Whole-process Risk Identification of Urban Rainwater Resource Utilization and Construction of Evaluation Index System in Loess Plateau Region

Li Qin¹, Chengxiang Ma¹* and Yunxiao Mu¹

¹ Gansu Academy for Water Conservancy, Lanzhou, Gansu, 730030, PR China
*Corresponding author’s e-mail: irrigation@126.com

Abstract. The whole process from the external environment of urban rainwater resource development and utilization, urban natural and social characteristics, engineering system, to engineering operations management, etc. was taken as the basic environment for the risk identification of urban rainwater resource utilization, and it was proposed that the urban rainwater resource utilization risk was the positive or negative effect generated by all uncertainties in the whole urban rainwater development and utilization process on the urban rainwater resource utilization goals; based on the risk identification environment and risk definition, the urban rainwater resource utilization risk was divided into social environmental risk, ecological environmental risk, water volume risk, water quality risk, and water price risk, and an list of evaluation indexes, which consisted of target layer, criterion layer and index layer, was comprehensively established for the urban rainwater resource utilization risk; according to the characteristics and current situation of typical urban rainwater resource utilization in Loess Plateau region, the principal component analysis (PCA) was used to screen out 14 evaluation indexes reflecting the urban rainwater resource utilization risks in Loess Plateau region, and an evaluation index system was further constructed, thus laying a foundation for the risk evaluation and control of urban rainwater resource utilization.

1. Introduction

With the continuous progress of industrialization and urbanization, the demand for water resources will present sustainable growth within a long time period, and impacted by the global climate changes, the imbalance between supply and demand of water resources will become more acute, especially the situation of water resources in Northern China will become severer [1], which has seriously restricted the sustainable socioeconomic development to a certain extent. Over 400 cities throughout China are in water shortage, and the number of cities of severe water shortage reaches 114, where the northern cities of water shortage account for 62% [2]. Under the background of the strictest national water resource management system, the available water supply added is limited, and it can be supplemented only by regulating the water utilization, saving the water, and increasing the unconventional water resources for the replacement [3]. Therefore, higher attention has been paid to the development and utilization of urban rainwater resources.

As a type of unconventional water resources, urban rainwater resources have been developed and utilized by a certain scale in cities in Loess Plateau region in recent years, especially since Qingyang City, Gansu Province, Guyuan City, Ningxia Autonomous Region, and Xining City, Qinghai Province, were included into the second batch of sponge city construction pilot project in 2016, the rainwater resource development and utilization-related plan has also been included into the general urban
development plan, the urban rainwater resource development and utilization ratio has been clarified, and a batch of urban rainwater resource utilization projects have been constructed. During the development and utilization process of urban rainwater resources, the risk sources are featured by high complexity, dynamic change and diversified types due to the unconventionality of urban rainwater resources. Therefore, studying the utilization risks of urban rainwater resources will be of great significance for facilitating the sustainable utilization of unconventional rainwater resources. The domestic (Chinese) and foreign studies regarding the utilization risks of urban rainwater resources have mainly concentrated on water quality, health, engineering construction and operations management [4-7], with the emphasis laid on the risks in a single link or aspect during the utilization process of urban rainwater resources. Hence, the risks were identified and an evaluation index system was constructed for the utilization risks of urban rainwater resources in Loess Plateau region from the angle of the whole process—external environment, development and utilization—influencing the urban rainwater resource utilization, expecting to provide a technical support for guaranteeing and improving the utilization amount and utilization efficiency of urban rainwater resources.

2. Method and Steps

2.1. Establishment of risk identification environment
On the precondition of ensuring the urban flood control safety and maintaining good hydrological and ecological environment, the available rainwater resources, which are acquired through the rainwater resource utilization engineering and can be included into urban water resources and uniformly configured, are increased to improve the water resource utilization efficiency, and this is called urban rainwater resource utilization. Urban rainwater resource utilization engineering refers to ancillary works such as sponge road, artificial lake, impounding reservoir, pond, and artificial water system built to support construction projects like city building and community, road, green space and plaza, and water system, which influence the rainwater system development, during the urban development process, and it is generally composed of current collection system, pipe network system, water quality pretreatment system, storage system, purification system, and utilization system. The risk identification is established based on the utilization environment of urban rainwater resources. The whole process, including the external environment for the urban rainwater resource development and utilization, urban natural and social characteristics, rainwater resource utilization engineering system, engineering operations management and user utilization, was taken as the basic environment for the risk identification of urban rainwater resource utilization.

