THE

RIVERS OF "CHIH-LI"

AND

The Floods During the Summer, 1890.

A REPORT PRESENTED TO

H. E. LI HUNG CHANG,

VICEROY OF CHIH-LI, ETC., ETC.

BY

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PREFACE.

In preparing this paper, which is the result of my observations during about two months travelling after the floods of this year, I have been careful to state only what I have seen with my own eyes and of course so short a time has not been sufficient for making extended surveys or taking levels to any great extent. All the information that could be got from the natives was of course much coloured and had to be carefully sifted. Among the uneducated classes of all nations there is a marked tendency to exaggerate, unconsciously perhaps, and to describe the dimensions of a natural phenomenon quite out of proportion to the reality. As much of the information required for making plans for river improvement must be obtained from people living on the spot it is one of the difficulties of survey parties in China that the natives meet them with distrust and suspicion whenever enquiries are made.

Further surveys are necessary before a final and detailed plan can be made; but I believe I have obtained sufficient data for pointing out in what direction further investigations should be undertaken.

It is something quite new and perhaps incomprehensible to Chinese that before undertaking any engineering work a good deal of money should be spent, in return for which nothing can be shown except some drawings and figures; we saw the Hankow—Peking Railway and the route it was to follow sanctioned without any preliminary survey having been made; and when Engineers in the service of the Chinese try to impress upon them the absolute necessity of knowing something about the country before locating any kind of works there are always some persons who are ready to do anything at any place and at any time without waiting for these troublesome surveys.

Only when China shall have invested hundreds of millions of Taels in Public works she will find out that detailed surveys and exact information are required in order to avoid spending two dollars when one would suffice. The more the service of engineering advances the greater nicety in all operations will be necessary, because the tasks set will become of greater magnitude, and both the technical and economical success will depend upon the accuracy of the information upon which the plans have been made

(I.) EXPLANATIONS OF THE ACCOMPANYING MAP.

The Map which accompanies this paper has been constructed partly from the survey of the Jesuits who determined the longitude and latitude for every Chinese City from the rank of a "Hsien" and partly from surveys of my own. The latitudes given by "Perny" in his Dictionnaire—Français–Latin–Chinois are as a rule too high, one or two minutes too northerly, and the relative longitude of places in one province can probably not be relied upon as being nearer the truth than five to ten minutes of arc.

It has been rather difficult to lay down, not the exact, but even an approximate course of the several rivers. On my way to Tai-yuan-fu in 1889 I passed between Pao-ting-fu and Huei-lu the rivers, Tang-ho, Sja-ho or Cha-ho, and the Hu-to-ho and had an opportunity of determining with sufficient accuracy the position of the places where I crossed them.

The important question to be answered, however, is not so much where the exact courses of the rivers are, as to what rivers the streams coming down from the mountains are tributaries, and at what points their confluences take place.

Another important feature of a map of the river system is an outline of the mountains in order to show to what extent the course of each river and its tributaries lay in mountainous country.

This has been comparatively easy as there are certain routes skirting the mountains which have often been travelled over by missionaries and others.

The Hun-ho or Yung-ting-ho it has been impossible for me to examine in the whole of its length owing to there being no roads available and not enough water for a boat because the river had broken out through its embankments and nearly emptied itself into the plains southwest of Peking.

(II.) DESCRIPTION OF THE SEVERAL RIVERS OF PECHILI.

A glance at the map shows that reckoning from the Huei river the mouth of each succeeding river is at a less distance from the mountains than the preceding one; this distance goes on decreasing until the Lan-ho which issues from hills only some fifty li from the sea.

THE RIVER LAN has for a couple of months a plentiful supply of water but is during this time not navigable owing to the rapid current. Later on in September and October flat bottomed boats of a few inches draught bring down to the sea some produce from the hills beyond Yung-ping-fu.

The quantity of water that after heavy rains is discharged by this river is enormous, and owing to the great fall the rapidity of the current is in proportion; even before the Lan-ho issues from the hills the width during floods is over half a mile and depths of over twenty feet may be found. Now and then a village on the banks or part of it is swept off, but owing to the short distance between the mountains and the sea and also to the some whathigher ground on both sides no very extensive inundation can take place.

