp (°C)	Min. Temp (°C)	Rainfall (mm/m)	Evaporation (mm/m)
January	19.4	4.2	13.2	46.6
February	22.3	7.2	17.7	57.8
March	27.9	12.5	25	112.4
April	33.4	18.1	18.2	189.4
May	38.4	22.9	15.4	293.3
June	40.7	27.1	24.6	285.5
July	37.2	27.5	109.6	264.6
August	36.2	26.7	89.5	215.2
September	35.8	23.9	34.1	196
October	33.2	17.4	5.9	149.3
November	27.6	10.3	3.6	94.1
December	21.7	5.4	9.1	48.1
Mean	31.1	16.9	365.9	1952.3

Water Supply and Distribution

Water Sources

4Soil investigation at certain areas, other than Canal, shows that the alluvial aquifer underlying the Faisalabad area is stratified and non-uniform. Groundwater levels are currently between 25-30 meters. In the past, the depth of ground water tables was observed at 16-19 meters below surface. The sources of groundwater recharge are rainfalls, rivers and irrigation canals. Tests also revealed that a highly mineralized, brackish groundwater plume exists between two canals i.e. Rakh and JhungChanab with TDS values of more than 3500 mg/l. theses canals effectively form hydro geological barriers preventing subterranean flow between the two groundwater divides. This has a corresponding effect on the water quality.

Due to saltish taste of groundwater, the treated water is supplied from the canals in limited quantities. Therefore, in order to provide the drinking water to the city of Faisalabad, sources of bulk water supply are the Chenab Well Field and the tube wells along the Rakh Branch canal.

Water Supply Coverage

WASA has estimated the water demand of 410,000 m3/day till the end of 2018. But unfortunately the system available for the water supply is only 325,000 m3/day. The WASA official's claim that a recent consumer survey indicated 45-48 % coverage for water services. These values are well below the previous estimates and lies in the range of 60 %. The present network cannot sustain adequate pressures as well in the distribution system. It is expected that the effective demand and the number of connections will grow as WASA has now commissioned the improved bulk supply. However, the distribution network also needs to be improved. WASA has recently completed three projects as JICA projects, in collaboration with Japan, to meet the water supply requirements of the city.

Table 2 Existing Drains in Zone no. 1 Faisalabad

Channel No.	Location	Length (KM)	Drainage area (ha)
1	Western Zone: Nishatabad- Agricultural Uni.- G.M.Abad-Paharang Drain	10.0	5,070
2	Western Zone: City Center- Model Town-Channel No. 1	4.2	160
3	Western Zone: Jhang Road- Faujianwala- Paharang Drain	6.2	840
4	Eastern Zone: Abdullah pur- Jaranwala Road - Qasim Shah Chowk – Madhuana Drain	10.0	2,270
4D	Eastern Zone: D-Type &Allama Iqbal Colony-Barkatpura	7.8	780
5D	Eastern Zone: Jaranwala Road- Mansoorabad	7.0	390

