UTILIZATION OF RAIN WATER ON LOESS PLATEAU IN NORTHWEST CHINA

Department of Environmental Protection,
Ministry of Water Conservancy of
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CONTENTS

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The loess plateau in the northwest of China is situated at east longitude 104° - 114° and north latitude 34° - 41°. It lies in the middle reaches of the Huanghe (Yellow) River, extending over the whole or parts of shanxi, Gansu, Shaanxi and Henan provinces and of Ningxia Hui Autonomous Region. This region covers a total area of 400,000 km^2 and is at an elevation from 800 to 2,000 m. The most part of the plateau (about 275,000 km^2) is overlain by a layer of loess varying generally from 20 to 30 m and exceeding more than 150 m in some places.

The region has an arid and semi-arid continental climate. The annual precipitation is lower than 500 mm and amounts to only 250 mm in the western arid plateau, but the annual evaporation exceeds 1400 mm. The rainfall distribution within a year is quite uneven. The precipitation in July, August and September constitutes more than 60% of the annual precipitation. Therefore, this loess plateau region is severely deficient of water resources.

The loess is mainly composed of silt, being the deposits of Quaternary period in North China. It has a grey-yellow or red-yellow colour, loose structure, high permeability, and visible pores, and will disperse or slake quickly when submerged in water.

Owing to the above - mentioned characteristics, the loess soil is susceptible to intensive erosion caused by rainstorms in summer. Consequently, the loess plateau is disfigured by flowing water into rolling land and numerous gullies, where the loss of water and soil is very serious. The specific soil loss is 10,000 - 20,000 tons per km^2 per year, and even reaches 30,000 tons per km^2 per year in the most ~~serious~~ affected regions. The intensive soil erosion has caused the exhaustion of soil fertility in this region and also resulted in severe sedimentation in the reservoirs and river channels downstream, bringing great trouble to flood protection works.

In developing the agricultural and industrial production and in satisfying the demands of people's life, the loess region is facing with a serious deficit in water resources. Through long struggle against natural calamities, the people in this region have created many an effective measure for full utilization of local water resources. This paper deals briefly with the water storage works practised by the broad masses of people in this loess region.

I. WATER-STORAGE WELLS

A water-storage well is a kind of earth structure for storing rain water. It has been widely used in the loess plateau, because of its long history, simple technique, low investment and quick benefit. In Huguan County, Shanxi Province, more than 45,000 water-storage wells were constructed from 1970 to 1974. In many villages of this county each farmer house has a water-storage well. Hence, such wells play an important role in meeting the water need for domestic use and for irrigation.

1. Type and structure of water-storage wells.

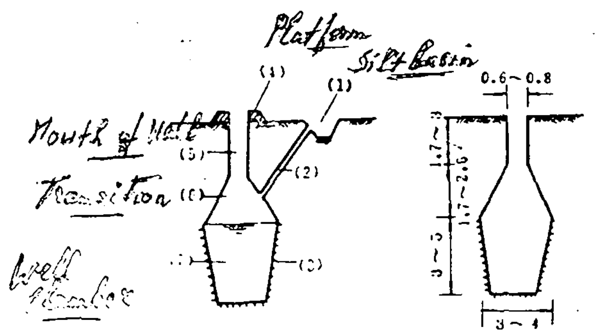
According to its form, water-storage wells may be of bottle-shaped, jar-shaped or kiln-shaped. (Figs. 1. 2 and 3).

A water-storage well consists of three parts:

A. Inlet: It includes water collector, silt basin and inflow pipe.

B. Dry shaft: It is composed of the mouth of well and the transition section, which are the portions not for storing water in a water-storage well.

C. Well chamber: This part is for the storage of rain water. In order to prevent the seepage losses, the wall and the bottom of the water-storage well are provided with a waterproof layer. The bottom of the well is also protected by a bed layer against erosion.



(1) - Silt basin

(2) - Inflow pipe

(3) - Holes for impervious layer

(4) - Platform

(5) - Mouth of well

(6) - Transition section

(7) - Well chamber

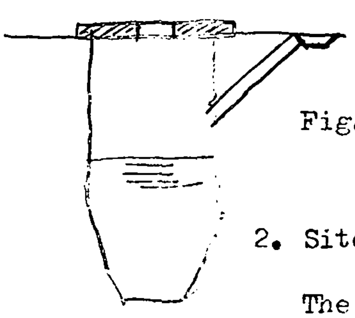


Fig. 1. Cross section of a jar-shaped well in Gansu Province.

2. Site selection of water-storage wells

The site of a well should have a certain catchment area for collecting sufficient rain water. The well is usually situated nearby the farmyards, roads, barren slopes or nearby the houses. Of course, it should not be so near to the buildings that it may ~~not~~ endanger the safety of buildings if the water-storage well collapses.