2.2. Concept definition of urban rainwater resource utilization risk
Organizations of all types and scales are faced with internal and external factors and influences making them fail to determine whether and how their goals can be realized, and the influences of such uncertainties on the organizations’ goals are called risks [8]. In short, a risk refers to the influence of uncertainty on goals, and this definition points out three fundamental elements of risk, that is, goal, uncertainty, and their influence relation. On this basis, the urban rainwater resource utilization risk is the positive or negative influence of all uncertainties in the whole process of urban rainwater development and utilization on the urban rainwater resources utilization goals.

2.3. Risk identification and construction method and steps for evaluation index system
In this study, based on the established risk identification environment for urban rainwater resource utilization and the risk concept and by reference to the predecessors’ study results, related laws and regulations, and standards, an integrated and extensive list of risks based on potential risks or risk events, which may create, reinforce, impede, reduce, accelerate or delay the realization of rainwater resource development and utilization goals, was constructed, thus determining a relatively comprehensive list of urban rainwater resource utilization risk indexes. On basis of such list, an evaluation index system,
which could collectively reflect the rainwater resource utilization risk in Loess Plateau, was screened out via the principal component analysis (PCA) in consideration of various risk evaluation indexes.

The PCA method is a mathematical statistical method, which transforms many original variables into a few new variables by using the correlations between variables, and reserve the information reflected by the original variables. Its mathematical principle is as follow: Based on the concept of variance maximization, multiple variables with complicated relations are transformed into uncorrelated principal components with the dimensionality being smaller than the original variables via the eigenvector of correlation coefficient matrix, the dimensionality and load of each principal component are finally determined through eigenvalues, the related factor with the maximum absolute value of correlation coefficient is chosen to replace the original analyzed factor, so the multivariable problem is simplified. [9]. SPSS v26.0 statistical software of PCA method was adopted, and the analytical procedures were presented as follows:

1. The original index data was transformed to obtain the standardized data \( ZX_i \), where \( ZX_i = (X_i - X_i')/\sigma_i \), \( X_i' \) denotes the standard deviation, and \( i \) represents the index classification, \( i = 1, 2, \ldots, 22 \).

2. PCA test. Firstly, the correlations between variables were analyzed via the KMO test. When KMO was greater than 0.6, the variables showed favorable correlation; secondly, Bartlett sphericity test was performed, if the significance level of the test result was lower than 0.05, the data presented spherical distribution, the variables were mutually independent to a certain extent, so the PCA could be implemented.

3. The initial factors were solved for the correlation matrix of evaluation indexes using the PCA method, and the determinative factors of principal components were determined. When the determinative factors were extracted through the PCA method, eigenvalue (\( \lambda \)) >1.3 was taken as the criterion to extract the principal components by following the principle that the accumulative factor contribution rate explained by the total variance of common factor was greater than 70%. Meanwhile, the index would be deleted if the information projected by the variance explained of common factor on the index variable was all smaller than 0.7, or otherwise it would be reserved.

3. Risk Identification of Urban Rainwater Resource Utilization

From the whole process of urban rainwater resource development and utilization, the uncertainties influencing the development degree, utilization amount, and utilization efficiency of urban rainwater resources come from external environment such as policies and economic level, and the risks of this type are called external environmental risks, and on the other hand, they derive from the water volume, water quality and water price reflecting the unconventionality of rainwater resources, and the risks of this type become development and utilization risks, including water volume risk, water quality risk, and water price risk.