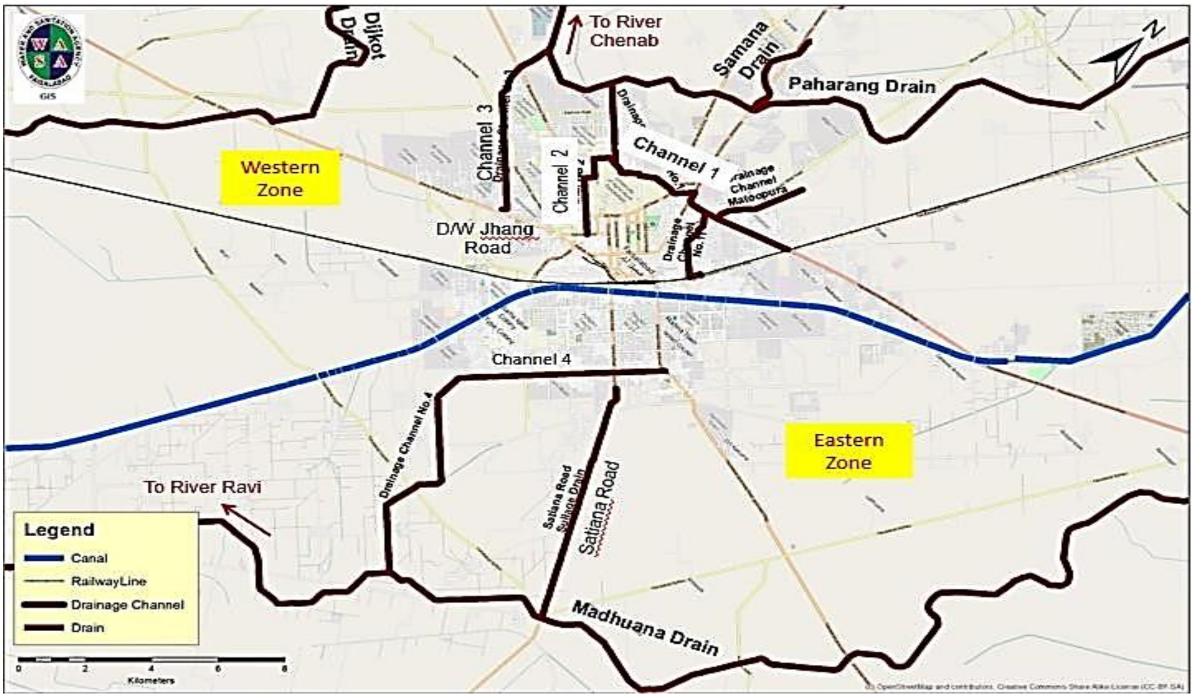

Figure 10 Major Drains of Faisalabad

These drains were used to carry the storm water. Their further plan was to use this water for either storage or supply it after treatment. But due to lack of funds this could not be executed. Moreover, in riots during 1996 most of the data was burnt in the fire and thus WASA was left with some files and limited records.

Now these drains were partially used and they are mixed with sewage line. Hence all the storm water is wasted along with the sewage water. And no further studies or implementation about the groundwater was made due to negligence of the authorities and their financial crisis.

Current Situation

In order to implement the whole master plan developed by NESPAK 1992-93, the whole development phase was segregated in 4 phases. But due to lack of funds, this could not be done. The phase 1 planning was ended in 1997. The phase 2 is in execution now a day. In such scenario it is clear that the reports parameters have not been followed in terms of execution. Therefore, the actual site situation has been changed as it was considered in the master planning. As a result, the present situation has reached a crucial stage. With no proper drainage system, the rain water drain out without any use. Hence due to improper drainage system rain water cannot be harvested properly for groundwater recharge with its full potential.

Thus water table is decreasing day by day and this situation is becoming more critical every year due the lack of attention and problems magnifies day by day.

The exploitation groundwater is significant adverse impact of improper groundwater management system in the city which require urgent plan in order to control and solve these problems.

Groundwater Condition of Faisalabad

Groundwater has now become a major natural resource contributing the water supply system in Faisalabad city. Usually groundwater gets recharged during rainfall period. Due to urbanization, surface infiltration has been vastly reduced while consumption of groundwater is ever rising. In addition, the over exploitation through excessive abstraction of groundwater (both shallow and deep) resource exceeding its replenishment capacity in the course of socioeconomic development has resulted to experience severe water stress in the region.

Faisalabad has a large number of textile and dying mills, where generally weaving, dying, printing and finishing of cloth is carried out. These operations usually produce intensely alkaline liquor high in dissolved materials and suspended soil. In the absence of adequate treatment facilities and effective drainage system, bulk of the effluent from these industrial units flow into open land and low lying areas with consequential severe damage to groundwater.

The groundwater here is mostly brackish due to no major water body is present in the near vicinity. Further the remaining potable water is polluted due to the sewage mixing in it. Sewage from the existing systems is discharged untreated into Maduana drain and treated or untreated in Pharang drain in the East and West respectively. It tremendously effect the ground water resources of that residential area. The wastewater is highly viscous with high- suspended solids and total dissolved solids. The groundwater contamination predicted for Faisalabad is shown in figure 11.