The water-storage well should be constructed in hard

Table 1. The Soil Characteristics of Water-storage Wells

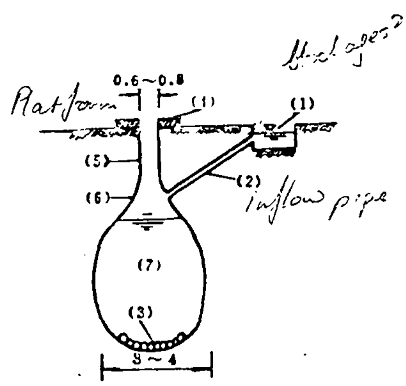
Location, Province, County	Natural State: Dry density t/m^3	Natural State: Moisture content %	Natural State: Porosity %	Specific gravity	Soil gradation %: Sand	Soil gradation %: silt	Soil gradation %: Clay	Unformity Coefficient	Soil type
Shaanxi Suide	1.44	6.0	48.5	2.70	29	60	11	8.9	Light silty loam
"	1.68	13.0	37.8	2.70	19	54	27	7.3	Heavy silty loam
"	1.45	10.0	45.3	2.70	30	64	6		Heavy silty sandy loam
Shaanxi Yulin				2.71	30	54	16	12.3	Medium silty loam
Gansu, Yuzhong	1.58	20.0	41.7	2.71	12	66.5	21.5	12.0	Heavy silty loam
"	1.14	13.9	57.8	2.70	17	66	17		Medium silty loam
Gansu, Dingxi	1.27	7.7	57.0	2.74	21	60	19		"
Shanxi, Linshi	1.30	12.8	51.2	2.68	18	59	23	22.0	Heavy silty loam
"	1.33	11.6	50.3	2.69	26	59	15	22.4	Medium silty loam
"	1.27	13.5	52.8	2.70	37	52	11	10.7	Light silty loam
Henan, Jiyuan	1.53	15.3	44.2	2.74	16	59	25		Heavy silty loam
Gan Gansu, Dingxi	1.26	12.0	58.7	2.73	19	54	27		"

soils, preferably in cohesive loess of low permeability. Table 1 shows the soil characteristics of water-storage wells in some counties.

The number of wells required ~~of~~ for an area should be based on the amount of precipitation and the catchment conditions so that economy can be effected.

3. Essentials of water-storage well construction

The construction method of the water-storage wells in Shanxi Province will be briefly described. The cross section of the well is shown in Fig. 2.



(1) - Silt basin

(2) - Inflow water pipe

(3) - Protection bed layer

(4) - Platform

(5) - Mouth of well

(6) - Transition section

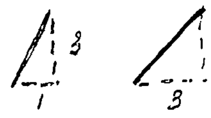
(7) - Well Chamber

Fig. 2 The cross section of a water-storage well in Shanxi Province

4. Excavation of well chamber:

The mouth of the well usually has a diameter of about 0.6-0.8 m and a depth of about 1 m. It should be finished with a smooth surface and an accurate dimension.

In between the mouth and the well chamber, there is a transition section with a depth from 1 m to 4.5 m. The transition section should be so excavated that for every 0.3 m deep downward it is enlarged laterally by about 0.1 - 0.3 m, thus being made a bell-shaped section.



The well chamber, beneath the transition section, has a depth from 8 to 10 m. At the bottom, the chamber diameter gets narrower.

8-10 m deep

After the well shaft has been excavated, it is covered at its mouth with a wooden plank to prevent cracking due to drying and weathering.

B. Silt basin

The silt basin usually has a shape of a square with each side 1.0 - 1.5 m long, and a depth of 0.5 - 0.7 m. The bottom of silt basin should be lower than the entrance of the inflow pipe.

Water overflows into the inflow pipe

C. Inflow pipe

When the well chamber has been excavated to a depth permitting the free standing of a man in it, the excavation of the inflow pipe can begin. After completion, digging may continue in the well chamber further downward.

The inflow pipe may be made of tile, earthenware or bamboo. Its gradient should be steep enough that the water nappes will fall directly onto the well bottom and not erode the wall of the well. The pipe end should extend out of the wall by a length of about 0.1 - 0.2 m, and the cavity between the pipe and earth hole should be grouted for fixing the pipe in position.

The entrance of the inflow pipe should be equipped with wooden trash rack or with wire meshes.

D. Seepage control

The construction quality of the impervious layer exerts a direct influence on the storage of water, therefore, it should be handed carefully.

In regions where lime is available, lime - clay mixture is used for the impervious layer. The well wall is compacted with hammer, and then coated three times with cemented material - lime-clay mixture. The proportion of lime to clay is 1:3 for the first coating, 1:1 for the second, and 3:1 for the third. The thickness of each coating is about 1 - 1.2 cm. If the wall of the well is of hard soil, application of two coatings may be enough.

waterproof by coating the wall of the well

In regions where lime is unavailable, red clay is used for the impervious layer. The red clay is first sieved to clear away the stones and than submerged under water for at least three days, during which stirring is repeated until it becomes a uniform thick slurry.

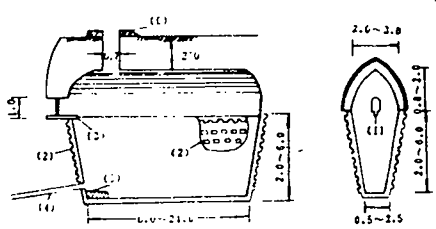
On the wall of the well, holes with a diameter of 7-10 cm and a depth of 17 cm are dug at a spacing of 15 cm. They are staggered in arrangement. On the third day after digging, the holes are filled tightly with red clay clubs and the area between the holes is also coated with red clay. The thickness of the impervious layer is about 2 cm at the upper part of the wall, 3 cm at the middle part, 4 cm at the lower part and 5-6 cm on the bottom of the well. As soon as the clay slurry is coated, it should be trowelled smooth immediately. Subsequently, the wall has to be hammered by force once or twice a day, and repeated till about 30 times, when the impervious layer appears shiny. The dry density then will reach 1.78 t/m^3.

E. A protection layer of sand and gravel is provided on the bottom of the water-storage well.

F. A platform laid with bricks or stones is provided at the mouth of the well, and a cover on it is needed to prevent the water from pollution and maintain a certain humidity in the well for protecting the impervious layer.