3.1. External environmental risk

The external environmental risks derive from the levels of social environment and ecological environment. Different risk sources influence the rainwater resource utilization goals independently or in a combined way. At the level of social environment, the uncertainty of laws and regulations will profoundly influence the general public to construct rainwater resource utilization projects and utilize rainwater resources, and the conditions, incentives and supporting policies for the general public to develop and utilize rainwater resources in different cities will have a direct bearing on the willingness or enthusiasm of the general public to develop or for developing rainwater resources; the uncertainties of economic development level directly affect the social public, especially the governmental input into the urban rainwater resource development; the uncertain degree of recognition among the social public for rainwater resource development and utilization directly influences the amount of rainwater resources developed and utilized. From the level of ecological environment, the rainwater quality is directly affected by the uncertainties in the underlying surface and atmospheric pollution in the regional environment; the construction degree of urban artificial water system, improvement of urban water
environment, and alleviation of heat island effect indirectly influence the water resource development and utilization levels; the uncertainties in the occurrence of flood disaster passively promote the construction of rainwater resource utilization projects; for cities in shortage of water resources, the uncertainties in soil erosion and water and soil loss due to the spatial and temporal distribution of precipitation passively increase the storage and utilization of rainwater resources, and indirectly influence the rainwater resource utilization. The external environmental risk identification is seen in Table 1.

Table 1. External Environmental Risk Identification

| Link of occurrence | Risk source | Potential risk or risk event | Reason of risk | Risk consequence |
|---------------------|-------------|------------------------------|----------------|-----------------|
| Social environment  | Policies and regulations | The general public refuse to implement or actively implement rainwater utilization projects | No compulsory laws and regulations, with lack of incentives and supporting policies, or otherwise | A or B |
| Economic level      | Macroeconomic development degree: rise or decline | Investment on rainwater resource development: increase or decrease | A or B |
| Social public       | The general public oppose or support the rainwater development and utilization | Cognition degree and acceptance level of social public: high or low | A or B |
| Regional environment| The pollution of regional underlying surface or air environmental pollution is serious | Urban pollution is serious or hazardous petrochemical and metallurgical products exist in the region | B |
| Flood disaster      | Loss of life and property, destruction of rainwater project, etc. | The design standard of excessive rainwater drainage system is low, the regulation and storage capacity of rainwater project is limited, etc. | A or B |
| Artificial water system | Heat island effect is acute, runoff pollution is serious, etc. | Urban development occupies urban water system space, and water systems are reduced | A or B |
| Water and soil loss | Urban area is reduced, and gully cutting is accelerated | Conflux scours soils, and sediments entering the rivers are increased | A or B |

Note: A-Positive influence, B-negative influence, similarly hereinafter.

3.2. Water Volume Risk

Serving as a type of resource, urban rainwater needs to meet certain water volume and quality conditions in order to satisfy or supplement the water demands of different industries. Water volume risk is the most important and fundamental risk in the utilization process of urban rainwater resources. In the aspect of resource endowment, precipitation is the water resource of urban rainwater resource utilization engineering, while the uncertainties in its interannual variation and seasonal distribution will directly impact the utilization amount of rainwater resources; the exploitable or usable amount and water quality of urban underground water and surface water as well as the guarantee extent of water supply will all be uncertain, thus directly or indirectly influencing the development and utilization degree of urban rainwater resources. In the management link of project construction and operation, the type and size of catchment basin are uncertain with the change in the urban underlying surface, which influences the water storage capacity; the capacity of impounding reservoir can be used to regulate the changes in the volume of runoffs and harvested rainwater, and the engineering design standard and the coupling relation between the standard and change in the catchment basin influence the safety of rainwater resource utilization projects, utilization amount and water supply efficiency; the related uncertainties in the engineering construction quality and engineering operations management process directly influence the operating efficiency of rainwater resource utilization projects, and any problem in any link may impact the water supply. The water volume risk identification is seen in Table 2.
Table 2. Water Volume Risk Identification

| Link of occurrence | Risk source                  | Potential risk or risk event                                                                 | Reason of risk                                                                                     | Risk conseq |
|--------------------|-----------------------------|-----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-------------|
|                    | Precipitation               | Utilization amount of rainwater resources is sharply increased or decreased                   | Interannual change of precipitation causes drought, floor disaster, etc.                          | B           |
| Resource endowment | Surface water               | Surface water is reduced or water quality becomes poor, with water shortage                  | Rainfall runoffs are reduced, water pollution is generated, or water quality is poor, etc.       |             |
|                    | Underground water           | Groundwater reduction, along with generation of groundwater funnel, surface subsidence, etc. | Excessive exploitation, insufficient groundwater supplementation, etc.                            |             |
|                    | Catchment area              | Obvious decrease or increase in the utilization amount of urban rainwater resources           | The change in the rainwater catchment due to the change of urban land use type                    | B           |
| Construction and operations management | Storage capacity | Insufficient or unstable water supply                                                        | Insufficient water storage or overflow due to too large or too small volume                        | B           |
|                    | Design standard             | Insufficient engineering water supply or occurrence of geological disasters like landslide  | Low engineering design standard, limited regulation and storage capacity, etc.                    | B           |
|                    | Engineering construction    | Leakage in the pipe network system and storage system, etc.                                   | Engineering construction quality does not meet the related standard                                | B           |
|                    | Operations management       | Water supply is interrupted or unstable, with health risk, etc.                               | Damage to works, pipeline misconnection, disorderly sewage discharge, etc.                         | B           |