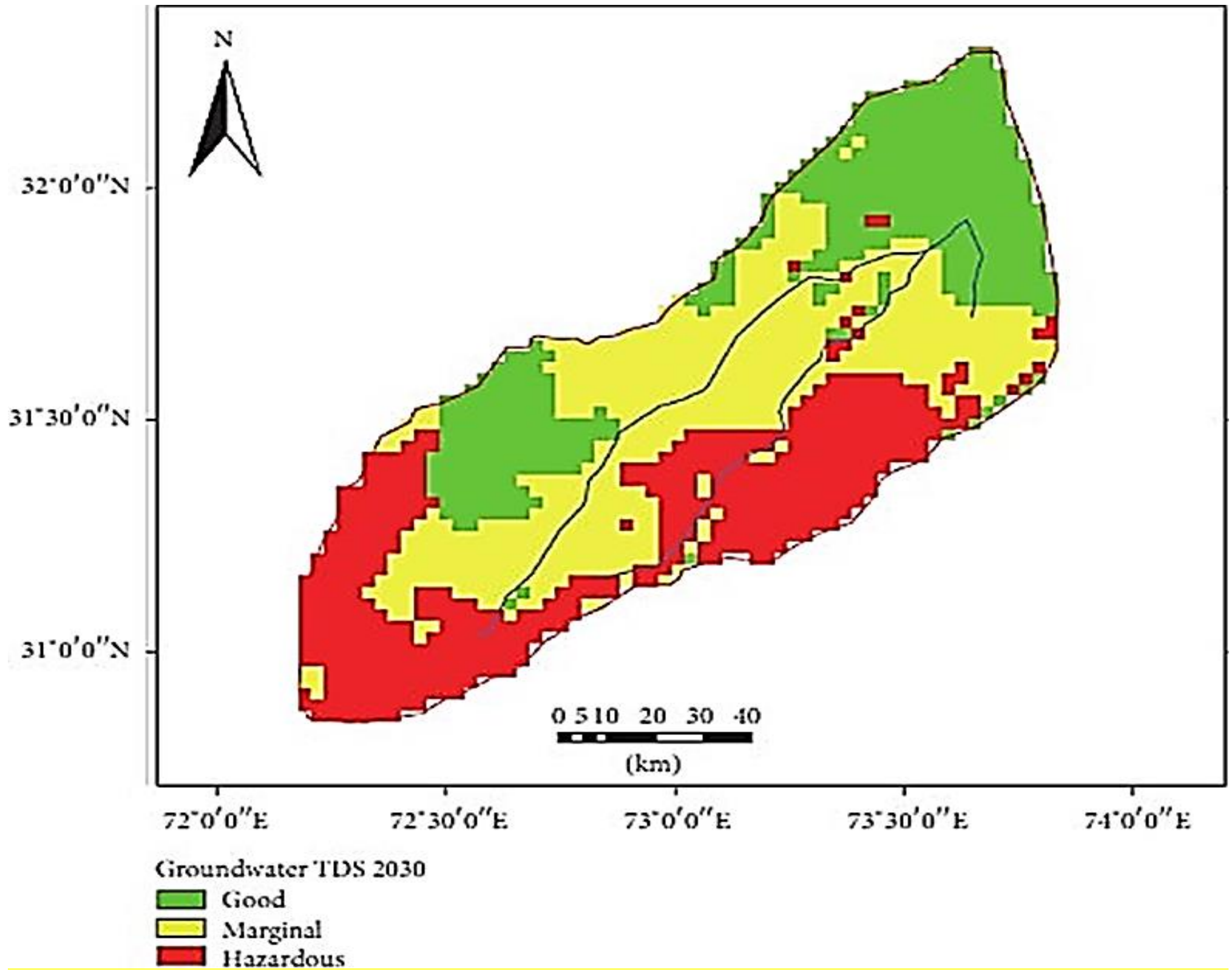

Figure 11 Groundwater Contamination Predicted in 2030

Despite of the pollution, the groundwater is still used for many purposes other than drinking. The main supply for drinking is taken from the nearby canal by pumping out of groundwater. So, the levels of water table are continuously decreasing.

The groundwater level was 30-35 ft. which due to exploitation has decreased to 80-90 ft. in some areas. Thus its rapidly decreased levels have a great negative impact on the surrounding and the people. Therefore, pollution of water resources needs a serious and immediate attention through periodical checkup of water quality. However due to rapidly increasing population the demand for fresh water is also increases every year. So, different methods are suggested at suitable sites to be practiced in order to meet the demands and quality of groundwater.