The next river of some importance is the PE-TANG-HO. This river does not drain large tracts of mountainous country but merely the plains to the east of the Pei-ho; as the water from a flat country is drained off more slowly the Pe-tang-ho has a more equal supply of water throughout the year which tends to maintain a more regular

and well defined bed and accordingly a larger discharging capacity, so when in time of floods the Pei-ho is not capable of carrying to the sea the rain water fallen in the mountains, the Pe-tang-ho is available for the relief of the overcharged Pei-ho. The Chinese have made canals between the two rivers for that purpose, with what result we shall see below.

THE PEI-HO. In order to understand the nature of this river I will divide it into two sections, the one above its junction with the Pao-ting-fu river or Chang-tze-ho also called Ta-ching-ho, the other below.

The Pei-ho has its sources in the mountains north of Peking and drains a considerable area of hilly country; the quantity of water in the Pei-ho above its junction with the Pao-ting-fu river therefore varies considerably during the year. To relieve the river in time of floods canals have been constructed connecting it with the Pei-tang-ho, one about twenty li above Ho-hsi-wu and another near Yang-tsun; a third canal starts from a place between the latter town and Tientsin, all of these canals communicate directly or indirectly with the Pei-tang-ho. When flooded the Pei-ho brings down sand sometimes of a rather coarse quality, which when the current is reduced is deposited and forms shoals. Near Tientsin the three rivers Ta-ching-ho (Pao-ting-fu river) Sia-ho and the Huei-ho (Grand Canal) join the Pei-ho, and while in its upper section this river is only navigable for boats of two feet draught sea going steamers pass between Taku and Tientsin.

Moving westwards from the Pei-ho the next river we meet is the YUNG-TING-HO or HUN-HO which may for all practical purposes be considered as a mere torrent. A glance at the map shows what an enormous area of mountainous country is drained by this river.

I have examined it from its issue from the hills west of Peking down to the place below the Lu-kow-chao bridge where during this summer's floods the breach occurred.

On both sides the Yung-ting-ho has embankments constructed of sand or very sandy earth with a facing of rubble masonry, the distance between the embankments where the breach occurred is about half a mile and the whole of this space was during this year's floods a torrent with in some places twenty feet of water. When I visited the Yung-ting-ho the water had partly subsided and a part of the bed was dry and covered with stones, gravel and coarse-grained sand; the river had in fact emptied itself through the breach into the plains southwest of Peking which are at a lower level than the bottom of the river bed, and left the space between the embankments below the breach nearly dry.

One branch of the Yung-ting-ho or Hun-ho as it is called on its lower course joins the Ta-ching-ho at a place about twenty li from Tientsin.

The river is here embanked with two embankments wide apart; and alongside each embankment there is a channel about one hundred feet broad while the space between the two channels is at a higher level than the plains on both sides of the river.

This high land I found cultivated and as the crops were not ruined it could only have been flooded to the extent of some inches.

From what I observed near the Lu-kow-chao bridge and twenty li northwest of Tientsin it is evident that the two narrow channels are under ordinary circumstances sufficient for the discharge of the Hun-ho's water and that in a flooded state the rule is that it breaks through the embankments somewhere south of Peking and that the water passing across the plains runs into the Pei-ho on the one side and into the Ta-ching-ho on the other.

That the floods in the Hun-ho never or very seldom reach its mouth where it joins the Ta-ching-ho is evident from the fact that the soil between the embankments twenty li northwest of Tientsin is mud containing very little sand which could not have been deposited while the river was in a flooded state. From the junction of the Hun-ho and the Ta-ching-ho to Tientsin is a distance of about twenty li, the Ta-ching-ho is here full of shoals of fine grained sand which has been brought down by the two channels inside the Hun-ho embankments when this river is in a half flooded state and before the embankments southwest of Peking have given way. There is another connection between the Yung-ting-ho and the Ta-ching-ho some where near Pao-ting-hsien.

THE TA-CHING-HO passes between Pao-ting-fu and Tientsin through large areas of depressions which as a rule are filled with water and considered as lakes though in many places the ground is alternatively dry and covered with water.

This continual change results in no two maps being found to agree as to the number and extent of the lakes through which the Ta-ching-ho flows.

Owing to these lakes the sand carried down from the hills is deposited and no shoals formed as far as its junction with the Hun-ho except in a few places where sand is brought into the river by small tributaries or where water from the plains streams over the banks into the river; otherwise the Ta-ching-ho is very suitable for navigation and we shall see later on what slight improvement would make this river navigable for vessels of at least six feet draught as far as Pao-ting-fu.

