Journal of Himalayan Earth Sciences 46(2) (2013) 113-119

Estimation of groundwater balance for the Pabbi region, Khyber Pakhtunkhwa

Tabinda Masud[1], Amjad Ali[1], Hazrat Hussain[2], Khan Shahzada[1], Bashir Alam[1], Noreema Masud[3] and Muhammad Rizwan[1]
[1]Faculty member, Department of Civil Engineering, UET, Peshawar
[2]Principal, Government Advance Technical Training Centre, Hayatabad, Peshawar
[3]Faculty member, Department of Civil Engineering, CECOS University of IT & Emerging Sciences, Peshawar

Abstract

This paper presents the study carried out to estimate groundwater balance for the Pabbi Region, Khyber Pakhtunkhwa. Due to heavy rainfall, excessive irrigation and seepage from irrigation canals, the adjacent areas of Kabul River in the study area have suffered from water logging for a long time. It has been calculated that the recharge to groundwater storage due to seepage from canals and their distributaries flowing in the Pabbi Region is 26 mm/year. According to the data collected from Pakistan Meteorological Department, Peshawar, mean annual rainfall of Pabbi Region is 262.77 mm/year and recharge due to rainfall is calculated as 60.63 mm/year. Discharge through tube wells and hand pumps in the area are estimated as 35 mm/year and 14 mm/year respectively. It has been concluded that the average increase in groundwater level in the study area is 37.63 mm/year.

Keywords: Pabbi; Pakistan; Groundwater balance; Rainfall; Discharge and water logging.

1. Introduction

Total area of Pabbi region is 427.5 km^2. Its geographical coordinates are 34°00′38″ N and 71°47′56″ E. It is bounded by Kabul River in the north, Bara River in the west, Cherat Mountains in the south and Nowshera City in the east. The study area (Fig. 1) has ten union councils: Pabbi, Khashor Garhi, Dak Behsaal, Jallozai, Dak Ismail Khel, Spin Khak, Shah Kot, Chowk Mumraiz, Taru and Dagi.

Recharge to the groundwater storage in the area under study mainly takes place due to precipitation and seepage from canals. According to Irrigation Department, Peshawar, depth of water table from the ground surface of study area varies from 3.05 m (10 ft) in Pabbi to 18.29 m (60 ft) in Jaroba.

The canals and distributaries flowing in the study region (Fig. 2) are: Warsak Gravity Canal, Warsak Lift Canal, Kabul River Canal and Hazar Khani Canal. The level of water table in Mardan, Nowshera, Pabbi, Swabi and areas in the vicinity of Kabul River in Khyber Pakhtunkhwa was about 21.34-24.39 m (70-80 ft) below the ground level at the time of establishing irrigation system. By 1925 water table came up to 12.20 m (40 ft) and in 1940 up to 7.62 m (25 ft) below ground level. In 1960 it reached 3.05-3.66 m (10-12 ft) and finally in 1970 it reached as close as 0.61-0.91 m (2-3 ft) of the ground level and even touched the ground surface in rainy season. A decrease by more than 50% in the yield has also been recorded in this connection. It was not before 1980 that the problem was diagnosed and remedies started. Water and Power Development Authority (WAPDA) used a number of techniques for reducing the level of water table. These techniques included construction of surface drains, installation of tube wells and construction of subsurface tile drains (Javed and Nasim, 2005).

In order to fulfill the desired demand of water for increasing population (annual growth rate of 2.9%) of the study area, some more tube wells were installed by Irrigation Department Peshawar, Public Health Engineering Department Pabbi and Tehsil Municipal Administration Pabbi with the passage of time. Residents of the study area have installed hand pumps in their homes to discharge groundwater for their domestic use. It is an exigency of the time to evaluate the present situation of groundwater balance in the area under study and to take the remedial measures in case of the risk of water logging.

2. Methodology

This study is carried out to estimate the current situation of groundwater balance for the Pabbi region for which recharge to and the discharge from groundwater has been found.

2.1. Recharge to the groundwater

Seepage from canals, infiltration due to precipitation, water applied for irrigation and water stored in depression storages play an important role in increasing groundwater level. In this study, the first two factors, being mainly responsible for recharging groundwater of the project area are considered.

Nazir formula (Ahmad et al., 2007) is used to measure seepage from canals and is given as:

$$S = \frac{0.04Q^{0.68}}{1.61}$$

where, S = seepage loss (ft^3/sec per km of canal) and Q = channel discharge (ft^3/sec).

