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CONTROL OF THE YELLOW RIVER IN CHINA

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Contents

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Introduction

River improvement is a science of much complexity. It is not susceptible of rigid mathematical analysis which obtains as in the field of bridge construction. There is no generalization. Laws which hold good in one case seemingly reverse themselves in another. Each river has its own definite characteristics and presents its own equation.

It is then evident that for a definite river the system of treatment must be so chosen as will be adaptable to the existing conditions. Such conditions should be recognized by means of a clear observationand coordinated with the same spirit of all scientific procedure. So is the adoptation of the reservoir project on the Colorado and the upper Mississippi, not because the Amrican engineers want apply such a project to these rivers: but because they realize the necessity of their adoptation owing to the demands of these riv rs themselves. Again theearly German practice on the Rhine was to give dikes a considerable inclination downstream.Such dikes, however, had found to cause a considerable settlement and a caving of banks between them. Nowadays, "the practice on German rivers is to give dikes an inclination upstream of 105°to 110°on straight reaches, 100°to 102.5°on concave banks, and 90°to 100° on convex banks. They are spaced at 5/7 of the channel width in straight reaches, at half the channel width on concave banks and at the full width on convex banks". This simply shows a better progress , toward an understanding of this subject, that has been made by the German engineers. But,by no means, applications of such a disposition will guarantee their succes elsewhere. Consquently the Yellow Riverproblem must be studied with a view to revealing those characteristics which will satisfy the wants of the river.

Yet, in spite of these considerations, the writer has met with extreme difficulties in his study, on account of the lack of data. His endevour therefore, in these following pages will be to collate such which are definitely acceptable and to elucidate as far as p ossible the way toward the solution. For the solution, the writer does realize his duty, but a complete representation with regard to the theory and practice is not allowable with such a limited number of facts within such a short interval of time.

1. Geophysical Features

Above all things, the Yellow River is probably the muddiest in the world. Nor is the fact at all surprising. From the very nature of the case little else could be expected, since the geophysic conditions of the river basin predetermine it simply as a matter of fact. Starting from the Inner Mongolia and southward to the Yantze valley, bluffs of a quaternary formation, calle by geologist loess, will be seen scattered everywhere. The origin of these has long been a mooted question among the geol gists. We are not interested here, however, to enter a detailed discussion in this respect. The present purpose is to reveal those facts and their influences upon which the Yellow River problem may be comprehensively studied.

In China proper, loess covers an area of about 630 000 sq.km. At the high land of Shensi, its thickness is about 1 800 m.: at Wu-ta-shan, 2400 m and at some western part, about 3000m. The head waters of the Yellow River derive their sources from those regions.

According to the estimation of V. Richtofen, the greatest thickness of loess plain in China is up to 6000 m. This shows that loess does not only cover high mountains but also fills up deep valleys. It leads then naturally to a conclusion that the origin of loess is wind. Think of the desert of Gobi in Central Mongolia. There is nothing but a boundless plain of sand. So in case a strong wind blows, especially the north wind, fine particles of sand were picked up, held in suspension and carried into the interior provinces of China. High mountains and vegetations would induce sedimentation of sand just in the same process as silt arresters in a stream. As soon as the intensity of wind reduces, the suspended particles begin to deposite everywhere.

In the Yellow River valley, heavy rains usually occure during July and August. June and Septimber are also in the rainy season but generally bring only light rains. Irrespective of the retardation of ground vegetation, runoff of rainfall has been a constant endeavor to erode settled loesses and transfere them from high mountains to ravines and from upper fields to low ones. Evidently these mobile soils have the same intention as that of the flowing water to approach the river or its tributaries as soon as possible.

In the Yellow River valley fields are usually in a stepped form. Each or a group of them levels itself, but differs in altitude. A heavy precipitation produces such a volume and velocity of discharge as to create a powerful erosive action which removes surface soils of fields and tranfers them either to the roads and canals, if any, or overflows over the boundary of high lands to low ones Owing to the latter overflow, boundaries are sometimes cut into gorges

Loess in China has the same physical properties as that in the Mississippi and Rhine valley It is very porous and yellow in color and the diameter of grains varies from 0 05 to 0 026 mm. On account of its porous and fime structure, it offeres little resistance to traveling trames and running horses. So it has been a notable feature of highways in north China that the road beds are usually in the bottoms of canyons of loess. Often you find yourself travelling some yards below the level of fields, so that you could see nothing of the country. At some places such roads lead directly to the river or its tributaries. During dry season, wheels are usually burried by a layer of powder of trampled soil. In windy days fine particles will fly and find a new home. After rains, the road becomes a silt bearing canal and sometimes, with the contribution of flow from fields, a trrent.