During the last floods the water on the plains on the left bank of the Ta-ching-ho was about three feet higher than the river; the result was that the embankments were broken and the water rushed into the river, the level of which was thereby raised, and the embankments on the right bank now gave way and an enormous quantity of water poured over the right bank passed across the obliterated banks of the Sia-ho towards the Huei-ho (Grand Canal) and broke into this river which now threatened the city of Tientsin with ruin. Orders were then given to cut the embankments on the right side of the Huei-ho (Grand Canal); this was probably quite unnecessary as the embankments could not long have resisted the rush of water from the plains which run straight against them and caused breaches in several places.

THE SIA-HO is of all the rivers of Pechili the most difficult to define. During the floods the plain between the Ta-ching-ho and the Huei-ho was one sheet of water without any trace of the banks of the Sia-ho being visible.

In the southwest of Pechili this river seems to consist of a great number of branches that probably are dry except after exceptionally heavy rains. It changes its course very often in that part of the province; and bridges are in existence that span old river beds where now water is never seen.

In 1889 I passed near Cheng-ting-fu the Hu-to-ho, a river of much the same character as the Yung-ting-ho or Hun-ho, which is a tributary of the Sia-ho. To the Hu-to-ho is due the inundation that occurred this year over the plains southwest of Hwei-lu.

THE HUEI-HO—YU-HO or Grand Canal as it is erroneously called by foreigners, and its affluents have their sources in the mountains of southeastern Shan-si. Its junction with the Grand Canal is at Lin-sing; as the Grand Canal has locks or sluices there is no direct communication between the Hoang-ho and the Huei-ho.

The deposit formed on the slopes of the embankments of the latter river was mud mixed with very little sand and that was of the finest quality.

The depth of its water was nearly uniform except in places where the embank-

ments were broken, in fact on the fourth or fifth of August this year when I passed up this river from Tientsin I never found a greater depth than nine feet or less than eight feet. Above the Sao-san Canal which connects the Huei-ho and the Pei-ho the depth was also uniform, though greater, about fifteen feet.

Later on in this paper I shall return to these observations, so important for determining ways of improving the drainage system and of rendering the navigation more satisfactory.

The Huei-ho on its long course through the plains has already deposited sand and other heavy suspended matters before it reaches Tientsin or even before its junction with the Sao-san Canal and to this it is due that of all the rivers that meet at Tientsin the Huei-ho is the most navigable.

The Chinese have through several canals near Tsang-chow provided a direct outlet to the sea for the surplus water. These canals have weirs constructed across them so that they only act when the water in the Huei-ho reaches a certain height. The Sao-san Canal during the last floods discharged more water into the Pei-ho than the Huei-ho did by way of Tientsin. At the junction of the Sao-san Canal with the latter a bridge has been built across the former, it serves also as a sluice when it is desirable to keep all the water in the Huei-ho.

(III.) THE FLOODS IN THE SUMMER, 1890.

In the previous chapter I have attempted to give a description of the different features of the rivers of Pechili that the reader may understand what happened when the recent floods occurred.

Among the causes to which this calamity is due the Hun-ho or Yung-ting-ho occupies the central and chief position. From what has been said above and from a glance at the map we know that this river drains large areas of hilly country in Pechili and northern Shan-si, in these parts rain falls mostly during a short period in the summer only and varies very much from one year to another. Under such circumstances it is not to be expected that the river should be able to maintain a stable and well-defined bed; as long as it is confined to the valleys of the hills the turbulent torrent is confined within a narrow limit and can cause no great destruction, but when after heavy rains the enormous quantity of water containing stones, gravel and sand is poured into the plain west of Peking the velocity of the current is soon reduced and stones, gravel and coarse-grained sand deposited which year after year tend to raise the bottom of the river.

The Yung-ting-ho is bridged at Lu-kow-chao by the famous stone bridge mentioned by Marco Polo, it is about seven hundred feet long but only a little more than four hundred feet is left for the passage of the water, which is not much more than one seventh part of the width of the river one mile lower down where the large breach occurred.

Beginning at the bridge the embankments, built of sand with a rubble stone facing, diverge until they are about three thousand feet apart.

It is one of the errors of the present system of river management in China that it is believed that the best safeguard against a turbulent river is the construction of embankments wide apart in order to give plenty of room for the water.