4. Essentials of water cave construction

A water cave is another kind of water-storage wells. Its chamber is similar in shape to the cave dwelling in this region and so it is referred to as water cave. The water cave can hold more water than the water-storage well. A cross section is shown in Fig. 3



(1) - Entrace

(2) - Holes for impervious layer

(3) - Intake flume

(4) - Release pipe

(5) - Protecting basket

(6) - Platform

Fig. 3 Cross section of a water cave

A water cave is usually constructed on the terrace or near to the earth precipice, having a height more than 3 m. Its construction procedures are as follows:

A. An opening of (1.6 - 2.0) m x (1.o - 1.2) m in size is dug from the foot of the terrace as the entrace to the water cave. When the entrance corridor reaches

2 m deep horizontally, excavation then proceeds laterally both in left and in right directions and downward. The water cave is thus formed in this way.

B. An inflow canal which is lined with masonry is built for diverting rain water through the cave entrance to the water cave. The intake pipe stretches out of the cave wall about 5 cm, and a protection layer is placed with stones at the bottom of water cave.

C. Near the entrance, a pit is dug to the same depth as the water cave. From the bottom of the pit an outlet hole leading from the water cave is excavated in which tile (or earthenware) pipe is laid for realising the water. The pipe end should be 15 cm higher than the bottom of the water cave. The release pipe is quipped with a gate which can be operated from above the entrance.

D. The mouth of the water cave is excavated and the platform of bricks or stones is laid.

E. The impervious layer is made in the same manner as the water-storage wells.

5. Maintenance of water-storage wells

After completion of a water-storage well, it is necessary, either before storing rain water or in the service time, to hold a certain amount of water in the well so as to maintain a certain humidity in it. The purpose is to prevent the impervious layer from cracking due to drying and ensure its proper function.

During the water storage, the water level in the well should not rise to the transition section.

The mouth of water-storage well should be covered all the time to ensure the cleanliness of drinking water.

In accordance with the degree of silt deposition, the well is cleared of the deposits once every 3 - 5 years.

6. Comments

The water-storage well is adaptable to local condition. It can be constructed either on the slope of highland or on the flat land where water flow can be collected through the gully. Rain water accumulated in the well has a high rate of utilization, because evaporation and seepage losses are reduced to a minimum.

The construction technique is simple and can be easily mastered by the broad masses of people.

Moreover, the well uses only local materials, and so the cost is low.

Owing to the above-mentioned advantages, the water-storage wells are widely used in the loess region either to solve the drinking water problems or to develop the irrigation. In each county such wells usually number tens of thousands.

hard to believe

An investigation shows that a water-storage well, having a capacity of 15 m^3, needs only 25 - 30 work-days and 100 - 150 kg of lime.

In the construction of water-storage wells, attention must be paid to the following points:

(i) Investigating the defects of geologic conditions so as to avoid construction accident and guarantee good quality of wells completed.

(ii) Improving the construction method and raising its productivity.

(iii) Improving the method of collecting rain water and also improving water quality.

II. PONDS

The pond is a kind of water storing facilities in the region of loess plateau. It is built on depressions surrounded by low levees to store the surface runoff and the water from mountain springs and creeks. Its storage capacity ranges from several hundred to several thousand m^3.

The ponds are usually constructed near the villages, roads, slopes, lowlands or the heads of gullies, where surface water may accumulate in required amount. The soil at the site of the pond should be stiff soil, preferably clay.

The pond is surrounded by levees, and so it is constructed partly by excavating and partly by filling. The levee usually has a top width of about 1 m and side slopes of 1:1.5. Its top should be higher than the maximum water level by 0.5-0.7 m. The water depth in the pond is desirably to be within 2-3 m. The levee should be of good placement quality to ensure safety requirement for storing rain water.

In order to prevent overflowing and erosion of levees, a spillway must be installed on it. The spillway may be lined with turf or bricks.

The bottom of the pond should be treated carefully to prevent seepage. The seepage control measures are as follows:

(i) At the bottom of the pond, a layer of red clay with a thickness of 0.1-0.2 m is placed and firmly compacted.

(ii) The loess soil at the pond bottom is tamped, and on it 200-300 g of salt are spread for every square metre. After another tamping, imperviousness can be obtained.

(iii) A layer of red clay - sand - gravel mixture (proportion 6:2:2) is placed on the pond bottom with a uniform thickness of 0.2 m and then tamped heavily. This will satisfy the requirement for seepage control.

(iv) The placement of a layer of lime - clay mixture (proportion 1:5) will also give good result of imperviousness.

An outlet pipe equipped with a wooden plug or a small valve is buried beneath the levee to control the flow from the pond. When the water level is lower than the surrounding fields, it is necessary to pump up the water for irrigation.

In order to reduce the evaporation, it is preferable to plant poplars and willows around the pond. In the time of operation the pond should not be dried up for protecting the impervious layer from damage. cracking

The pond makes use of lowland to store water, so it is simple in technology and construction. It requires a little amount of work, but has a relatively large storage capacity.

The disadvantages of ponds are its high evaporation losses and low water quality in comparison with water-storage wells. Hence, the pond water is usually used for irrigation and stock water supply. only

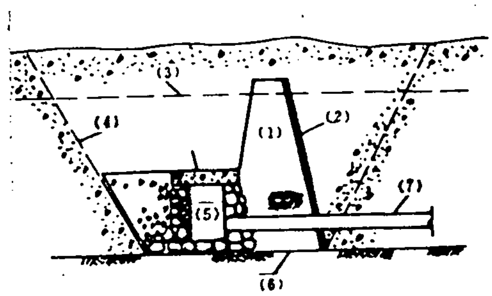
III. UNDERFLOW INTERCEPTION PROJECTS

The gullies in the loessial highland are mostly seasonal small rivers and are dry ordinarily. Impervious cut-offs are built through the deposits in the channels of such mountainous gullies, ravines or rivers to intercept underflow for water diversion. Such works are called "underflow interception projects". A project of this type at Guishi Gully, Pingding County, Shanxi Province permits the diversion of a discharge up to 200 l/s, solving the problem of drinking water for 60,000 peoples.