All of the eroded soil either from mountains, fields or roads will find its way and finally reach the river. These considerations are especially true for the upper basin of the Yellow River above Lun-ji in Honan. Below Lun-ji the river is continuously protected by dikes.

Yet there is a secondary source of silt contribution to the river. On account of the tubelar structure of loess, mostof the river banks are vertical bluffs. If no external forces are applied to them, these bluffs may stand for ever. However the river course is tortuous, and naturally cross slope would be created between concave and convex sides. Owing to the cross slope, there is produced a cross current. But this current carries energy and m omentum.If the banks are so shaped and their geological structur is so constituted that they could adapte the condition of flow, or if we state in a different way, the condition of flow is simply a result of natural adjustment of banks, the condition of equilibrium between the water and boundary could then be mainyained and these upright bluffs would still be able to stand for ever Unfortunately such cases are very rare Erosion and sliding are unavoidable as shown in Fig 1

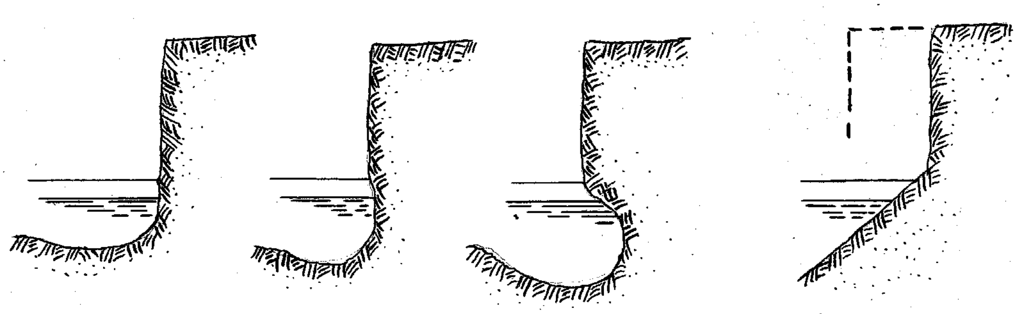

Fig. 1

The silt deposition data as obtained at Lo-ku in Shantung are represented in the annexed Table.

1902	June 23&27				July 17	Aug. 15		Nov.28	
Stage m	28.76		30.71		29.57	30.59		29.14	
Silt:%	0.52	0.57	2.93	4.07	0.65	2.6	2.63	.53	."

wt of water

In the year 1898 the river broke the dike at Wang-chia-liang in Shantung. The silt deposites covered an area of about 300 sq. km. with a thickness of 0.6m to 2 m.

Conceiving of these facts, every engineer who is interested in the Yellow River problem should realize that the question of silt reduction merits first consideration.

Above Lun-ji the river flows over a steep slope and the current is so great that there is practically no sedimentation. Though, on account of high bank walls, people find it difficult to develop irrigation yet they do not suffer from inundation. But below Lun-ji the river, like the Mississippi, flows through a bed of its own creation. Low bank walls, moderate slope and considerable width of the river are found in this portion. Alterations of the river course had always been taking place within this alluvial plain. These alterations are due to the fact that the river has, in the upper stream, enough force to carry its load, but after it enters the plain, the current becomes weaker, deposition occurs and the river bed raises up day by day. So an engineer would fail to meet this problem, if he only wants to improve the lower course within the delta without paying any attention to the upper stream.

2. An Eastern View and the Modern Tendency in River Improvement

No doubt the first hydraulic engineer of China is Yü. His work is supposed to be dependent upon the principle of action of non-effort (行所無事) By this we mean Yu carried away the waters by doing what gave him no trouble, or by doing what gave him full accomplishment with the least effort. He made the four seas as the receptacle So at that time waters even of the Kiang, the Hwai, the Ho, and the Han pursred their proper courses through the country. There were no inundations for more than one thousand year. Unfortunately at the down fall of Chou dynasty, the whole kingdom separated into warring states. Dams and dikes are supposed to be built at the will of these petty states Still worse, they like Chei-bei led waters to inundate their enemies Yu's system was broken into pieces

In the Han dynasty Cia-jon proposed three plans to regulate the Ho or the Yellow River The first one is nothing but to try to rediscover the old channel of the river in Yu's system. It is the best of all, but not feasible on account of its enormous expenses The second is to develop the irrigation in Chee-chow by means of lateral canals as a method of flood control. This may be recommended even at present. While the third or the most unfavorable one was to maintain a dike system by simply increasing the height where low or the thickness where thin, officers of the present Yellow River Bureau have acted as a golden rule. They simply built dikes and maintain them but do not care about the regimen of the river.