The sudden widening of the Yung-ting-ho between the Lu-kow-chao bridge and a place three li lower down the river results in a reduced current which must necessarily

be followed by deposits being made and shoals formed and instead of offering less resistance to the flow it actually increases that resistance as soon as the width of the channel is too much in excess of the depth of the water.

The immediate effect of a too wide channel is therefore to raise the level of the river. This is of course bad, but there is another consideration which makes it a much more serious blunder to widen the bed to a width that is seven times what it is a mile higher up the river, as is the case of the Yung-ting-ho near the Lu-kow-chao bridge.

In order to keep the embankments of a river in good order it is absolutely necessary that the main current should run parallel to them, for if it does not it runs against some part of the embankments, and the earth must soon be carried away. If now the Yung-ting-ho had during the whole of the year a plentiful supply of water its not having a uniform section would not be so disastrous, as the result would merely be that the bottom of the river would be raised, while it might be expected that the main current would keep to the middle of the bed; but when, as is actually the case with the Yung-ting-ho during the greater part of the year, an insignificant stream a couple of hundred feet wide and very shallow runs between embankments three thousand feet apart the channel soon assumes a tortuous course, running from one embankment over against the other and back again.

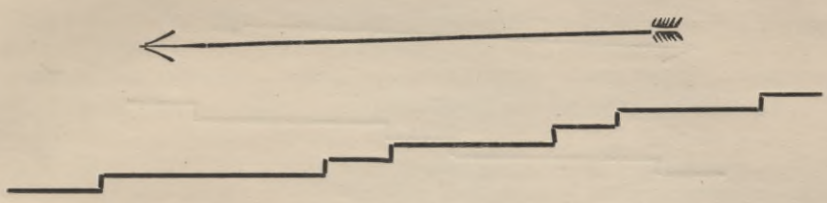
It is also very often the case that when the high water subsides two channels are formed, one along each embankment. When the water begins rising after heavy rains the main current will, anyhow in the beginning of the floods, follow the deeper channels that offer less resistance, the consequence being that in some places the water would run against the embankments, and it was under such circumstances that the Yung-ting-ho broke through its left bank about three li below the Lu-kow-chao bridge.

The embankments were otherwise in good repair but as soon as the current had undermined the foundation of the stone facing, the embankments gave way for a length of between two thousand and three thousand feet and the river emptied itself into the lower plain towards the Imperial Park. Thence the water went south, and when its level became about four feet higher than the Pei-ho it broke through the embankment on which the Tientsin–Peking road is carried and into the Pei-ho over its right bank; soon after the embankment on the left side gave way and the plains east of the Pei-ho were flooded.

The arrows and the blue painted stripes on the map show the general direction of the movement of the floods.

Part of the water found an outlet into the sea through the Pe-tang-ho or ran back into the Pei-ho at places between Tientsin and Taku.

I do not know whether a breach occurred in the embankments on the right bank of the Yung-ting-ho but the plain between this river and the Ta-ching-ho (Pao-ting-fu river) and its affluent the Pai-gou-ho were under water the level of which was above that of the river. At last the water broke into the Ta-ching-ho over the left and away again over the right bank, hence the floods passed across the Sia-ho and into the Huei-ho (Grand Canal). Tientsin being now threatened with destruction orders were given to cut the embankments on the right bank, and in consequence of this and the breaches made by the inrush of water from the plains the country between the Pei-ho—Huei-ho and the Sao-san Canal was at once flooded; somewhere near Hsien-sui-ku on the Pei-ho the water found an outlet into that river. In the Sao-san Canal no embankments were broken owing to the sensible way in which they were protected by a narrow strip of land between the foot of the embankments and the Canal, planted with willows.



Level of the water in the "Pei-ho" at "Hsien-sui-ku."

do. do. do. on the plains between "Pei-ho" and "Huei-ho."

do. do. do. in the "Huei-ho" at "Ching-hai-hsien."