The sites of underflow interception projects should be selected at places where the gullies are long with larger catchment area and narrow with rock outcrops on both abutments, and where the river bed deposit is shallow (preferably within 5-10 m deep).

Generally, an underflow interception project comprises of three parts, namely, the impervious cut-off, the collecting passage (gallery) and the conduit.

There are two types of cut-off: the central core and the sloping core, which serve the function of intercepting the flow (Fig. and Fig.). The cut-off is mostly built of clay, or of stone masonry, or of concrete. It should, in general, extend to the bedrock or to the impervious layers. The base thickness of the clay core is 1/3-1/4 of the height of core and the top thickness 1-1.5 m. Special attention should be paid to the construction quality of its contact with the bedrock and the abutments.



(1) - Central core

(2) - Filter layer

(3) - Original underflow surface

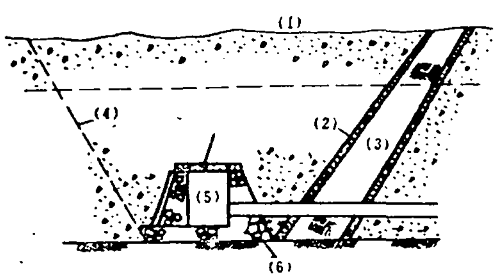
(4) - Excavation line

(5) - Collecting passage

(6) - Impervious layer

(7) - Conduit

Fig.4. Intercepting underflow by central core cut-off



(1) - Original river bed surface

(2) - Filter material

(3) - Sloping core

(4) - Excavation line

(5) - Collecting passage

(6) - Impervious layer

Fig. 5. Intercepting underflow by sloping core cut-off

Collecting passages are used for gathering the underflow, being usually in rectangular section. Their upstream sides are built with dry-laid masonry or partly with masonry laid with cement mortar and their downstream sides are wholly masonry laid with cement mortar. For the convenience of construction and management, the width of the passages should not be less than 80 cm, and their heights not less than 1 m. Filter materials should be backfilled against the outside faces to ensure safe seepage.

Diversion conduits, may be of concrete pipes or stone masonry culverts, which will lead the underflow gathered in the collecting passages to the canal downstream. Inspection wells are provided at certain intervals along the diversion conduits.

Underflow interception projects can solve the problem of lack of surface water. The flow is steady and the quality of water is good, but it demands a good geologic condition and a large amount of construction works.

IV. DIVERTING THE FLOOD FOR WARPING

"Diverting the flood for warping" means diverting the flood from the gullies and also diverting the rain water falling on the barren hillsides, the villages and the roads to the farmland after the rainstorm by building some small works. The purpose is to fertilize the soil with silt and organic matters contained in the water and to irrigate the crops. This is an effective measure for fully utilizing the water and soil resources in the loess region to the advantage of decreasing the menace of water and soil erosion.

According to observation data, one hectare of farmland can generally retain 1995-3000 m^3 of water. The soil moisture of the warped farmland may be higher than that of the unwarped farmland by 10%, and even by 77% in drought period. The organic matters may increase by 21.8% and nitrogen by 13%, resulting in a marked increase in agricultural production.

Diverting the flood for warping will decrease the flood hazards through dispersing the runoff and cutting the flood peak. One example is the warping district along the Bali River in Dingbian County, Shaanxi Province. Its area is approximately 50 km^2. A total annual runoff of 23.4 million m^3 and a sediment yield of 3.70 million m^3 were completely stored by diverting the flood for warping. Another example in the same province can be mentioned of the Mawan Creek in Jingbian County. The catchment area is 101.2 km^2. In nearly one hundred years, except in one year of extreme flood, no water and silt have been released from the gully since the practice of diverting flood for warping.

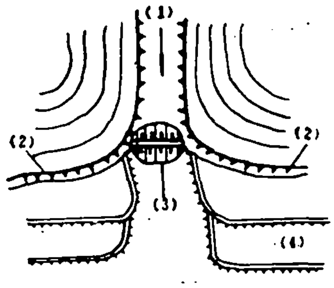
Warping can also turn the barren gully and flat into fertile land with a consequent expansion of cropland. In some localities, the flood water is diverted for leaching saline or for ameliorating the saline-alkali land.

1. Types of warping

Warping may be divided into four types according to sources of flood.

A. Diverting the torrents from the gully

A dam is constructed at the mouth of a gully to divert the muddy water for warping the farmlands at the foot of the hill and at the flats on either bank of the stream (Fig. 7).



(1) - Gully

(2) - Diversion canal

(3) - Earth dam

(4) - Terraced field

Fig. 6. Warping by gully flood

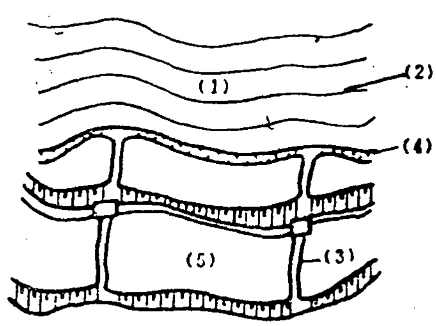
river diversion

B. Diverting the flood from the river

When the flood water is diverted from a large or a medium river, warping is mostly done in the river flats.

C. Intercepting the overland flow on barren hillsides

Intercepting ditches and diversion canals are constructed along the contour line to intercept the overland flow on the hill slope for warping the river flat and terraced field.



(1) - Barren hillside

(2) - Contour line

(3) - Diversion canal

(4) - Intercepting ditch

(5) - Terraced field

Fig.7. Intercepting flow on hill slopes

D. Collecting the overland flow on the village and roads.

In accordance with the local topography, levees are constructed to collect the overland flow onto the farmland.