Wang-chin during the time of Han-min-ti did wonderful work about the Yellow River. Although no special records could be obtained, from the Chinese history we could notice that he did use sluice gates spaced at a distance of ten li or about four miles to control floods, embank ravines to secure regimen and remove obstacles to make flow ease. His work agrees with the modern practice to a higher degree. So after him till the begining of Sun dynasty for about thousand year, there were no floods.

In the Min dynasty, Pan-chi-suen knew very much about the principle of dike construction. He utilized the dike not omly for flood protection, but also for the purpose to confine water so that it will be able to discharge the charged sediments. His work was continued by Chin-fu with no alteration either in theo y or in practic. They constructed dikes so wisely that for hundreds of years people did not suffer from any floods.

These few persons mentioned above are only the representatives whose theory and practice are supposed to be very important to the Yellow River problem. Of course there are many others to whom the writer pays equal respect, but no space is here allowed even to make a brief account about each

At present both the American and European engineers have the common tendency toward the natural theory in river improvement. It was originate by M. Girardon and supplemented by M. Fargue. "When this method is followed, the sinuous course of the river is preserved, so as to render more stable the location of the bars. No attempt is made to obtain uniform depth nor uniform slopes. The bars are permitted to form in the crossings and their crests to rise with a rise in the river stage, but during a falling stage the currents are given such a direction as to scour a channel of the desired depth across them. .."

By so doing it is supposed to be in harmony with the economy of natural forces manifested in the tendency of nature to accomplish her work with least labor. So is the explanation of the phenomena that though the course of a river, flowing over an alluvial plain, might be the most sinuous, the banks may be found practically free from erosion. Because erosion means a waste of energy and necessitates the river doing more work: it is against the purpose of nature. As a good example ".. the course of Mississippi for the last seventy or eighty miles below New Orleans consists almost entirely a seri es of reversed curves of radii so large that they lengthen very little the course of stream, and although the banks and bed are of fine silt, practically no erosion takes place..."

While the natural theory seems to be favorable, the engineer must be cautious about the particulars of a river. River and bank exist as they are. River wants to carry out its work with least labor, but bank wants to keep its condition of undisturbance. The changes as shown in Fig. 1 are either due to the inadequate geological constitution and physical configuration of the stationary bank or due to the improper energy and momentum of the flowing water. So in river improvement, human effort should be spent in such a way and in such a manner that these influences would approach a limit.

3. Utility of the Existing plans

lt has been a universal fact that many of the western friends who came to China and knew the condition of floods of the Yellow River have advocated that forestry is the only means for flood relief. This may be true to a certain extent, but does not give a right attack to this problem. Forestry should be developed for its own purposes. If it were developed sorely for flood protection, it is quite questionable. One reason is that the Yellow River valley is thickly populated and cultivated lands are maintained. If forestry should be developed to a small extent, itwould be ineffective for protecting floods but if not, it would do harm to those lands upon which farmers depend for living. Another reason is that even the condition permissible, forestry is rather a slow process.

In the year 1922 Mr. J. R. Freeman published an interesting paper under the title" Great Flood Problem in China " (Eng News Record, vol. 88). lt may be quoted in the following way:

" ... The chief object in the river training now proposed is protection against floods by ultimately forming a thick flood proof dike by means of silting up the space between the present inner dike and a new straight dike built to confine the new straight and narrow channel and hold this from meandering so that it will henceforth flow everywhere between new banks protected against undercutting by spur dikes..."