Infiltration due to precipitation is found by taking a difference of precipitation and surface run off. SCS Curve Number Method (Das, 2000) is used to find surface run off and is given as:

$$Q = [P - 0.2S_M]^2 / [P + 0.8S_M]$$

where, Q = surface run off (mm), P = average rainfall (mm), and S_M = soil moisture capacity.

$$S_M = 254 * \left[\frac{100}{CN} - 1\right]$$

where, CN = Curve Number

The curve number for a particular soil depends upon the characteristic of basin and soil moisture condition at the time of occurrence of rainfall.

The weighted curve number is the average curve number representing different land use conditions of the area which are classified by hydrological soil groups (Table 1).

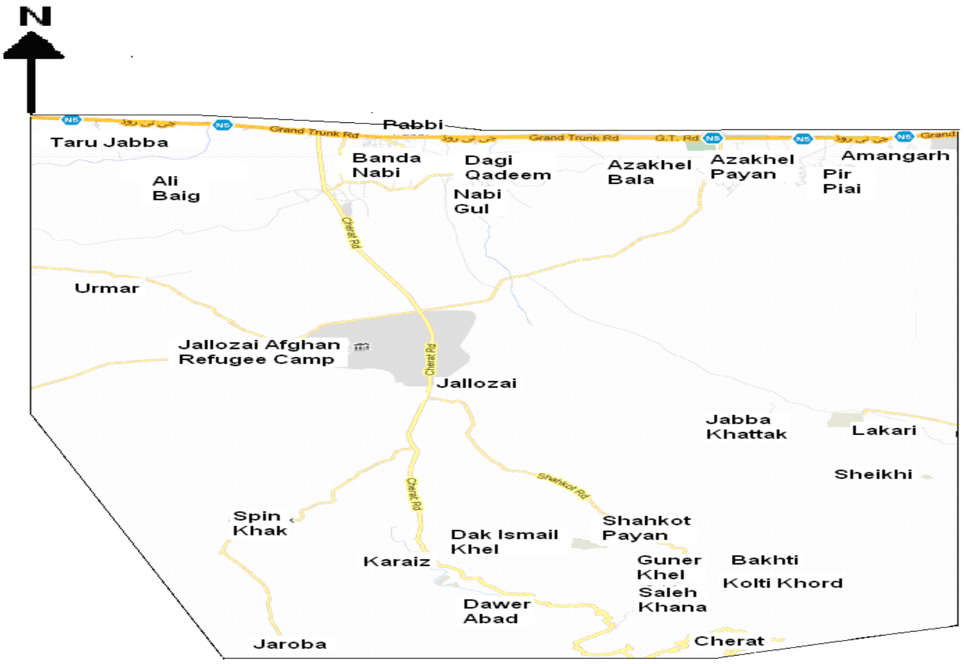

Fig. 1. Site map of the study area. (Source: Google Earth. Not to scale)