Rainfall Available Data

Initially, the available rainfall data for Faisalabad was limited to daily rainfall observations at Agricultural University and hourly rainfalls at the Meteorological Department Lahore. But the rainfall intensities are not obtainable. The recording rain gauges are installed at the Ayub Center, operated by Metrology Department. But currently this data is not obtainable as equipment present there is not functional and the up to date work is not obtainable. The daily Monsoon Rainfall data is available in WASA and is shown in table 3.

Table 3 Rainfall Data of Monsoon

Date	Precipitation (mm)	Date	Precipitation (mm)	Date	Precipitation (mm)
10.06.2016	01 mm	11-06-2017	18.8 mm	17-06-2018	25.0 mm
22.06.2016	15.5 mm	21-06-2017	39.0 mm	20-06-2018	03.0 mm
27.06.2016	23.4 mm	06-07-2017	27.0 mm	22-06-2018	02.0 mm
03.07.2016	0.5 mm	12-07-2017	75.0 mm	23-06-2018	15.0 mm
06.07.2016	0.6 mm	05-07-2017	16.0 mm	17-06-2018	18.0 mm
07.07.2016	25.5 mm	20-07-2017	1.0 mm	30-06-2018	32.0 mm
09.07.2016	22.2 mm	28-07-2017	60.0 mm		
18.07.2016	24.8 mm	31-07-2017	11.0 mm		
23.07.2016	40 mm	01-08-2017	37.0 mm		
26.07.2016	06 mm				
27.07.2016	0.2 mm				
28.07.2016	81 mm				
08.08.2016	10 mm				
10.08.2016	62 mm				

Groundwater Available Data

The groundwater recharge in Faisalabad city is not practiced due to the negligence of the authorities. Up till now WASA has done nothing about the groundwater recharge. There is no available data or literature regarding the groundwater situation and its preservation.

They have installed about 25 tube wells at the Jhang Barrage Canal (JBC) under the JICA Project in collaboration with Japan. Their groundwater level data is available and is shown in the table 4.

Table 4 Water level at JBC Tube Wells (2018)

Tube well No.	Water level (ft.)
1	21.64
2	22.79
3	22.73
4	25.91
5	24.04
6	21.48
7	20.40
8	23.48
9	26.56
10	26.56
11	23.41
12	23.48
13	24.27
14	25.97
15	26.04
16	25.71
17	--
18	28.04
19	28.53
20	28.66
21	29.42
22	29.84
23	34.89
24	34.70
25	35.98

Selected Study Area

In order to resolve the problem of the groundwater, the Western zone is selected. This is because it is the most developed area with least storm drainage control and it's the area where the after effects of spilled storm water are seen rather magnified at road edges and this rainwater is drain out without any use.