3.3. Water quality risk

Rainwater quality is a prerequisite for the water use of different industries or users, and the water quality risk mainly derives from storage pollution and water treatment links. In the storage pollution link, as the accumulated rainwater runoffs are influenced by different types of urban underlying surface pollution and human activities, the pollution type (physical pollution and chemical pollution) and degree are of extreme uncertainties, which will directly influence the rainwater quality; when it comes to natural eutrophication, nutrient substances like nitrogen and phosphorus are collected in the storage system with the rainwater runoffs and continuously accumulated, which gives rise to excessive multiplication of some algae and aquatic organisms, makes the water body turbid, changes it components, and thus influence the rainwater quality. In the water treatment link, uncertainties exist in the selection of water purification processes and technologies due to the random and complicated characteristics of urban rainwater quality, and the water purification facility design and the matching degree of capacity of primary water quality with the change in the passive pollution of underlying surface that harvests rainwater will influence the effluent quality to different degrees. The water quality risk identification is presented in Table 3.

3.4. Water price risk

The ultimate goal of urban rainwater resource utilization is to supply users with water, but because of the particularity of harvested rainwater resources, the rainwater price formed by fixed-asset investment on rainwater resource utilization projects and annual operating cost accounting is higher than the water price in the conventional water supply, so a large deviation is formed with the expectation of water users. Under constant fixed-asset investment of the projects, their annual operating cost decides the rainwater
price to a certain extent, and the uncertainties of project maintenance cost and water treatment cost jointly influence the rainwater price. The water price risk identification is displayed in Table 4.

### Table 3. Water Quality Risk Identification

| Link of occurrence | Risk source | Potential risk or risk event | Reason of risk | Risk consequence |
|--------------------|-------------|------------------------------|----------------|-----------------|
| Storage pollution  | Chemical pollution | Heavy metals, leakage of hazardous chemicals, gas station accident, etc. | Catchment basin is polluted by hazardous goods and chemicals like greasy dirt | B |
| Physical pollution | Physical pollution | Pathogenic microorganisms enter the water transportation pipe network, and damage the pipe network, etc. | Catchment basin is polluted by pathogenic microorganisms or sediments | B |
| Eutrophication      | Eutrophication | Stored rainwater has foul smell, the water body is turbid, etc. | Nitrogen and phosphorous accumulation results in excessive multiplication of algae and aquatic organisms | B |
| Purification process| Purification process | Purification process fails to satisfy the change in quality of harvested rainwater | Defects exist in the purification process design | B |
| Purification facility| Purification facility | Finished water quality does not meet the related standard, or does not conform to water demand | Purification ability of purification facilities is limited or the water quality is changed greatly | B |

### Table 4. Water Price Risk Identification

| Link of occurrence | Risk source | Potential risk or risk event | Reason of risk | Risk consequence |
|--------------------|-------------|------------------------------|----------------|-----------------|
| Rainwater price    | Maintenance cost | No maintenance, maintenance standard is not high, and maintenance cost is high, etc. | No maintenance fund, rainwater price can hardly support the maintenance cost | B |
|                    | Treatment cost   | Users refuse to use rainwater; water treatment facilities come to a standstill, etc. | Water treatment cost is high, price difference exists between water price and water treatment cost | B |

### 4. Evaluation Index System Construction for Urban Rainwater Resource Utilization Risks

#### 4.1. Preliminary list of risk evaluation indexes

Based on a comprehensive identification of risk factors playing critical roles in different links of the whole process of urban rainwater resource development and utilization, according to the principles of analytical hierarchy process of risk measurement, a list of evaluation indexes for the urban rainwater resource utilization risks was preliminarily established, and this list contained three layers: target layer, criterion layer and index layer as seen in Table 5.