2. Diversion projects

A. Headwork of the diversion canal

The position of the headwork of a diversion canal should be selected at the narrow reach or at the downstream of the concave bank of the river, where the river bed should also be stable. The elevation of the weir crest should be higher than that of the irrigated farmland. Generally, the headworks may be classified into three types.

(i) River bank inlets

While the river flood discharge is great and the diversion flow is small, the inlets may simply be constructed at the river bank, e.g. the sluices and culverts. Sand and soil bags or rice straws may also be used as temporary measures.

(ii) Diversion dam

If the most part of the flood water will be diverted from the river, an overflow dam is constructed across the river with the diversion headwork arranged on one bank adjacent to the dam (Fig. 8).

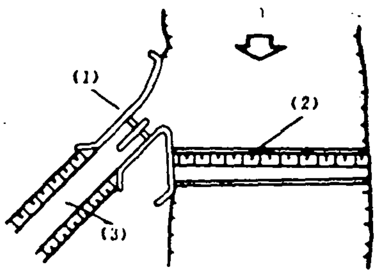


Fig. 8
Diversion dam

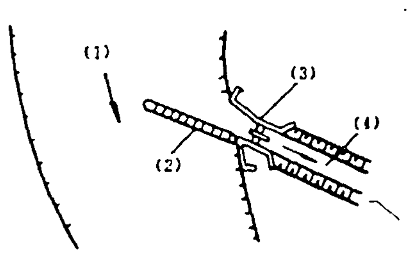
(1) - Diversion headwork

(2) - Overflow dam

(3) - Canal

(iii) Spur dike for diversion

Spur dikes are constructed on one side of the river to divert a part of the flood water (Fig. 9).



(1) - River

(2) - Spur dike

(3) - Diversion headwork

(4) - Canal

Fig. 9. Diversion by spur dikes

B. Canal

The flood water is conveyed onto the farmland through the canal. Because the flood is of short duration, high silt content and quick occurrence, and because the diversion discharge is large, the diversion canal has the following characteristics:

(i) Multiple inlets

The flood may quickly be dispersed and diverted by multiple inlets. The spacings between the adjacent inlets are generally about 200 m, but nor more than 500 m.

(ii) Short canal

The length of the main canals is mostly shorter than 1000 m.

(iii) Great gradient

The gradient of the canals is 1/100–1/500, preferably 1/300.

(iv) Gross section of the canal

The cross section of the canal is wide but shallow.

(v) Great diversion discharge

The diversion discharge is determined as follows:

$$\text{Diversion discharge} = \frac{\text{Warping area (mu)}^{*}}{\text{Warping time (hr)}} \; \frac{\times\, 667 \times \text{warping depth (m)}}{\times\, 3600 \times \text{utilization coefficient of canal}}$$

The warping time is the duration of one flood (hr) averaged over multiple years.

The utilization coefficient of canal is 0.5–0.7 for a main canal, and 0.6–0.8 for a branch canal.

* 1 mu = 667 square meters = 1/15 hectare

The depth of warping varies with the type of crops and their growing period. The depth of warping for some crops in the north part of Shaanxi Province is shown in Table 2.

C. Field projects

Farmland projects are the key link for ensuring effective warping. Generally, the farm-plots are arranged along the contour line. The borders of the plots are bounded by small levees of earth or rock. The size of a plot depends on the slope of the farmland and the pattern of cultivation. The area of the plot is about 60-150 mu for flat land and 4-10 mu for hilly loess land.

The levees also play an important role in storing silt and water. They must be finished before the diversion of flood. The suitable height of the levees is 0.3-0.5 m, and may be as high as 0.5-1.0 m, when the slope of the farmland becomes steeper. The tope width of the levees is 0.3-0.5 m.

Outlets should be provided on the field plots for dewatering the excessive water. This will ensure the safety of levees and facilitate the utilization of the warping land.

Table 2. Depth of Warping for Some Crops in the north part of Shaanxi Province

Kind of crops	Sowing period	Harvesting period	Warping period and depth				
			May	June	July	Aug.	Sept.
Hemp	The last decade of March	The second decade of Sept.		Shal- low	Me- dium	Deep	Shallow
Spring wheat	The 1st decade of April	The second decade of July				Deep	Deep
Pea	The 1st decade of April	The second decade of July				Deep	Deep
Millet	The last decade of April	The second decade of Sept.			Me- dium	Shal- low	
Black beans	The 1st decade of May	The last decade of Sept.			Shal- low		
Broom Corn, Millet	The 1st decade of June	The first decade of Sept.	Shal- low		Me- dium		
Buck- wheat	The last decade of June	The second decade of Sept.	Deep	Shal- low			
Winter wheat	The 1st decade of Sept.	The last decade of July					

Note: Shallow - about 0.15 m; Medium - 0.25 m;
Deep - less than 0.5 m

Field projects

Farmland projects are the key link for ensuring effective warping. Generally, the farm-plots are arranged along the contour line. The borders of the plots are bounded by small levees of earth or rock. The size of a plot depends on the slope of the farmland and the pattern of cultivation. The area of the plot is about 60-150 mu for flat land and 4-10 mu for hilly loess land.

The levees also play an important role in storing silt and water. They must be finished before the diversion of flood. The suitable height of the levees is 0.3 - 0.5 m, and may be as high as 0.5 - 1.0 m when the slope of the farmland becomes steeper. The top width of the levees is 0.3 - 0.5 m.

Outlets should be provided on the field plots for dewatering the excessive water. This will ensure the safety of the levees and facilitate the utilization of the warping land.

3. Technique of warping

The duration and depth of warping vary according of the kind of crops, growing season and cropping system.

It is desirable to take notice of water quality for warping. When the muddy water becomes dark yellow, it contains greater amount of organic matters and has greater fertility. Flood water which contains red clay or higher alkalinity is unsuitable for warping.