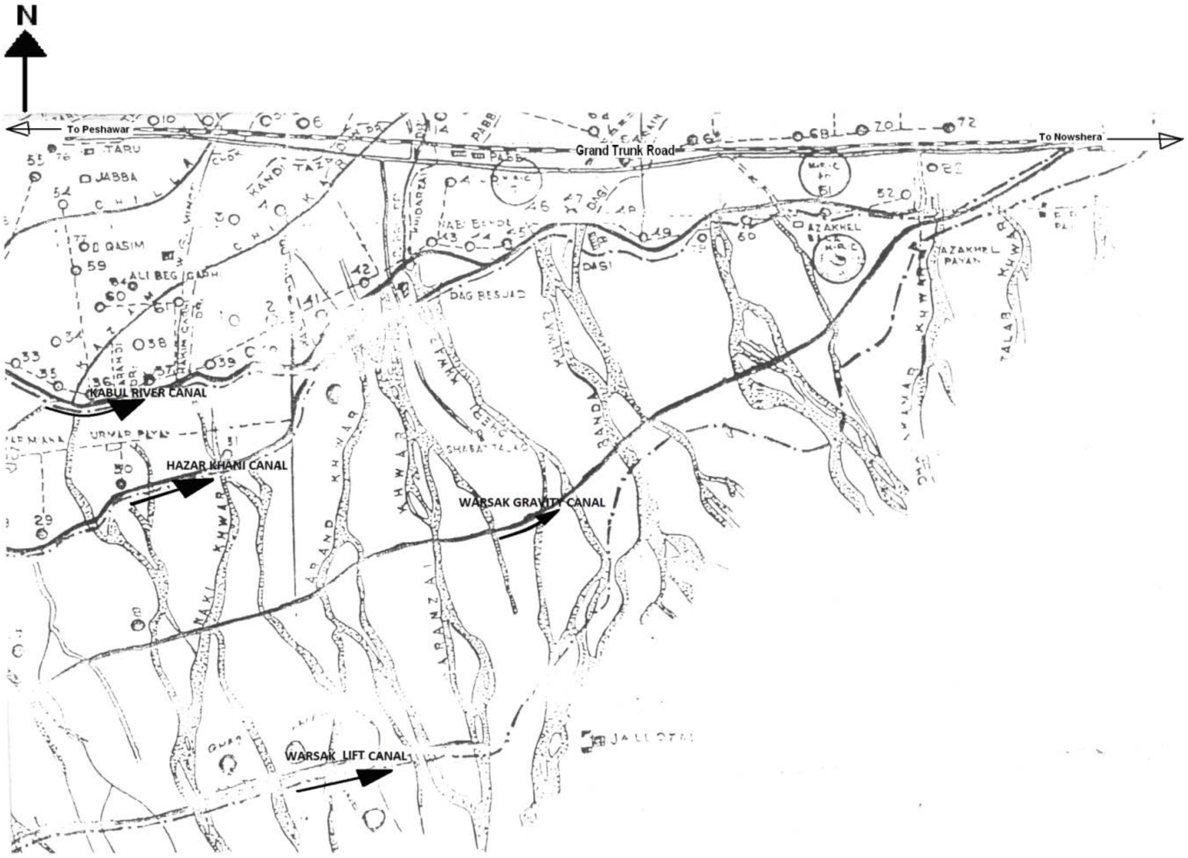

Fig. 2. Map of canals in the study area.
(Source: Water and Power Development Authority (WAPDA). Not to scale)

Table 1. Hydrological soil groups

S. No.	Soil Group	Type of Soil	Run off Potential
1	A	sand, loamy sand or sandy loam	Low
2	B	silt loam or loam	Moderate
3	C	sandy clay loam	High
4	D	clay loam, silty clay loam, sandy clay, silty clay or clay	Very High

2.2. Discharge from groundwater

Tube wells, dug wells, hand pumps, sub-surface drains and evapotranspiration are responsible for decreasing groundwater level. The factors considered in this study are tube wells and hand pumps.

Data of tube wells discharge is collected from Tehsil Municipal Administration Pabbi, Public Health Engineering Department Pabbi and Irrigation Department Peshawar. To calculate the amount of water withdrawn through hand pumps, a survey of all union councils is conducted i.e. five houses of each union council are visited. Number of people in these houses is counted and discharge through hand pumps is found by measuring the period of time required to fill a container of known volume.

3. Results and discussion

3.1. Recharge to groundwater

Seepage loss through canals and part of precipitation, infiltrated into the soil, play an important role in increasing groundwater level of the Pabbi region.

3.1.1 . Seepage from canals

Warsak Lift Canal and the distributary of Kabul River Canal i.e. Hazar Khani Canal, passing through the study area, are lined with cement concrete. Since seepage losses through lined canals are very small, therefore, recharge due to seepage through these canals has been neglected.

Seepage loss through the other two canals i.e. Warsak Gravity Canal and Kabul River Canal, passing through the study area, has been found as 0.36 m^3/s by Nazir formula (Tables 2 and 3). There is no lined section of Kabul River Canal flowing in the study area; however, seepage loss through the lined sections of Warsak Gravity Canal, being very small, is considered as negligible.

Dividing the seepage loss (0.36 m^3/s) by total area (427.50 km^2), increase in groundwater recharge is found as 8.42 * 10^{-10} m/sec. Thus, the groundwater level of the Pabbi region is increased by 26 mm per year.

Table 2. Measurement of seepage loss through Warsak gravity canal

RD-RD	**Length,** *L* **(km)**	***E/L**	**Discharge,** *Q* **(ft^3/sec)**	**Seepage Loss per km of length** $S = \frac{0.04Q^{0.68}}{1.61}$ **(ft^3/sec / km)**	**Seepage Loss =** *SL* : **(m^3/s)**
145+900–147+700	0.55	E	50.52	0.36	0.006
147+700–150+400	0.82	E	47.69	0.34	0.008
150+400–152+600	0.67	E	38.78	0.30	0.006
152+600–155+600	0.92	E	36.00	0.28	0.007
155+600–159+300	1.13	E	36.00	0.28	0.009
159+300–161+400	0.64	E	27.47	0.24	0.004
161+400–162+900	0.46	E	25.01	0.22	0.003
162+900–168+900	1.83	E	20.86	0.20	0.010
168+900–169+900	0.31	E	16.87	0.17	0.001
169+900–170+900	0.31	L	---	0	0
170+900–171+900	0.31	E	14.52	0.15	0.001
171+900–174+900	0.92	L	---	0	0
174+900–175+900	0.31	L	---	0	0
175+900–178+900	0.92	L	---	0	0
178+900–183+400	1.37	E	11.11	0.13	0.005
183+400–186+300	0.88	L	---	0	0
186+300–186+900	0.18	E	10.00	0.12	0.001
				Total seepage =	**0.061**