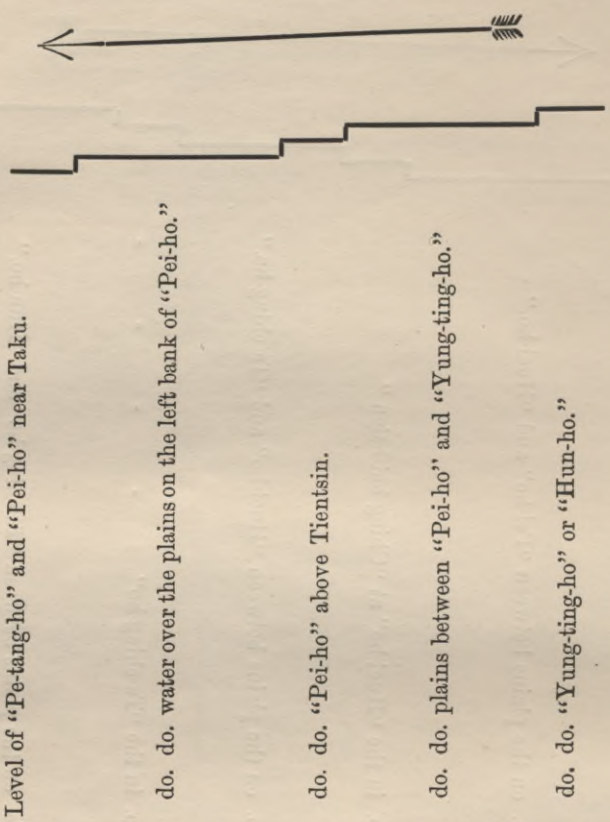
do. do. do. on the plains between "Huei-ho" and "Ta-ching-ho."

do. do. do. in the "Ta-ching-ho" - - - -

do. do. do. on the plains between "Ta-ching-ho" and "Hun-ho."

do. do. do. in the "Hun-ho" or "Yung-ting-ho."

The above diagram gives graphically a resumé of the movement of the floods reckoning from the Yung-ting-ho to the right bank of the Pei-ho near Hsien-sui-ku. The difference in the levels of the water over the plains respectively on the right and left bank I measured when I visited the several rivers, but as some days elapsed between these observations, which ought to have been made simultaneously, they are not of much value except for giving a general idea of the movements of the floods. On the 4th of August the water in the Huei-ho near Ching-hai-hsien was about one foot three inches above the plain on its right bank, and about three feet below the water over the plains on the left bank, and in the case of the other rivers there was an average difference of two feet, except on the upper course of the Yung-ting-ho where, when the floods were at the highest, there has been a difference of levels of over fifteen feet.



The above diagram show the levels on the right side of "Yung-ting-ho." When the levels of the Pe-tang-ho and the Pei-ho near Taku are made the same it does not of course mean that they were actually so but is only meant to indicate that they were both the lowest in the scale and that the water that came over the left bank of the Yung-ting-ho passed partly into the Pe-tang-ho and partly into the Pei-ho between Tientsin and Taku.

(IV.) CHINESE SYSTEM OF RIVER ENGINEERING.

It is always a difficult matter to deal with dangers that occur only at long intervals; if a plain can be cultivated in peace for twenty years there is on the part of the population a strong temptation to leave well alone and reap all the benefit that can be had during that time.

If it was a question of dollars and cents only it might he computed whether it was most advantageous to spend yearly the necessary amount for the maintenance of such works as would ensure permanent immunity from wholesale inundations or spend nothing but reap the full benefit of the good years and then of course being prepared to suffer when the unavoidable ruin arrived. This policy is very often followed by private

individuals when a risk is of so hazardous a nature that the insurance premium is so high that it is preferred to "take one's chance."

When however nations are concerned this policy is to be condemned because the strength of a government depends upon the stable and settled conditions under which its subjects live.

We know very little about the methods applied by the Chinese to their management of rivers; that they must have plenty of experience is undeniable, but whether records have been kept by which one generation may learn from the preceding one I do not know, but I think it is very likely; only none have tried to improve on methods that had been successful in former days when the facts may have been very different from what they now are.

The Chinese must always have been hampered by the want of accurate levelling instruments and knowledge of applied mathematics, probably also no large sums of money have ever been spent on experiments or in thorough investigations. More than anything else I think that the fact that such a river for instance as the Hoang-ho is under the management of several provincial governors, besides a director, must necessarily prevent any uniform measures being adopted.

Now in Europe and America it also happens that embankments give way, that the adjoining land and everything on it is ruined by water, and people drowned, but if it happens that a hundred square miles are flooded, fifty persons drowned and perhaps three or four thousand left destitute it is spoken of as a national calamity, the news flashed through the telegraphs to all parts of the world, while in China such a petty matter would be left to be dealt with by some local mandarin.