### 4.2. Utilization status of urban rainwater resources in Qingyang City, in Loess Plateau region

Qingyang City is located at the west of Loess Plateau, east of Gansu Province and interaction of Shaanxi Province, Gansu Province, and Ningxia Autonomous Region in China. Belonging to the gully area of Loess Plateau on the middle and lower reaches of the Yellow River, it is a resource-oriented and engineering-type city in quality-induced water shortage, and an important energy-chemical industry base in China, where the shortage of water resources has become a bottleneck restricting the socioeconomic development. In Xifeng District, the average annual precipitation is 561 mm, average annual amount of water resources is 0.23 billion m³, and per capita water resources quantity is 44 billion
m$^3$. The terrain is high and water level is low within the territory, along with large quantity of river sediments, high degree of mineralization, poor water quality, and difficult utilization; 60% of annual precipitation is concentrated during July-September, and mostly appears in the form of rainstorm and continuous rainfall, the headwaters at the head of gully are eroded in full swing due to the discharge of rainfall runoffs, thus destructing the integrity of ecological environment and tableland.

The rainwater resources in Qingyang City can realize the utilization potential of 4.87 million m$^3$, which is relatively great, with very good development and utilization prospect [10]. In 2004, an artificial lake with rainwater storage capacity of 138,800 m$^3$ was constructed in Xifeng District, Qingyang City, for the sake of suburb irrigation, watering of urban green land and street, etc. [11]. Afterwards, 22.824 km$^2$ of hardened ground surface was taken as the rainwater harvesting field in Xifeng District, five artificial lakes “Qingyang Lake, Beihu Lake, Eastern Suburb Lake, West Lake, and East Lake” were gradually constructed, the total water area was 1.25 billion m$^2$, total reservoir capacity was 2.87 billion m$^3$, the stored rainwater resources mainly served as urban landscape water and irrigation water, and artificial lakes constituted the main rainwater resource utilization engineering in this city. Besides artificial lakes, the projects with small rainwater harvesting scale include rainwater tanks, for instance, two rainwater tanks with total rainwater harvesting scale of 180,000 m$^3$ are built in Xifeng Industrial Park to supplement the industrial water in this park; secondly, rainwater resource utilization works are constructed in administrative office buildings and communities in the sponge city construction, rainwater is harvested by installing rainwater harvesting modules and regulating and storage facilities at the bottom of permeable pavement, ecological parking lot and low-elevation greenbelt facilities, or rainwater storage ponds are constructed on urban road, plaza and green land for watering, and thus the total rainwater regulating and storage capacity reaches about 410,000 m$^3$.

### Table 5. List of Evaluation Indexes for Urban Rainwater Resource Utilization Indexes

| Target layer | Criterion layer | Index layer | Target layer | Criterion layer | Index layer |
|--------------|-----------------|-------------|--------------|-----------------|-------------|
| External environmental risk | Social environment | Policies and regulations X$_1$ | Development and utilization risk | Water storage capacity X$_{12}$ | Water price |
| | | Economic development level X$_2$ | | Design standard X$_{13}$ | |
| | Ecological environment | Public acceptance X$_3$ | | Engineering construction X$_{14}$ | |
| | | Regional environment X$_4$ | | Operations management X$_{15}$ | |
| | | Artificial urban water system X$_5$ | | Physical pollution X$_{16}$ | |
| | | Flood disaster X$_6$ | | Chemical pollution X$_{17}$ | |
| | | Water and soil loss X$_7$ | | Natural eutrophication X$_{18}$ | |
| | | Precipitation X$_8$ | | Purification process X$_{19}$ | |
| Development and utilization risk | | Underground water X$_9$ | | Purification facility X$_{20}$ | |
| | | Surface water X$_{10}$ | | Maintenance cost X$_{21}$ | |
| | | Catchment area X$_{11}$ | | Treatment cost X$_{22}$ | |

## 4.3. Construction of risk evaluation index system

### 4.3.1. Data acquisition and standardization

According to the concept of urban rainwater resource utilization risk, the risk corresponding to each factor at the index layer is expressed by risk consequence ($R_i$), which is described by the product of risk possibility ($P_i$) and severity of the risk consequence ($S_i$). The integers within 1-5 are used to express the occurrence probability of risk at each grade and severity of risk consequence, and represent the specific grade where the risk consequence is located, and the standard (Tab. 6). Given this, experts and officials occupied in rainwater resource utilization from water conservancy department, urban construction department, and water users were invited to score the $P_i$ and $S_i$ values of all preliminary established evaluation indexes for urban rainwater resource utilization according to the current situation of urban rainwater resource utilization in Loess Plateau region, and the organized $R_i$ set constituted the original
data of evaluation indexes. The standardized data were automatically acquired via SPSS software. Meanwhile, the PCA was carried out for the external environmental risks and whole-process utilization risks in the list of evaluation indexes for urban rainwater resource utilization risks in this study.

