The Collecting and Storing Flood Runoff Technology in Slopeland*

—A Study of Associated Storing Water System of Pool-Vault and Its Application

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Abstract: This article introduces in detail the basic definition, research background, design thought, system composition, function character, and design point of associated storing water system of pool-vault in slopeland, and makes an analysis of the effect of its practical application. Experiment proves that this system, possessing the functions of adequately storing and effectively separating flood runoff, can transform rainwater into resources, raise the utilization rate and efficiency of rainwater, control soil and water loss, improve ecological environment, and carry out sustainable economic development in semi-arid and arid regions. It is a new thought and method of realizing the effective exploitation of rainwater resources on the Loess Plateau, even in all the semi-arid and arid areas in northern China.

Keywords: flood runoff in slopeland, optimal collection, associated storing water system of pool-vault

1 Research background of associated storing water system of pool-vault

With the implementation of the Western Expansion Program, water resources shortage becomes the bottleneck that seriously checks the construction of ecological environment in China's northwestern region. For this, in our country, either the intellectual field or the governmental departments get to a common view. In particular, in the sandy areas on the Loess Plateau in northern Shaanxi, northern Longdong and the hilly areas of southern Ningxia, water resources shortage has been a long-standing problem and is becoming more and more serious. To make matter worse, Huanxian Country and Huachi County, located in the arid and bitter-water areas in northern Longdong of Gansu Province, are among the 18 counties seriously short of water in Gansu Province. People here have long suffered a lot from water shortage in farming production and in their daily life. For hundreds of years, to solve the water problem, people here have taken many measures, among which pools and vaults were dug, but they cannot get rid of the difficult situation. When making an investigation of the utilization of pools and vaults in the mountainous arid areas in northern Longdong from 1986 to 1988, we have found the root cause of water shortage and the vital damage of pools and vaults is that there is something wrong with the traditional way of storing water, which hinders the development and utilization rate of rainwater in this area. The associated storing water system of pool-vault suggested in the article will effectively overcome the shortcomings existing in the traditional approach of flood control. Practice proves that the system is advantageous to control and store natural flood and is a new thought and method of efficiently exploiting slopeland flood resources in the sandy areas on the Loess Plateau and even in the semi-arid and arid areas in the northern regions of our country.

2 The basic definition and design thought of associated storing water system of pool-vault

2.1 The basic definition

The associated storing water system is a new type of soil and water conservation project, in which pools and vaults are dug optimally at the place (they used to be dug separately in the semi-arid and arid in the northwestern China) to store rainwater.

2.2 The system design

As to the common problems, when people from semi-arid and arid areas, namely, on the Loess Plateau of east part of Gansu, make use of pools and vaults to store the rainwater (especially in the flood season), we should analyze the type of rainfall, flood runoff, flow concentration ranges, the characters of the pools and vaults and advantages and disadvantages of the way in which rainwater is store according to the principles of adequately storing and effectively separating flood runoff, our basic design is as follows.

2.2.1 Character analyses of rainwater

The research results reveal [1] that flood runoff in the semi-arid and arid areas on the Loess Plateau is mainly caused by a few heavy rainstorms in flood season every year (from May to October) the flood runoff in flood season amounts to 80% to 90% of the total proportion from June to August, and the frequency being up to 89.8% to 95.0%, that is to say, the runoff in flood season is the main rainwater source for the development of flow concentration irrigation. But there is too much soil and sand in the runoff that the proportion of them is up to 300kg/m^3 to 500kg/m^3. Vaults and pools will be easily damaged if the rainwater is stored there without filtration. Therefore, some measures are to be taken to separate water from soil and sand.

