# Characteristics of Groundwater Recharge in Small Watersheds in the Hilly Region of the Loess Plateau (Postprint)

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## Abstract

Groundwater recharge reflects the renewability of aquifers and is one of the key parameters for groundwater resource management and rational development and utilization. To quantitatively investigate the recharge characteristics of groundwater in small watersheds in the hilly and gully region of the Loess Plateau, this study estimated the groundwater recharge of the Chabagou watershed using recession curve analysis, based on precipitation and daily runoff observation data from three hydrological stations (upstream, midstream, and downstream) during 1959–1969, and analyzed its relationships with precipitation and baseflow as well as the intra-annual variation process of recharge. The results show that the mean annual baseflow of the Chabagou watershed is 13.09 $mm \cdot a^{-1}$, the residence time is 124 d, the recharge amount is 11.46 $mm \cdot a^{-1}$, the precipitation infiltration recharge rate is 0.025, and the baseflow recharge rate is 0.89. From upstream to downstream, both groundwater recharge and infiltration recharge rate increase gradually, with significant differences between upstream and downstream ($P<0.05$); the baseflow recharge rate decreases gradually, with significant differences among all sub-catchments. Groundwater recharge exhibits a linear positive correlation with precipitation ($R^2>0.40$), showing greater sensitivity to precipitation variation in the downstream catchment. Baseflow also shows a positive correlation with precipitation ($R^2>0.77$), with over 80% of the mainstream baseflow originating from precipitation recharge. With May as the dividing point, the groundwater recharge process can be divided into two main stages: "primary recharge" and "secondary recharge," which account for approximately 30% and 70% of the total annual recharge, respectively, and the "secondary recharge" is the main stage causing differences in groundwater recharge among different catchments in the Chabagou watershed. This study can provide a reference for evaluating groundwater resources in small watersheds in ungauged regions.

# Full Text

## Abstract

This study investigated groundwater recharge characteristics in the Chabagou Watershed of the Loess Plateau using daily precipitation and runoff data from three hydrological stations (upstream, midstream, and downstream) for the period 1959–1969. The recession curve method was employed to estimate groundwater recharge. Results showed that the average annual precipitation was 489.00 mm, with a runoff depth of 75.17 $m^3 \cdot s^{-1}$. Baseflow and the baseflow recharge index were 13.09 mm and 0.89, respectively. Groundwater recharge and the recharge index were 11.45 mm and 0.03, respectively, with a residence time of 124 days. Groundwater recharge increased significantly from upstream to downstream ($P < 0.05$), though no significant differences were observed between adjacent sections ($P > 0.05$). The baseflow recharge index decreased gradually downstream, with significant inter-catchment variation. Groundwater recharge exhibited a strong positive linear correlation with precipitation ($R^2 > 0.40$), with a Pearson correlation coefficient of 0.69. The downstream catchment showed the largest amplitude of recharge increase with precipitation. Baseflow also correlated positively with precipitation ($R^2 > 0.77$), with Pearson coefficients exceeding 0.80. More than 80% of mainstream baseflow originated from precipitation transformation. The recharge process in May comprised two distinct stages: "first recharge" and "second recharge." The supplementary amounts for each stage across catchments were: upstream (3.02, 5.58 mm) < midstream (3.76, 8.84 mm) < downstream (4.75, 11.54 mm), accounting for approximately 30% and 70% of annual total recharge, respectively. The "second recharge" stage represented the primary difference between catchments.

**Keywords:** Chabagou Watershed; catchment; baseflow; groundwater recharge

## 2 Methods

### 2.1 Data Collection

Meteorological and hydrological data were collected from three stations positioned in the upper, middle, and lower reaches of the Chabagou Watershed. The observation period spanned 1959–1969. Data quality control included homogeneity testing and outlier detection to ensure reliability for hydrological analysis.

### 2.2 Groundwater Recharge Calculation

The recession curve method was applied to separate baseflow and calculate groundwater recharge. Key parameters included the recession coefficient and baseflow recharge index. Statistical analyses comprised Pearson correlation analysis and significance testing ($\alpha = 0.05$). The method proved effective for watersheds with clear seasonal runoff patterns.

### 2.3 Recharge Process Analysis

The groundwater recharge process was characterized by two main stages occurring in May: the "first recharge" and "second recharge." The first recharge represented rapid infiltration following initial precipitation events, while the second recharge reflected sustained groundwater replenishment during the rainy season. Spatial analysis revealed increasing recharge amounts downstream, with the downstream section exhibiting the highest total recharge (15.15 $mm \cdot a^{-1}$) and recharge index (0.035).

### 2.4 Factor Influence Analysis

Precipitation intensity, slope gradient (15°–30° and 45°–65° categories), land use patterns, and soil properties significantly influenced recharge rates. Slope gradients of 15°–30° showed higher recharge efficiency (4.69 mm) compared to steeper slopes (1.70 mm). Land use analysis indicated that areas with vegetation cover >80% exhibited optimal recharge conditions, with a recharge coefficient of 0.84.

## 3 Discussion

The estimated groundwater recharge rate of 11.45 $mm \cdot a^{-1}$ aligns with regional studies in the Loess Plateau. Comparisons with SWAT model simulations from similar watersheds showed consistent patterns, though local topographic and soil characteristics created distinct spatial variations. The two-stage recharge process reflects the region' s precipitation regime and soil infiltration capacity. The dominance of the "second recharge" stage (70% of total) indicates that sustained seasonal precipitation is critical for groundwater replenishment. The strong correlation between baseflow and precipitation ($R^2 > 0.77$) confirms that precipitation is the primary source of baseflow generation.

## 4 Conclusion

Quantitative analysis of groundwater recharge in the Chabagou Watershed from 1959–1969 revealed significant spatial variation, with recharge increasing downstream. The recession curve method provided reliable estimates, showing strong correlations between recharge, precipitation, and baseflow. The two-stage recharge process, dominated by the "second recharge" stage, characterizes the watershed' s hydrological response. These findings provide a reference for groundwater resource evaluation in small, ungauged watersheds of the Loess Plateau.

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**Figure Captions**

Fig. 4 Relationship between precipitation and groundwater recharge
Fig. 5 Relationship between groundwater recharge and baseflow in Chabagou Watershed
Fig. 6 Annual distribution and proportion of groundwater recharge

*Note: Figure translations are in progress. See original paper for figures.*