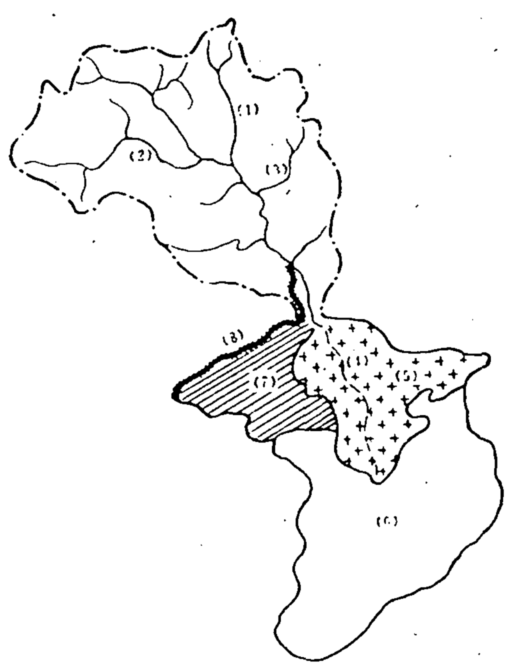
Warping is a kind of work which should usually be accomplished at critical point of time and under bad climatic condition, therefore it calls for a good organization.

4. An example of diverting flood for warping

The Zhaolao Gully warping district is situated in Fuping County, Shaanxi Province. Its history can be dated back to more than 2300 years ago in the time of Qin Kingdom of Spring and Autumn Period. It diverts the flood from Zhaolao Gully, upstream of the Shunyang River, to irrigate 34,000 mu of farmland located at the alluvial fan. Marked results have been achieved in utilizing the water and silt resources and in turning harms into benefits.

Zhaolao Gully is that reach of the Shunyang River situated in the mountainous area. The length of the main gully is 24.2 km. The catchment area is about 200 km^2. The soils in the catchment are mainly loess. The annual precipitation is 600-700 mm. Generally, there are about 10 flash floods a year, occurring mostly in the period from the second decade of July to the first decade of August. The peak discharge is 120-160 m^3/s, with a maximum of 327 m^3/s in extraordinary case. The organic matter content of in extraordinary case. The organic matter content of the muddy water is 1.4-2.02%. The nitrogen content is 0.062-0.107%.

Along the river banks of 9.5 km long in the irrigation district, there are 37 diversion inlets and 24 diversion canals. The total diversion capacity is 205 m^3/s. A plan view of the flooding irrigation district is shown in Fig. 10.



(1) - Zhaolao Gully

(2) - Jiangjia Gully

(3) - Lanshan streamlet

(4) - Seasonal streamlet

(5) - Old irrigation district

(6) - Ancient irrigation district

(7) - New irrigation district

(8) - Hongwei irrigation canal

Fig. 10: Plan of Zhaolao Gully flood irrigation district.

In most cases, no dams are provided at the inlets of the irrigation district. The dimensions of the inlets are given in Table 3.

Table 3. Dimension of the inlets

Area of warping	Diversion discharge	Width	Height
(Mu)	(m^3/s)	(m)	(m)
500	3.0	2.7	1.2
1000	5.0-7.0	3.2	2.0
2000	9.0-12.0	4.8	2.5

In order to increase the diversion discharge at low water level, spur dikes of stone masonry are provided at all the inlets.

One diversion canal can warp about 1000 mu of farmland, in other words, diversion of the flood water on one occasion will inundate the area on the whole. Canals are divided into two classes, the main canal and the branch canal. For an irrigation area less than 500 mu, there is only the main canal. The gradient of the canal is 1/200-1/300. The area of each plot is less than 30 mu.

The effectiveness of warping is remarkable. The water content of the soil is notably increased. The top 30-cm soil layer of the warped land has a water content 2.8-4.4% higher than that of unwarped farmland. After warping, the soil composition has also changed. The sand content decreases from 71.2% to 46.9%, and the clay content increases from 28.8% to 53.1%. The soil is thus ameliorated.

According to the calculation that 180 m^3 of muddy water are diverted for each mu of farmland, the nutrients that are carried by the water onto farmland will be as follows: Nitrogen 37.3 kg/mu, effective phosphorus 0.9 kg/mu, effective potassium 3.96 kg/mu. A view of warped farmland is shown in Fig. 11.

Fig. 11 Warped farmland in Zhaolao Gully

FAO Interest

Owing to the reasons mentioned above, the crop yields increase remarkedly by diverting the flood for warping. Comparison of the crop yields is shown in Table 4.

Table 4. Comparison of crop yields

Kind of crops	Crop yield kg/mu		
	Wheat	Maize	Millet
Warped farmland	275	300	255
Unwarped farmland	60	150	90
Increased yield	215	150	165

Because the flood water was diverted totally for warping over many years, it hardly discharged into the downstream. The river flats along the downstream river were reclaimed gradually. The river flats along the Shunyang River, extending a length of 40 km downstream of the mouth of the Zhaolao Gully, have been turned into fertile land. The riverbed then disappeared. This river with a total length of 60 km has thus become the first river that carries no silt into the Huanghe River in our country.

V. SILT-ARREST DAM

A silt-arrest dam, constructed of earth or rock across a stream or gully, is used to impound flood and to catch silt for forming flat land. Thus, the waste gully is transformed into farmland. It has the same effect as that of diverting the flood for warping.

In recent years silt-arrest dams have been developing, from the construction of individual ones to the construction of a group of them under the unified planning of stream basin. They have constituted a multiple-purpose dam - system for agricultural production, silt retaining, flood detention and irrigation.