2.2.2 Flow concentration range

Most parts of Qingyang Prefecture are covered by loose loess. Except for the places where people often move about, such as highways, courtyards and villages, the runoff rate is comparatively lower in the fields, in the woods or on the grassland (especially in the fields). The flow concentration ranges which have been developed on the Loess Plateau so far are mainly highways (including the asphalt road and unpaved road), threshing ground and courtyards, roofs (including tiled roofs and concrete roofs) and man-made concrete ground, plastic film and rammed ground, waste slopeland, water ditch, wasteland and uncultivated land can also be used as natural grounds to collect rainwater, which is still regarded as an unfavorable way to the development of the farm irrigation with supply of stored water, in fact, the important index of measuring the flood control rate depends on the utilization rate of flow concentration ranges and the rainwater collecting rate on the uncultivated slopeland and land yet to be cultivated. The reasons are as follows: firstly, 80% of the land on the Loess Plateau is the cultivated slopeland and waste slopeland yet to be cultivated, of which slopeland at an incline of more than 7 degrees covers 55% of the total area; secondly, on the vast areas of the Loess Plateau, slopeland is, extensively scattered, the land yet to be opened up and developed. According to an investigation, the natural flood runoff rate on the waste slopeland during the course of the heavy rainfall is as high as 0.41 to 0.67, being the main source of flood runoff as well on the Loess Plateau; thirdly, it is often the case to choose semi-arid hilly areas and gully reaches to construct the associated storing water system of pool-vault. Based on an investigation of small reaches of the hilly and gully areas in the northwestern of Huanxian Country, apart from 15% to 20 % of flat farm in the lower reaches, 80 % to 85% of saddled land and slopeland belong to natural wasteland. Plants of algae are thick enough to produce flood runoff. Thus, it is quite satisfactory for us to construct associated storing water system of pool-vault so far as location and conditions are concerned, but unfortunately low in utilization rate.

2.2.3 Character analyses of pool-vault

Pools can be easily dug in the ground to store large amount of rainwater. Rainwater from pools can be conveniently utilized, but easily evaporate, sink and get polluted as well since pools are often constructed in the open air. Vaults are often dug underground with less capacity and too much labor force. But rainwater in vaults, less free from underground temperature, is not evaporating and sinking so much as rainwater in pools. So we should consider the advantages and disadvantages of pools and vaults at the same time in practice.

2.2.4 Method analysis of blocking and collecting the flood runoff

People in the prefecture still stick to the traditional way of blocking and storing the flood, namely, in the course of the rainfall, the flood runoff is channeled into the vaults directly by the way of man-monitoring. In recent years, when the vaults are built, much attention has been paid to the construction of the trashscreen and settling basin. But because the basin built was so small in volume (generally $1m^3$—$1.5m^3$) that the flood overflows out of the basin into the vault without sedimentation. The main disadvantages of the traditional way of retaining flood runoff are: (1) the vault capacity decreased sharply for the sand and mud siltation and it is a pains-taking task to remove. (2) Once unmonitored, the vault will be discarded as useless as a result of its collapse due to overstorage. (3) When the rainstorm occurs at night, generally it is a tremendous waste of available rainwater for it is impossible to monitor, block and conduct the rainwater into the ditch.

Based on the above-mentioned analyses, we put forward a design plan and put it into practice that the pools and vaults should be constructed together as a complete set to retain flood effectively. By using the time-space differentiation principle, the runoff and sand in the flood are separated with clarifying method and stored in separate places.

3 The composition and function features of associated storing water system of pool-vault

3.1 The system composition

The rainwater collecting and storing system is a vital integral part of the flow concentration and utilization project, and the foundation of the exploiting rainwater resources as well. The system is the updated thought and way of planning the rainwater collecting and storing system, its objective is to block, collect, purify, and store the runoff produced in flow concentration ranges in flood season for future use. The system is mainly composed of pools as flood collecting and storing facilities and vaults as the clean water (settled water). As to the system, the main function of the pools is to collect rainwater in short-term. While the role of the vaults to store the clean water over long period for supplying drinking water to man and domestic animals and for farming irrigation.

Like the common rainwater collecting and storing system, the system also needs flow concentration ground, trashscreens, rainwater ditches or pipelines and outlets etc. for the purpose of conducting the settled water in the pool into the vault, a siphon is also needed. But the difference is that the system retains mainly the runoff produced in the natural uncultivated surface like natural uncultivated slopeland, generally with seepage-control treatment to flow concentration ground. In the meanwhile, in order to raise its runoff-producing rate, some measures like natural vegetation management and chemical material processing can be taken to control seepage, on the premise of not occupying or polluting the land around the flow concentration ground.