* E = Earthen (unlined) section of a canal
L = Lined section of a canal

Table 3. Measurement of seepage loss through Kabul River Canal.

RD-RD	**Length,** *L* **(km)**	***E/L**	**Discharge,** *Q* **(ft^3/sec)**	**Seepage loss per canal km** $S = \frac{0.04Q^{0.68}}{1.61}$ **(ft^3/sec / km)**	**Seepage Loss =** *SL* : **(m^3/s)**
43+200–49+204	1.83	E	281	1.15	0.06
49+204–56+194	2.13	E	281	1.15	0.07
56+194–61+181	1.52	E	281	1.15	0.05
61+181–66+168	1.52	E	281	1.15	0.05
66+168–71+155	1.52	E	281	1.15	0.05
71+155–7 2+155	0.31	E	281	1.15	0.01
				Total seepage =	**0.30**

* E = Earthen (unlined) section of a canal
L = Lined section of a canal

3.1.2. Infiltration due to precipitation

Recharge due to precipitation can be simply calculated by excluding surface run off from precipitation.

Rainfall gauges in the study area are installed at Dagbesud, Pabbi and Warsak Gravity Canal. The rainfall data of these stations for nine years i.e. 1998-2006 is shown in Table 4. Mean annual rainfall is found as 262.77 mm/year.

In order to measure surface run off by SCS Curve Number Method, precipitation and weighted curve number (CN) are mainly required.

To find CN, the study area is divided into different land use patterns i.e. roads, uncultivated area and cultivated area. These land use patterns are further divided into different hydrological soil groups. Roads (0.67 km^2) come under soil group B (0.10 km^2) and C (0.57 km^2), uncultivated area (295.79 km^2) comes under soil group A (68.18 km^2), B (48.43 km^2), C (166.18 km^2) and D (13.00 km^2) while cultivated area (131.04 km^2) comes under soil group A (90.33 km^2) and B (40.72 km^2).

Using Tables 5 and 6 for average condition of the soil of the Pabbi region, weighted curve number (CN) is calculated as 80.83. On the basis of CN, soil moisture capacity (S_M) and surface run off (Q) are calculated as 60.25 mm and 202.14 mm. Thus, recharge to groundwater due to precipitation is 60.63 mm/year.

Table 4. Rainfall data.

Years	Rainfall at DagBesud (mm)	Rainfall at Pabbi (mm)	Rainfall at Warsak Gravity Canal (mm)	Mean Annual Rainfall (mm)
1998	470.92	515.87	625.93	537.57
1999	694.69	*NA	247.65	314.12
2000	135.13	*NA	123.19	86.11
2001	105.26	96.22	119.48	106.98
2002	77.55	195.94	26.04	99.85
2003	229.57	174.47	*NA	134.67
2004	305.28	219.91	*NA	175.06
2005	608.33	358.60	407.92	458.29
2006	889.00	94.16	373.63	452.27
			Total Mean Rainfall =	**2364.92**

***Data is not available**

Table 5. Seasonal rainfall limits for antecedent moisture condition (AMC) classes (USSCS, 1964).

AMC Classes	**5-Day Total Antecedent Rainfall (cm)**	
	Dormant Season	**Growing Season**
I (Dry condition of soil)	< 1.25	< 3.5
II (Average condition of soil)	1.25-2.75	3.5-5.25
III (Wet condition of soil)	> 2.75	> 5.25

Table 6. Curve numbers for hydrologic cover complexes for AMC-II (USSCS, 1964).

Land Use Cover	**Treatment**	**Hydrologic Condition**	**Hydrologic Soil Group**			
			A	**B**	**C**	**D**
Row Crops	Straight Row	Good	67	78	85	89
Roads, hard surfaces	………………	……………	74	84	90	92

3.1.3. Total recharge to groundwater

Total recharge to groundwater due to seepage loss through canals (26 mm/year) and infiltration due to precipitation (60.63 mm/year) is, thus, found as 86.63 mm/year.