1. General considerations of silt-arrest dams

A silt-arrest dam is generally composed of an earth or rockfill dam, a spillway and a conduit. Because the principal purpose of the dam is to catch silt for forming farmland, supplemented with water storage for irrigation, the requirements for dam design are somewhat different from those for ordinary dams in that the geological conditions and the operation conditions required of by the silt-arrest dam are simpler or less rigorous.

The location for a silt-arrest dam should be selected at a place where a larger storage can be obtained and where the slope of the gully is gentler. It is also necessary to have better geological conditions and sufficient construction materials.

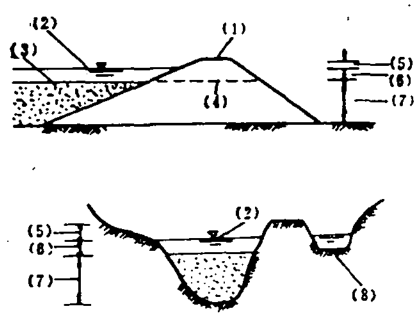
Most of the silt-arrest dams are homogeneous earth dams. In the area where the soil materials are unavailable in sufficient amount, rockfill or earth-rock dams are adopted.

The height of the dam is determined according to the flood discharge and volume and to the total amount of silt to be trapped. In the north part of Shaanxi Province, a 10-yr (10%) flood is adopted for designing a dam having a height less than 10 m and controlling a catchment area less than 2 km^2. In other conditions, a 20-yr (5%) flood is adopted.

The design dam height is determined as follows:

Design dam height = Height of siltation + Depth of flood detention + Freeboard.

The height of siltation is determined according to the storage capacity required for holding 3-5 times the average annual silt amount.



(1) - Crest

(2) - Highest water level

(3) - Elevation of silt deposit

(4) - Elevation of spillway

(5) - Freeboard

(6) - Depth of flood-detention

(7) - Height of siltation

(8) - Spillway

Fig. Cross-section of a silt-arrest dam and a stream channel

Annual silt volume

$$\frac{(\text{Average soil loss per unit area}) \times (\text{Catchment area})}{\text{Dry density of silt}}$$

The depth of flood detention is equal to the water depth above the spillway crest. It is 0.5-1.0 m in general and 1.5 m at most.

The freeboard is 0.5 - 1.0 m.

The dam section is dependent on the dam height, soil properties, construction method and traffic requirements. The slope of dam is 1:1-1:3 and the crest width is 1.5-6.0 m.

A spillway has great influence on the cost and safety of the dam project. It is composed of open channel, chute and stilling pool.

The conduit is used to release the clear water from the reservoir, so that the reservoir can have space again to store the flood. It is also used for irrigation and flood diversion for warping. It consists of an inclined intake (or a shaft), conduit section and stilling pool.

The design principles and the structure of the spillway and outlet conduit are the same as those in the case of ordinary spillway and outlet.

2. Utilization of the deposited land

The silt deposit behind the silt-arrest dam will form the cultivable land. However, cultivation on such land may hamper the passing of flood as to endanger the dam during flood season. The contradiction between cultivation and flood prevention can be handled by the following measures:

A. Flood storage on the upstream and land cultivation on the downstream.

In a gully with small floods, a number of silt-arrest dams are built in stages from downstream. After the silting up of the first reservoir downstream, a second dam is built on the upstream.

Similarly, a third and others are built further upstream.

The upstream dam is mainly used for flood detention and also side by side with the cultivation of deposited land, but the downstream one is mainly used for farming, which develops simultaneously with the silt depositing.

B. Storing and farming in rotation

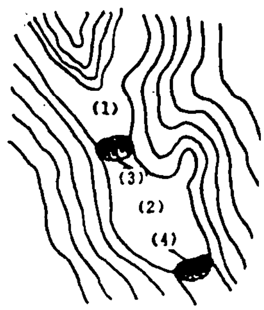
After a series of silt-arrest dams has been built in a gully, most of them are used for cultivation, while the remaining for flood storage. When these storage dams are silted up, some of those dams for farming are raised to function as flood storage dams again.

C. Flood release and a combination of flood release and flood diversion for warping:

If a series of dams has been built in a gully and if it is impossible to raise the dam height or to build another flood storage dam, the flood water may be diverted away for warping from both banks so that the land deposited might not be flooded.

D. Partial releasing and partial warping

While a series of dams has been built in the gully and inflow can be dispersed, measures of partial releasing and partial warping may be adopted, i.e., most part of the flood water is diverted for warping, and the rest is released out of the gully.



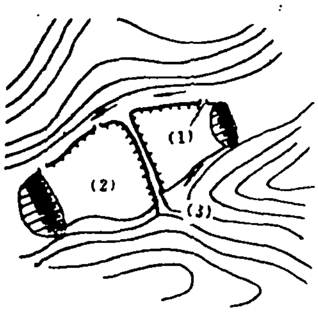
(1) - Flood detention

(2) - Cultivation

(3) - Downstream dam

(4) - Upstream dam

Fig. 14. Flood storage on the upstream and land cultivation on the downstream



(1) - Inlet

(2) - Land inundated

(3) - Flood-way

Fig. 15. Flood release as the main feature, combined with warping

E. Provision of conduit for storing muddy water and releasing clear water

When a stream channel or gully is well under control and the amount of flood water is not large, the dam may be provided with outlet conduit which can release only the clear water so that the sediment is retained.

3. Practical example of comprehensive control of a stream basin

Jiuyuan Gully, a small tributary in the middle reaches of the Wuding River, is situated in Suide County, Shaanxi Province. It has a catchment area of 70.1 km^2. Its main channel is 18 km long. There the mean annual rainfall is 516.9 mm. In the basin there are 9334 inhabitants and 32311 mu of cultivated area. The basin is under the jurisdiction of Juiyuangou People's Commune and the people there all engage in agricultural production.