Partial inundations will happen now and then because in every part of the world there are people who neglect their duty, and because there is a limit to our experience and because combinations may arise that could not possibly have been foreseen when the plans for improvements were devised, but we can point to a steady advance in the degree of security in which populations occupying land exposed to inundations live.

It is however not by such general observations that I expect to convince those concerned of the errors of the present system of river management, but wherever I have travelled during the recent floods it has been my object to find instances of construction that were so obviously wrong and deficient that any person without the least knowledge of these matters could be made to see it.

I will begin with the Sao-san Canal that runs between a point a little above Ma-chang on the Huei-ho and a place on the Pei-ho near Taku.

This Canal is partly constructed for the salt traffic and partly, I suppose, to relieve the Huei-ho in time of floods; it is well designed, and would fulfil these purposes well if it were not for some bridges which are built across it.

Near the Huei-ho there is a bridge with four stone piers with grooves in which timber can be placed so as to act as a sluice when it is desirable to shut out the water of the Huei-ho during low water. The five openings under the bridge have an aggregate width of about eighty feet, about half of the width of the Canal itself, and the result is that the water in the Huei-ho is kept at a higher level than if there had been a passage of a proper width for the water. When I visited this place the water just above the bridge was about one foot higher than immediately below. There is another bridge of about the same pattern near Sao-san, with the same result of course.

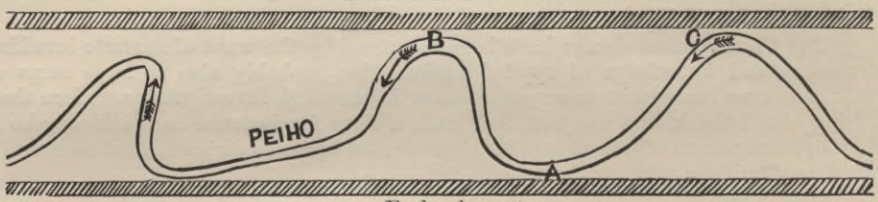
Here is a case of a Canal constructed at the cost of hundreds of thousands of Taels and then simply, in order to save perhaps ten thousand Taels, two bridges are built that,

for want of sufficient openings for the passage of the water, keep the Huei-ho during floods at about two feet higher level than if the thing had been done properly.

The principal means employed by the Chinese are of course embankments; it is the first and natural impulse when threatened to interpose something between one's self and the danger, and that is really all that Chinese embankments are; the provision that must be made in order to ensure other benefits from them, and make them more stable, have either not been understood, or they have been neglected.

The Pei-ho between Tientsin and Tung-chow affords a good instance of the system that has been followed.

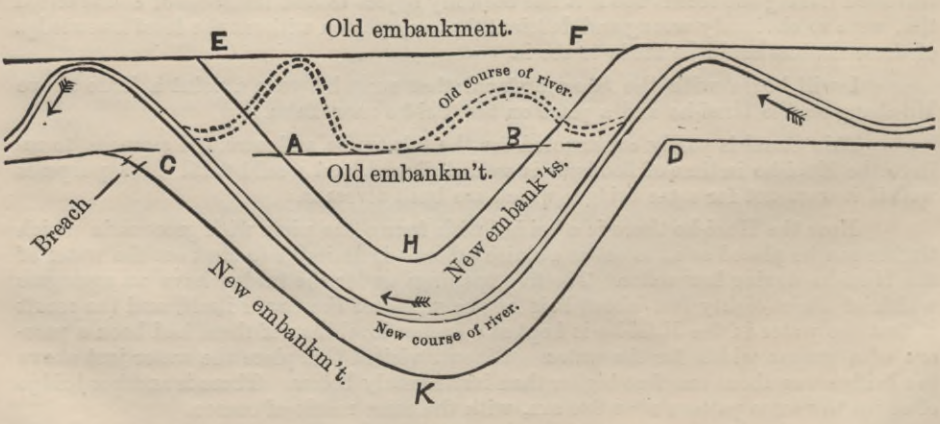
Embankments.



Embankments.

The above diagram shows better than any words how the facts are. The tortuous course of the river has not been followed, whereby the length of the embankments have been considerably reduced, and expenses reduced.

During floods there is of course every chance of a breach occuring at A, B or C. It is probably believed that when the whole of the space between the two embankments is covered with water the main current will be in the middle and run parallel to them, and of course if the floods lasted long enough this would happen, but in the beginning the low water channel will, with the exception of a "short cut" now and then made by the current, be followed by the main current, and endanger the stability of the embankments.