" ... .The river would be compelled to flow in straight courses 5, 10, or 20 miles in length, laid out nearly midway between the present inner dikes as may best fit existing condition in different localities. ... The space of from 2 to 3 miles in width thus left between the old inner dike and the new straight dike, .. forming the most fertile kind of agriculture land, but presenting the great superiority of having the admission of flood water always controlled untill growing crops had been harvested by substantial sluiceways and gates built into the new dike. "

As a citizen of China the writer appreciate the auther and his proposition a great deal. This proposition is based upon the auther's actual observation and also very practicable for the present condition of China. But the could not see why straight dike and straight channel are necessary. These of course have the advantage as stated by the auther " the necessary works of river training and dike building , although extensive are of a simple character " The question is that do the simplicity and reclaimable land justify the injurious effect of straightening a river? An excellent example is afforded by the improvement of Mississippi in front of the city of St Louis " On account of the commercial importance of that city the river was so constructed as to follow the Missouri bank, within the city limits This contracting and straightening has reduced the slope to 0 2 foot per mile on a river which normally has a slope of 0 6 foot per mile, and an excellent channel exists in front of the city, but the slope on the Chain of Rocks immediately above have been injuriously affected and annual dredging is required on the crossings below the city " So should the Yellow River be trained according to the auther's proposition, it would be equally hard,even worse, to protect the new dike and channel than the old. Reclaimation may be rendered uncertain. It is supposed that the auther understands this objection and so he said "...But all of this is no short or simple task, nor can the works be designed in their best shape untill after scientific tests and pains takin observations..." But anyway his proposition seems to be limited itself to the portion of river below Lun-ji and nothing about the upper stteam where the river derives nearly ninety percent of its load.

Mr C M Townsend understands the trouble of the Yellow River to be the silt from the vast and easily eroded loess deposites of the provinces just up stream Lun-ji So he suggests to build levees at Honan to prevent the detritus which is washed down from hills from spreading over bottom lands, as on Lake Biwa, Japan (Townsend: Rive r and Harbor construction p 112) It is a good ideal but not suitable to the condition of the Yellow River This unsuitability needs no explanation, if a comparision will be made between the geological conditions of these two places The writer should think that Mr Townsend neglects the physical features of the upper Yellow basin entirely

For his own consideration, the writer should say that the solution of the Yellow River problem is governed by the natural theory and derived from an operation of an unique method. It would not be unique, if the improvement should be limited only within the delta as it has been the case for thousands of yea rs The futu re improvement must conside r the whole basin as a unit While the main should present its peaceful serpentine figure, head waters of the Yellow River badly need a "thorough cleaning".

4. Importances in Regulation

The Yellow River problem is not a problem of reclaimation but protection. So are the following proposed methods rather protective in nature. They are considered to be fruitful to investigation either in a hydrotechnic laboratory on a portion of the river itself as on the Garonne.

A. Stability of the river channel

According to Mr. Taylor's observation, silt deposites of the Yellow River raises the river bed more than three inches per year. So it is very hard to predict that the river would not shift its course in the recent future. However there must be at least one section on the river where will be found no sedimentation, no erosion and with enough width and depth for navigation. This normal section teaches that the equilibrium of the river would be secured, if the stream should be regulated in accordance with this section. So in the improved channel, either the width, the depth or even the curvature of the channel must follow thoee in the normal section as close as possible. By so doing the three elements: the discharge, the amount of silt, and the slope of river bed would be in a condition of equilibrium, because they do in the normal section and the improved section follows the former without any arbitrary alteration.

Concering the amount of silt which could pass through a cross section, Franzius gives the following formula:

$$G = X(1000i)^2 \int_0^b (t - t_0)\, t\, dx,$$

where G: amouut of silt carried through in cu. m.

X: a coefficient depending on the character of silt and on the river

i: slope of river bed

t: depth of water in m which creats a tractive force $S = 1000it$ kg per sq m

t_0: limit depth in m which makes $S = 0$

b: total width of water surface in m. dx: an element of b.

Consquently we have three cases to be considered:

(1) When $t=t_o$, $G=0$

This shows the normal condition and neither increase nor decrease in the value of G.

(2) When $t<t_o$ $G=-$

This shows that the value of G would decrease, or that the river will no longer be able to carry the amount of silt G. Sedimentation will necessarily occur.

(3) When $t>t_o$ $G=+$

This shows that the value of G would increase or that the river is not only capable to carry the amount of silt G but more Then scouring may happen

For bank slope, Franzius gives another formula:

$$\frac{S}{S_o}=\frac{t}{t_o}\frac{\text{SinA}-\text{SinB}}{\text{SinA}+\text{SinB}}$$

where S, S_o=tractive force in kg per sq m coresponding to t and t_o respectively

A=angle of repose of earth

B=angle between the bank surface and the surface of equilibrium

Evidently when B=0, t=t and it is under the normal condition. By means of this equation we could determine the bank slope under any depth of water.