3.2 System function features

The core technique of the system lies in solving the contradictions between retaining flood and rush-preventing and silt-preventing. Specifically speaking, during the process of runoff-producing rainfall (esp. heavy rain or rainstorm), firstly, the flood should be blocked and channeled into water-collecting facilities like pools or cistern and try to let rainwater or flood get settled in the pool for some time, (generally 24—36h). Then conduct the settled water or half-settled water (silt content is smaller than 5 kg/m^3) into the vault through the water-conducting ditch or siphon, the following are the features of the system: (1) it can block and store the runoff fully according to the need and raise the utilization rate of the runoff sharply so as to guarantee the amount and quality of water needed in production and daily-life. (2) It more or less reduces the tremendous damage of mud and sand siltation to vaults. Thus the vault capacity is improved and man power saved. Though the silt in the pools needs to be removed at regular intervals and it can be served as the material to reinforce the pool or to fill up the pits for obtaining the land. (3) The users can construct the system in favorable locations such as the place around the house or cropland area according to the production and daily life need. The numbers and capacity of the two are flexible. It can be either one pool with one vault as a set, or one pool with many vaults, or many pools with many vaults to form a water-supplying network for farm irrigation. (4) Due to the interval between rainwater retaining and water precipitating, the users only need to go to the spot to conduct the runoff into the vault at his convenience after the rainfall. Therefore, the passive situation can be avoided that the users must watch over water collecting on the spot during the rainfall for fear that the vault would collapse with over input rainwater. It also reduces the damage caused by storm flood to the people. (5) If the system is widely put into practice, on a large scale, the goal of decreasing silt content in the runoff will be achieved.

4 The project design requirements on the associated water-storing system of pool-vault

4.1 The principle of choosing system sites

The following 4 main aspects should be taken into account when deciding on the system sites:

(1) The flow concentration range should be advantages in collecting flood runoff.

(2) The area of flow concentration range should be up to the design requirements.

(3) There should be advantageous terrain and well-structured texture to build pools and vaults.

(4) There should be a certain superelevation maintained between the water storage area and the use area so as to supply water automatically.

4.2 Type choice of the system facilities

4.2.1 The pool-type flood control facilities

If based on pools and with micro-drainage areas (or confluences) as independent collecting units, it is then supposed to build such flood-control projects as mini-dams in the flood gutter.

4.2.2 The vault-type water storage facilities

If based on water vaults and in places suitable for developing irrigation with catchment, it is then supposed to build vaults and cement collecting pools of large volume.

4.2.3 Facilities for delivering, diversing, and supplying water

All are done by laying underground plastic pipelines.

4.3 The determination of the system facilities size

4.3.1 The determination of the area of flow concentration ground

With reference to the experience obtained in catchment projects carried out in Provinces Gansu and Ningxia, the area of flow concentration ground can be calculated in the following equation:

in the equation, W_d —the annual catchment capacity of flow concentration ground; R_p—the annual precipitation corresponding to a certain frequency; A_i—the area of certain flow concentration range in the ground; n_i—the annual catchment efficiency of the said flow concentration range; n—the varieties of flow concentration range.

4.3.2 The determination of the volume of the food-control pools

If determined by the flood-producing capacity in the designed flow concentration range as for the maximum precipitation in 24 hours happening within 20 years, the volume of the single pool can be calculated in the following equation:

in the equation, $W_{p(5\%)}$—the volume of a single pool (flood-control volume) during the maximum precipitation within 24 hours (P=5%); $R_{p(5\%)}$ —the maximum precipitation within 24 hours (P=5%); A_i —the area of certain flow concentration range in the ground; η_i —the flood-producing parameter of the maximum precipitation within 24 hours of the flow concentration range (P=5%); W_f —the flood-control volume of a pool; W_d —the possible maximum siltation volume, W_f and W_d are generally calculated by 10% of the flood-control volume of a single pool.

The volume of a single pool should be generally limited between 50 m^3—100 m^3 with 200 m^3 as the maximum. When the flood-control capacity reaches about 200m^3, it is suggested to store in separate pools; while it excesses 500m^3, it is suggested to block and store by means of building mini-dams.

4.3.3 The determination of the total volume of a vault and that of a single one

It is supposed to determine the total volume of a vault by the quality of water consumption. The volume of a single vault is normally $20m^3$—$30m^3$, once over $50m^3$, the kiln vaults and cement pools are mostly adopted.

4.4 The construction types of the major system facilities

(1) The construction forms of pools are usually made in something like a semi-spheroid with a built-in lining layer. The bottom of the pool should be filled in with sticky clay and ooze to control seepage. The inner walls should be lined with plastic film to control seepage.