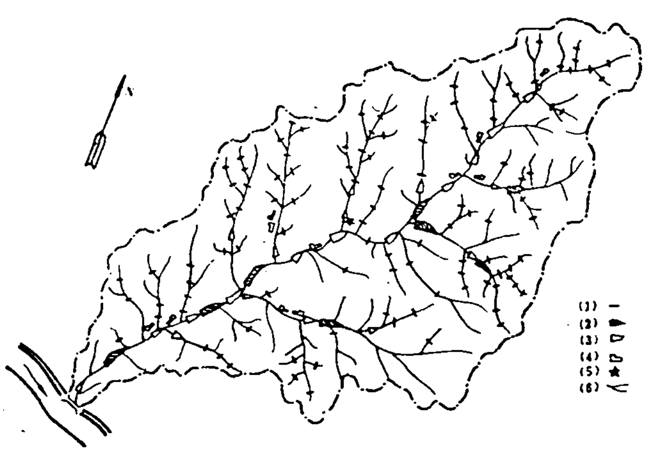
In the basin the soil erosion was serious. The gully density is 5.34 km per km^2. Before its control, the annual amount of soil erosion was 1,270,000 t corresponding to a soil loss of 18120 t/km^2 per year.

In this basin comprehensive control has been carried out according to the topographic peculiarities and landforms. The measures adopted are as follows:

On the sloping land are built the terraced field, bounded with earth dikes. Moreover, rotating the cultivation of grasses and crops, shortening the length of slope, deep ploughing, ameliorating the soil, etc, are also practised.

In the whole gully, silt-arrest dams are built from the upper reaches to the lower reaches to check the runoff and silt. All the gully slopes are afforested for increasing the area of vegetation.

Up to 1974, 10909 mu of terraced fields and 311 silt-arrest dams were built in the whole basin. In addition, there were 30 small reservoirs (the total storage capacity amounted to 1,118,000 m^3). The irrigated area had reached 2552 mu which was 11.3 times more than that before tthe control. The control of Jiuyuan Gully basin is shown in Fig. 15.



(1) - Small silt-arrest dam

(2) - Medium size silt-arrest dam

(3) - Reservoir built by the Commune

(4) - Village

(5) - People's Commune

(6) - Gully

Fig. 15. Layout of dams in Jiuyuan Gully basin.

After the control of the basin (see photo below) the amount of the average annual soil loss has decreased by 770,100 t and the trapped silt as a percentage of the

Drawing 1

	part	type	material	dimensions
4 x	32	connecting bolt	st. bolt	$\phi \frac{1}{4}$" x 1", with ring and 2 nuts
2 x	31	stroke limits	rubber	$\frac{3}{8}$" x 80 x 40
	30	handle	round st.	$\phi \frac{3}{8}$" x 250
	29	lever	black tube	$\phi 1\frac{1}{4}$" x 500
	28	bearing bolt	st. bolt	$\phi \frac{5}{8}$" x $5\frac{1}{2}$", threaded $1\frac{1}{2}$" with ring and 2 nuts
4 x	27	bearing house	st. ring	$\phi \frac{7}{8}$" inside
	26	lever house	black tube	ϕ 2" x 92
2 x	25	fork	st. strip	$\frac{3}{8}$" x $1\frac{1}{2}$" x 160
3 x	24	bearing	bronce	ϕ 1" x 15 to fit 28
	23	bearing bolt	st. bolt	$\phi \frac{5}{8}$" x 2" threaded 7/8" with ring and 2 nuts
	22	bearing connection	st. strip	$\frac{3}{8}$" x $1\frac{1}{2}$" x 2"
	21	upper rod	round st.	$\phi \frac{3}{8}$" x 440, with 1 nut
	20	rod connection	"	$\phi \frac{5}{8}$" x 40
	19	rod	"	$\phi \frac{3}{8}$" x L (L equal to 15)
	18	support	st. strip	1" x $\frac{1}{4}$" x 160
4 x	17	connecting strip	st. strip	1" x $\frac{1}{4}$" x 330
4 x	16	base bolts	st. bolt	$\phi \frac{1}{2}$" x 4 threaded $1\frac{1}{2}$"

Drawing 2

part	type	material	dimensions
15	delivery tube	galv. st.	$\phi 1\frac{1}{4}''$ see dr. 1
19	rod	round st.	$\phi \frac{3}{8}''$ "
20	rod connection	"	$\phi \frac{5}{8}''$ "
51	piston rod	"	$\phi \frac{3}{8}'' \times 440$
52	pipe socket	cast iron	$\phi 2\frac{1}{2}'' \times 1\frac{1}{4}''$
53	cilinder tube	galv. steel	$\phi 2\frac{1}{2}'' \times 350$
54	cilinder lining	brass sheet	191 x 350 x 1 glue with soldimex
55	piston bolt	st. bolt	$\phi \frac{3}{8}'' \times 1\frac{1}{2}''$ with ring + 2 nuts
2 x 56	valve disc	bronce	$\phi 47 \times 4$
2 x 57	valve cushion	rubber	$\phi 47 \times 4$
58	upper piston disc	bronce	$\phi 55 \times 7$
59	piston cup	leather	182 x 13 x 3
60	lower piston disc	bronce	$\phi 59 \times 4$
61	valve cage	strip	$\frac{1}{2}'' \times \frac{1}{8}'' \times 90$ and $\frac{1}{2}'' \times \frac{1}{8}'' \times 96$
62	valve bolt	st. bolt	$\phi 1\frac{1}{4}'' \times 1''$ with ring and 2 nuts
63	cilinder cover	cast iron	$\phi 2\frac{1}{2}''$ to be machined inside
2 x 64	bolt	st. bolt	$\phi \frac{1}{4}'' \times \frac{3}{4}''$ with two nuts.