From these considerations, it is evident that the value of t is the important among the all. But we would not increase nor decrease t directly. What we could do is to change the width of the profile or to modify the curvature of the channel. This necexsarily calls for a levee project. But the levees must be so constructed and so shaped that they will satisfy the wants of the river as claimed in the normal section. If so, the river would flow as it wishes and not against any undesirable obstructions done by human forces. Extraordinary high waters may be controlled by means of xluice gates, inverted syphones, etc as may best fit the existing conditions.

B. Reduction of silt

Probably the difficult question of the Yellow River problem is silt. Reservoirs and forestry are impracticable. Now refering to the firxt paragraph we notice that while the desert of Gobei is considered to be the source of loess, the loess plain of the upper river basin and the bank slides are the main sources of the sediments. The prevention of bank slides follows the normal condition. Even in extreme cases banks can still be protected by mattresses, etc which are quite within the reach of human power.

How to conquer the desert of Gobei? It seems to be a laughable question, but the writer should think that although we might not be able to conquer the giant desedt, yet it is not impossible to reforestry the Inner Mongolia. This would give a constant retardation to the transportation of loess to China proper. It is also impotant for the portion of the Yellow River flowing outside the Great Wall.

For the protection of the eroded soil from the loess plain to the river., three meth ods may be recommended:

(1) Plantation of field Osier

As mentioned before, fields in the loess plain are generally in a stepped form. During a heavy rain fal l runoff over flows high lands to low ones with its eroded soil and gradually steps down to the river or its tributaries. But if we plant one row of osier along the three boundarie s of the field as shown in Fig. 2., it will offer three advantages to this condition. Firstly the rootx of osier will reinforce the bank earth and prevent it from cutting into small gorges by the runoff. Secondly along each row, the land will gradually raise up to form a small dike against overflow. Thirdly boughes of osier are very thin that they not only no harm to crops but also good to make buskets, etc

(2) Transverse and Horizontal Ditches

This was really an old method and constituted an element of Yu's system. It was destroyed by Shan-yan in Chin dynasty. The arrangement of these ditches may be shown as in Fig. 3. They served for three purposes:

I. As small reservoirs, they will reduce the runoff of rainfall directly to the river. But they are not so hard and so expensive to construct as an ordinary reservoir. Local labors could do very well.

II. They will collect the erode loess and hold this in there. According to the investigation of V Richthofen the settled loess is a kind of very fertile soil and especially suitable to the growth of wheat, corn, etc.

III. At every spring farmers may take out all of the depositess from ditches to increase the fertility of their lands Buskets and shovels would do and steam dredges are useless

It is then evident that these ditches will not be able to facilitate the river control but also to benefit the agriculture. If we could the total area of the upper basin and the percentage of cultivated land: the runoff per sq. mile and the duration of heavy rainfal l and other features as related to local conditions, the demensions of ditches belong to one sq. mile, one acre or even one moo may be computed therefrom.

(3) Improvement of Highways

The conditions of highways in north China has been stated before. So if good roads were made according to new methods and runoff from road surface carried away by proper ditches on either side of road bed, each of the muddy canals after a heavy rainfall will be a broadway. Both transportation and river control will be facilitated to a great extent.

C Feasibility of Navigation

One of the Chines philosophers, Chu-si, in the Sun dynasty suggested that river improvement should begin from the lowest. It agrees with the modern practice exactly. Should the Yellow River be regulated , its mouth must then be the starting poijt. The Salena Pass on the Danube, the South Pass on the Mississippi and some of the others are excellent examples to be refered. After this has been done, the regulation is extented upstream section by section. Obstacles may be removed by dynamites or dredges. In the slope is too steep a method of canalization may be introduced.

Now the flood volume of water of the Yellow River ranges from 200 000 -300 000 cu ft per sec At low water stage, the discharge is about 37 700 cu ft per sec For this later case if we assume the velocity to be 3 ft per sec and the width of low water surface 1600 ft , the average depth of water will be about 7.85 ft In an inland river, even during a storm the impact of wave action is insignificant So this depth of water would be enough for vessels of about 400 tons capacity. For ordinary water stage it is quite possible to sail vessel of about 1000 tons capacity or over.