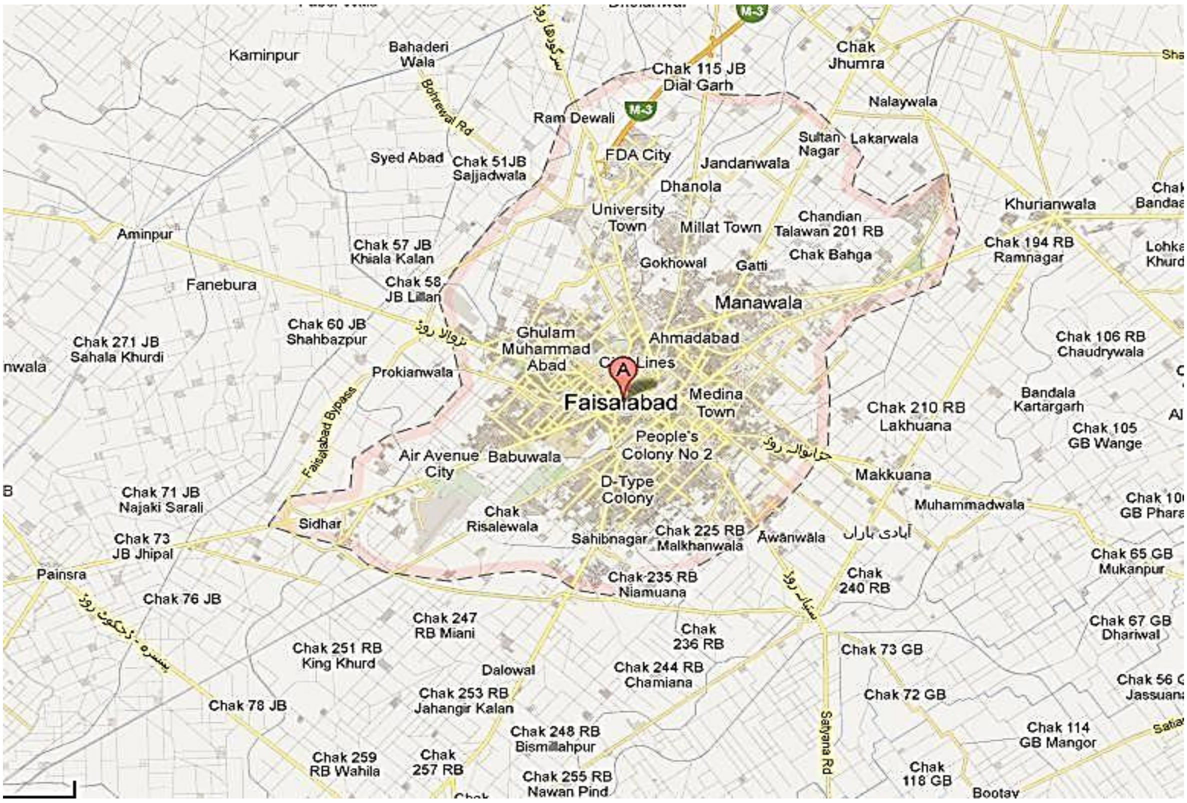

Figure 12 Study Area (Faisalabad City

Conclusion and Future work

The whole city is planned twice and infrastructure is planned by using best available resources but till date no major implementation has been done.

The groundwater level in the Faisalabad city is continuously decreasing at an alarming rate of about 3.3 ft. per year in some areas.

The quality of groundwater is also not suitable for drinking as it contains huge amount of TDS (Total dissolved solids).

to the controlling of drainage and sewerage at a same time and on the same route is creating a problem in the main city area. Thus resulting in the wastage of rain water which otherwise can be used as groundwater recharge.

The authorities dealing with water and sanitation for example WASA is not paying attention regarding the groundwater condition.

There is no groundwater preservation or management system in the Faisalabad city.

The green areas and open lands are in poor condition regarding holding of the water. Water remain stagnant for more than 72 hours as in our environment after such a long time the flies and mosquitoes starts to breed on that water.

The problem of lower water table is countered by considering groundwater recharge in the design of storm water network.

Not even a single project regarding groundwater recharge is running in the Faisalabad city.

Due to unplanned urbanization, the recharge area or open spaces in the city is getting reduced considerably and most of the rain that falls are drain out unused.

Due to the negligence the condition of groundwater is getting worse each year.

Recommendations

1. Rain water drains along the roads should be cleaned and maintained. To carry the rain water properly.
2. The rain water collected from the drains should be used as groundwater recharge or used for drinking after some treatment.
3. Parks and green belts should be used as groundwater recharge sites. Proper slopes should be given to them so that rain water does not become stagnant.
4. WASA should carry out a proper plan for the groundwater recharge.
5. Groundwater monitoring should be done on regular basis.
6. More funds should be allocated for the groundwater recharge and its preservation.
7. Rain water harvesting should be encouraged as it is best available source and can be easily utilized for recharging.
8. Provision of rain water harvesting in the design of roof tops should be provided by the WASA and FDA.
9. In all the developing colonies it should be made obligatory to develop storage tanks for the

collection of rain water. Then this rain water could be utilized for gardening, household use and groundwater recharge.

10. All the government buildings (offices, hospitals, schools, colleges etc.) should be used to collect rain water. Then proper bore system should be made to use this rain water to recharge the underground aquifers.
11. FDA should encourage the vertical growth so that more and more space can be utilized for the groundwater recharge. Constructed wetlands, wet ponds and many other storage facilities will not only increase the groundwater recharging but at the same time such open spaces can be utilized as recreational spots, walkways and children's play areas.
12. Public awareness and educational programs regarding groundwater importance should be done on large scale. So that literacy can help in having a precaution than more physical amendments. Usage of rain water as a groundwater recharge should be told to a common man and in this whole program electronic media can play a vital role.

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