Table 6. Risk Probability, Severity Level and Grade of Risk Consequence and the Evaluation Criteria

| Risk probability | Grade | Evaluation criterion |
|------------------|-------|----------------------|
| Risk probability | 1     | Almost improbable    |
|                  | 2     | Relatively probable  |
|                  | 3     | Probable             |
|                  | 4     | Extremely probable   |
|                  | 5     | Certain              |

| Risk severity    | Grade | Evaluation criterion |
|------------------|-------|----------------------|
| Risk severity    | 1     | Very low             |
|                  | 2     | Low                  |
|                  | 3     | Moderate             |
|                  | 4     | High                 |
|                  | 5     | Very serious         |

| Risk consequence | Grade | Evaluation criterion |
|------------------|-------|----------------------|
| Risk consequence | 1     | Very low             |
|                  | 2     | Relatively low       |
|                  | 3     | Moderate             |
|                  | 4     | High                 |
|                  | 5     | Extremely high       |

4.3.2. PCA and results

(1) PCA of external environmental risks

From the seven external environmental risk indexes, the linear common factor combination of original explainable variables was found. The principal component test of standardized indexes showed that the test KMO value was 0.746, the significance value of Bartlett’s sphericity test was about 0, indicating that the PCA could be implemented. From the software-assisted PCA results, the total variance explained latent roots were $\lambda_1 = 3.67$ and $\lambda_2 = 1.382$, the accumulative contribution rate of the first two principal components reached 72.164%, so most index information of external environmental risks could be expressed, and it was only necessary to extract two principal components, which were denoted as F11 and F12.

The information degrees projected by the two extracted common factor variance explained results on indexes X4, X5, and X6 were all lower than 0.7, the indexes could be excluded, and others could be reserved; from the factor loading of component matrix, X1, X2, and X7 had high loads on F11, X3 had high load on F12, a strong correlation was manifested, and they jointly denoted the influence of external environmental risk on the urban rainwater resource utilization.

(2) PCA of development and utilization risk

The principal component test was carried out for 15 standardized indexes constituting the external environmental risk, the tested KMO value was 0.686, the significance value of Bartlett’s sphericity test was about 0, so the PCA could be implemented. From the PCA results acquired via software, the total variance explained latent roots were $\lambda_1 = 6.819$, $\lambda_2 = 2.318$, and $\lambda_3 = 1.451$, the accumulative contribution rate of the first three principal components reached 70.581%, so most index information of development and utilization risks could be expressed, and only three principal components needed to be extracted, namely, F21, F22, and F23.

The information degrees projected by the five extracted common factor variance explained results on indexes X9, X12, X13, X16, and X20 were all lower than 0.7, the indexes could be deleted, while others could be reserved; from the factor loading of component matrix, X8, X10, X15, X17, X18, X21, and X22 had high loads on F21, X11 had high load on F22, and X19 had high load on F23, a strong correlation was manifested, and they jointly represented the influence of development and utilization risks on urban rainwater resource utilization.

Table 7. Principal Component Load Matrix of External Environmental Risks

| Index variable | Policies and regulations (X1) | Economic development level (X2) | Public acceptance level (X3) | Regional environment (X4) | Urban water system (X5) | Flood disaster (X6) | Water and soil loss (X7) |
|----------------|-------------------------------|--------------------------------|----------------------------|--------------------------|-------------------------|-------------------|--------------------------|
| F11 load       | 0.959                         | 0.949                          | -0.317                     | -0.483                   | -0.527                  | 0.568             | 0.956                    |
| F12 load       | 0.179                         | 0.249                          | 0.730                      | 0.498                    | 0.571                   | 0.400             | 0.144                    |
| Result         | Reserved                      | Reserved                       | Reserved                   | Deleted                  | Deleted                 | Deleted           | Reserved                 |
Table 8. Principal Component Load Matrix of Development and Utilization Risks