3.2. Discharge from groundwater

Tube wells and hand pumps are the main sources of decreasing groundwater level of the Pabbi region.

3.2.1. Discharge through tube wells

According to the data collected from concerned departments, total discharge through tube wells, installed in the Pabbi region is 0.94 m^3/s. Dividing the discharge (0.94 m^3/s) by total area (427.50 km^2), decrease in groundwater level is found as $2.20*10^{-9}$ m/s. For daily 12 hours combined operation of Public Health and Irrigation tube wells, this decrease in the depth of groundwater is calculated as 35 mm/year.

3.2.2. Discharge through hand pumps

According to the local people, 30% people of each union council have their own hand pumps. On the basis of data collected by general survey of each union council of the Pabbi region (Table 7), decrease in groundwater level due to hand pumps is 14 mm/year.

3.2.3. Total discharge from groundwater

Total discharge from groundwater due to tube wells (35 mm/year) and hand pumps (14 mm/year) is, thus, found as 49 mm/year.

3.3. Result

In this study groundwater recharge (86.63 mm/year) is found to be greater than groundwater discharge (49 mm/year), thus, 37.63 mm of groundwater level is increased per year in the Pabbi region.

Table 7. Discharge data of hand pumps.

Name of Union Council	**No. of people in 5 houses,** Error! Bookmark not defined. p	**Discharge of 5 houses,** Q **(10^6 mm^3/s)**	**Per Capita Demand ,** $D = \frac{Q}{P}$ **(10^6 mm^3/s)**	**Total Population,** P	**Total Water Consumption** $= 30\%PD$ **(10^6 mm^3/s)**
Pabbi	60	1.30	0.02	37,307	242.50
Khashor Garhi	50	1.45	0.03	27,855	242.34
Dak Behsaal	48	1.40	0.03	26,300	230.13
Jallozai	65	1.51	0.02	64,428	449.01
Dak Ismail Khel	52	1.49	0.03	27,700	238.11
Spin Khak	53	1.32	0.03	19,000	141.96
Shah Kot	56	1.46	0.03	2,986	23.36
Chowk Mumraiz	59	1.41	0.02	24,658	176.79
Taru	54	1.47	0.03	45,000	367.50
Dagi	55	1.50	0.03	27,528	225.23

4. Conclusions

Since, according to Irrigation Department Peshawar, average depth of water table from ground surface in the area under study is 10.67 m and the annual increase in groundwater level, according to this study, is very small i.e. 37.63 mm; the study area is, therefore, out of the risk of water logging (Joint completion report, 2002).

Precipitation plays a major role in increasing groundwater level of the study area. Infiltration due to precipitation has been found to be greater (60.63 mm/year) in this study as compared to seepage from canals (26 mm/year).

It is also found in this study that contribution of Kabul River Canal, flowing through the study area, in recharging the groundwater is more (0.30 m^3/s) as compared to that of Warsak Gravity Canal (0.06 m^3/s).

Acknowledgements

With profound gratitude and deep sense of devotion and obligation, the authors wish to recognize the help of Engr. Riaz Ahmad Khan, Chief Engineer, Irrigation Department, Peshawar, Engr. Zargul Khan, Sub-divisional Officer, Irrigation Department, Peshawar, Engr. Naseem Golra, Director Divisional Office, Irrigation Department, Peshawar, and Engr. Owais Islam, Assistant Engineer, Provincial Inspection Team, Khyber Pakhtunkhwa in data collection for this research work. The authors are grateful to the reviewers for their precious suggestions and comments, which have enhanced the quality of the paper.

References

Ahmad, S.J., Mohyuddin, Siddiqui, S.M., Bhutta, M. N., 2007. Tree Plantation for Intercepting Canal Seepage and Controlling Water Table, Pakistan Journal of Water Resources, 11, 35-42.

Das., 2000. Hydrology & soil conservation engineering. Prentice hall of India Private Limited, New Delhi, 70-76.

Javed, F., Nasim, M.A., 2005. Effect of increased soil permeability with passage of time on the spacing of perforated pvc drains. The Electronic Journal of Geotechnical Engineering, 10.

Joint completion report, 2002. A Methodology for Identification of Water logging and Soil Salinity Conditions Using Remote Sensing, Central Soil Salinity Research Institute, Karnal (India) and Alterra- International Institute for Land Reclamation and Improvement, Wageningen (The Netherlands) Publishers, India.