If the Yellow River is regulated in a proper way, it is truely a navigable stream. Consquently Chen-chow in Honan is would be a great port. The products of the north western pr provinces may transported out withojt difficulty.

D. Protection from Flood s

Floods in the Yellow River valley have always been due to e either overflow or break of dikes. But if we give the river a proper channel and at the same time control the runoff by means of ditches and high water by means of flood gates, it is highly probable that we can be free from floods.

E. Possibility of Irrigation

Right below Lun-ji, irrigation has been developed to a large extent. The water is distributed through lateral canals. There is no reservoir site on the Yellow as the sites on the

Colorado. But the writer should think that flood wateds which usually occure in each summer may be utilized to develop irrigatioj: to such an extent that it will not interfeic navigation.

5. Conclusion

In conclusion the writer has a strong belief that the Yellow River problem is not too hard to solve. But the solution pre-requires several preparations. First of all , young Chinese engineers must realize their duty. High mind and broadknowledge are not sufficient: sound morality and unusual endurance are indispensible.

Extensive inve tigation s upon the pr sent conditions and past records are primary importances. Labo ratory belong to the second stage.

However, any engineering project is always complicated by political influences. Should this problem be a national one or a coorperation betw ee n the provinces on the river? It is a question to be decided first.

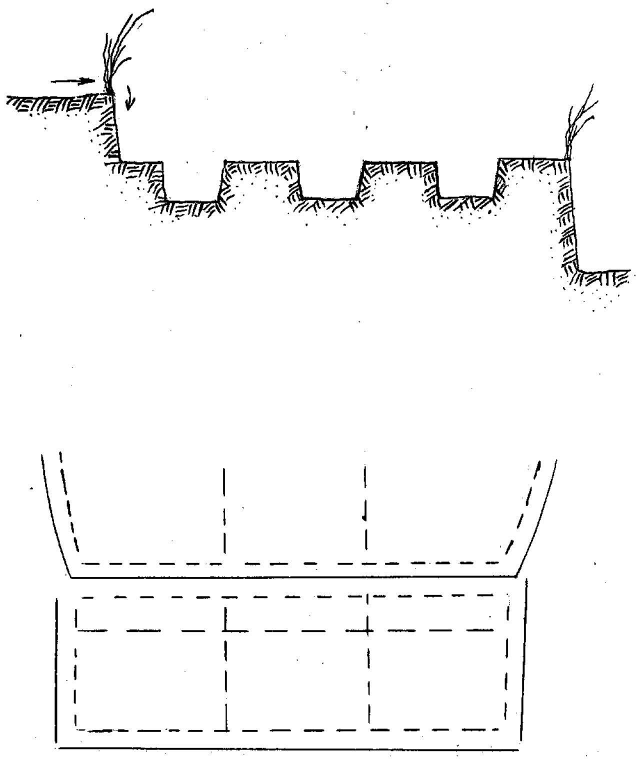

Fig.3.

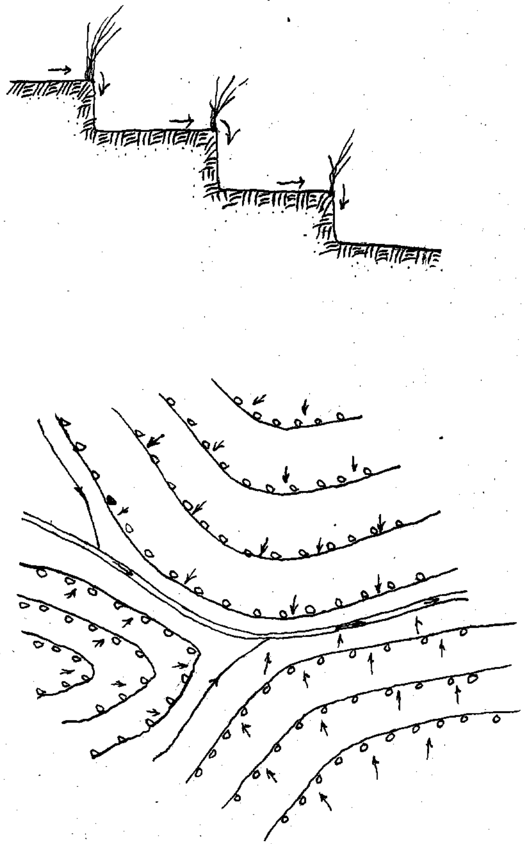

Fig.2.