| Index variable | Precipitation | Underground water | Surface water | Catchment basin | Storage capacity | Engineering design standard | Engineering design standard |
|----------------|---------------|------------------|---------------|-----------------|-----------------|-----------------------------|-----------------------------|
| F21 load       | 0.866         | -0.637           | 0.885         | -0.3            | -0.292          | -0.605                      | -0.658                      |
| F22 load       | 0.046         | 0.182            | 0.025         | 0.88            | 0.853           | 0.33                        | 0.33                        |
| F23 load       | -0.243        | 0.376            | -0.249        | -0.182          | -0.247          | 0.153                       | 0.136                       |
| Result         | Reserved      | Deleted          | Reserved      | Reserved        | Deleted         | Deleted                     | Deleted                     |

(3) Results
The PCA showed that five principal components reflected the urban rainwater resource utilization risks in Loess Plateau region, where the index information reflected by principal components F11 and F21 were quite concentrated, representing 10 main indexes, which could reflect the main features of target risks; a total of 14 key indexes screened jointly influenced the typical urban rainwater resource utilization risks in Loess Plateau region, and the risk index system formed on this basis is seen in Table 9.

5. Conclusion
Based on the list of identified urban rainwater resource utilization risks, the main risks influencing the urban rainwater resource development and utilization in Loess Plateau region included social environmental risk, ecological environmental risk, water volume risk, water quality risk, and water price risk. The PCA was used to screen out 14 evaluation indexes reflecting the urban rainwater resource utilization risks in Loess Plateau region, thus well evading the arbitrariness in the subjective determination of evaluation indexes. Through the qualitative description and quantitative analysis, the established evaluation index system for urban rainwater resource utilization risks in Loess Plateau region is of good scientificity and reasonability. It is noteworthy that with the continuous urban rainwater resource development and utilization, the rainwater utilization risk indexes and their influences on the utilization goals will change to a certain extent. The risk identification method and construction method of evaluation index system proposed in this study will provide a reference for the risk evaluation and control of urban rainwater resource utilization in the current phase.
Acknowledgments
This research work is funded by project of the International Science & Technology Cooperation Program of Gansu province (18YF1WA030), National Key Research and Development Planning Program (2017YFC0403506).

References
[1] Zhang, J., He, R., Qi, J., et al (2013) A New Perspective on Water Issues in North China. Advances in Water Science, 24:303-310.
[2] Chen, L., Wang, L. (2012) Study on the Evolution of Water Supply System in Large Cities With Typical Water Shortage in Northern China. Journal of Irrigation and Drainage, 12:119-124.
[3] Zhou, B. (2017) Analysis of National Key R&D Program of China “high-efficient development and utilization of water resource”. Advances in Water Science, 3:472-478.
[4] Lim, K.Y., Hamilton, A.J., Jiang, S.C. (2015) Assessment of Public Health Risk Associated with Viral Contamination in Harvested Urban Stormwater for Domestic Applications. Science of the Total Environment, 523:95-108.
[5] Sazakli, E., Alexopoulos, A., Leotsinidis, M. (2007) Rainwater harvesting, quality assessment and utilization in Kefalonia Island, Greece. Water Research, 41:2039-2047.
[6] Hou, P., Ren, Y., Wang, X., et al (2012) Research on Evaluation of Water Quality of Beijing Urban Stormwater Runoff. Environmental Science, 33:71-73.
[7] Cao, W., Jia, A., Li, X. (2008) Risk Evaluation on the Collection and Reuse of Stormwater in Residential Districts. Water & Wastewater Engineering, 34:71-74.
[8] ISO, AS/NZS. (2009) AS/NZS ISO 31000:2009 Risk management - principles and guidelines. Published in Switzerland, Bern.
[9] Xu, J. (2002) Mathematical Methods in Contemporary Geography. Published in Higher Education Press, Beijing.
[10] Sun, D., Jin, Y., Hu, X., et al (2013) Practice on Collection and Utilization of Rain Flood Runoff in Qingyang City. Bulletin of Soil and Water Conservation, 33:215-218.
[11] Lv, Z. (2006) Xifeng District Solves the Urban Water Shortage Using Rain-flood Resources, 15:59.