(2) The construction forms of vaults are comparatively various. With accordance to the geometrical shapes of the vaults, they are in a shape of a cylinder, a wine bottle, a square, and a cave, and so on. According to seepage control materials, vaults are made of clay, cement, bricks, etc. the most preferred form of vaults is made of cement.

5 Types of associated storing water system of pool-vault

Considering such factors as building purpose, necessary scales and types of flow concentration range, this system falls into the following types.

5.1 Courtyard type

In general, this type has one pool with 2 or 3 vaults as a complete set. The volume of flood-control pool is $30m^3$—$50m^3$, the total volume of the vaults $60m^3$—$100m^3$, the volume of each vault $20m^3$—$30m^3$, with annual water demand $100m^3$—$150m^3$. In addition to providing drinking water for human and animals, it can be used to develop garden economy for an area of $0.1m^3$—$0.1m^2$, which can be popularized to each household in the country on Loess Plateau, similar to 121 flow concentration project in Gansu Province. What is different is that this system has a flood-control pool and natural flow concentration ranges such as slopes, depressions, paths and alleyways are mostly chosen as catchment site. Particularly, it is good for farming families scattered over hilly areas to develop water-saving garden economy by making full use of the favorable terrain around their courtyards.

5.2 Roadside type

This type usually has one pool with more than 3 vaults as a complete set. The volume of flood-control pool is $50m^3$—$100m^3$, the total volume of the vaults is $200m^3$—$300m^3$, and the volume of each vault varies from $20m^3$ to $50m^3$. When the volume being bigger than $50m^3$, it's better for constructing vaults or cement water-storing pools, with an annual water-storing capacity reaching $500m^3$. This roadside type flow concentration project makes advantage of such striped flow concentration ranges as asphalt surface of highway, earth surface of township and country roads to carry out the program of collecting water. It can fully use runoff collecting terrain for flow concentration and storage, for example, dredging and linking gutters and culverts along roadsides, most of them can become water-supply units with considerable catchment quality, being the effective measures to develop roadside-type water-saving irrigation and to exploit rainfall resources.

5.3 Drainage type

Generally, this type is an associated storing network composed of more than 2 associated storing sub-systems of pool-vault. Its volume of a single flood-control pool is $100m^3$—$200m^3$, with a total volume of $500m^3$—$1,000m^3$ and more, most of the pools being located along water collecting sump within the drainage area. I the catchment unit whose catchment area is bigger than 1 km^2, storing dams are mostly used to control flood runoff, its flood-control volume normally being over $500m^3$. The total vault volume can amount to 1,000m^3—2,000m^3, the volume of a single vault varies from 20m^3 to100m^3, with an annual water storing capacity reaching more than 2,000m^3. This type is a kind of drainage-type catchment project, making the micro-catchment area cut by water course networks in the upper and middle reaches of a micro-watershed as a catchment unit. In line with the local conditions, it can make full use of the natural catchment conditions of each catchment unit in the watershed to retain flood separately and use networks. Also, it can be applied to develop large scale, effective, water-saving irrigational agriculture, forest and fruit industry in arid areas, especially suitable for the economic development in hilly areas and the comprehensive treatment of micro-watersheds.

6 Analysis of application effect

This system, after being put into practical use in Huanxian Country and other places of Gansu Province, mainly displays the following advantages: (1) Flood-control rate raises by 40%—50%, especially that of night time by 80%—90%; (2) Mud-and-sand siltation speed of a vault reduces by 90% and more, the interval for cleaning out the vault changes from once every two years to no cleaning, which overcomes the difficult problem of siltation in vaults; (3) Thanks to the realization of complete flood control in large scale, it not only meets the drinking-water demands, but also serves as the sufficient and clean water source of supplementary irrigation for developing intensive farming.

References

[1] Zhou Peihua, Wang Zhanli. 1992. A Study on Rainstorm Causing Soil Erosion in the Loess Plateau. Journal of Soil and Water Conservation, **3**(6): 1-2.

[2] Zhang Guanghui, Chen Zhihan. 1997. Main Types of Rainfall Collecting Cellar and Its Benefits. Bulletin of Soil and Water Conservation, **6**(17): 57-58.