On the above diagram the dotted line shows the old course of the river, at a place beyond Ho-hsi-wu before it broke through its embankments between B and D and re-

entered it between A and C. New embankments had been constructed joining the old ones at C, A, B and D and short pieces of the old embankments had been left at C, A and B inside the new ones; when this year the water rose and covered the whole of the space between the embankments a whirlpool was of course at once formed in the corner at C, resulting in a breach.

Anybody going up to Tung-chow sees dykes running sometimes at a right angle to the course of the Pei-ho; Baron von Richthofen in his "China" thought they might be remnants of embankments of the Yellow river, when this river had its mouth somewhere on the coast between Taku and Shan-hai-kuan, but in every case that I have examined, they turned out to be nothing but obsolete embankments of the Pei-ho, like E, F, and A B on the above diagram.

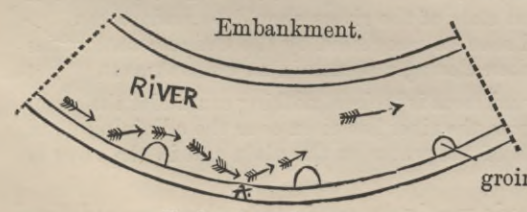
The distance between the embankments varies very much and is mostly considerably in excess of what it ought to be, thereby causing deposits to be made; no attention has been paid to providing a proper section of the river bed in time of floods, which should be uniform, capable of discharging the maximum quantity of water without the velocity of the current exceeding the figure at which the stability of the bed and the embankments is endangered or falling below that at which a too slow current would cause shoals to be formed.

What effect a suitable and uniform section of the bed has upon the maintenance of a uniform depth may be seen by anyone passing up the Huei-ho from Yang-liu-chin where it is scarcely possible to find a variation in the maximum depth of one foot.

By constructing the embankments of the Pei-ho and Yung-ting-ho so far apart in some places it has probably been expected that they would be less exposed, but every time the river is in a flooded state the mountain torrents that feed it will bring sand down which cannot be held in suspension where the section is too large and the current consequently too slow, but will form shoals and cause the bottom to rise.

The extreme consequences of this system I had an opportunity of seeing in the province of Shan-si on my way from Tai-yuan-fu to Fen-chow-fu, both of which are in the valley of the Fen-ho; the streams that come down from the mountain west of this river have been embanked, the embankments being very wide apart, and at present the bottom of some of them are nearly thirty feet above the plain. The road from Tai-yuan-fu to Fen-chow-fu crosses these streams, and it has been necessary to construct approaches, equally high; now and then an embankment is broken and the fields are covered with stones and coarse-grained sand; these calamities being of small extent only, one does not hear much about them; but a fertile and well cultivated field, close to another covered with stones and sand, left no doubt as to how it had occurred.

In the Huei-ho and other rivers the Chinese have attempted to protect the embankments in exposed places by short groins, jetties built of Kaoliang and secured by poles rammed into the ground, the object being to divert the current from the embankments, this of course can be successfully attained when the groins are not too far apart; but if the distance between two is in excess of what is correct, (which depends upon several circumstances) the groins constitute a danger to the preservation of the embankments; sweeping round the end of the jetty the current may, if there is space enough, return to a point A of



groins.

the embankment, and meeting it at a more or less acute angle, the attack is of course more dangerous than when as before the current ran parallel to it.

In some countries in Europe much use is made of projecting jetties or groins, in cases where the width of the river bed is excessive, and it is desirable to narrow it, but to make use of these constructions for the sake of protecting the embankments, when the width of the river is normal, is not a wise plan, because the uniformity of section is broken and a stronger current between the end of the groin and the opposite bank is created; the best thing to do would be to protect these parts of an embankment that are very exposed by a stone pitching or an apron of fascines.

The materials that at present are available in any considerable quantity for river embankments are: the alluvial soil of the plains, Kaoliang straw, reeds, and near the hills, stones. The alluvial soil varies very much according to the place; in the vicinity of the mountains it is very often sand. The Yung-ting-ho south-west of Peking has in some places embankments of almost pure sand that required a facing of rubble masonry, while at Taku it consists of fine silt with just the amount of sand that gives stability to clay without making it pervious to water.

As however during floods coarse sand may be carried even out to sea, the distance from the mountains is not a reliable index of the more or less sandy nature of the soil; and many are the exceptions to the general rule.

We know that at a certain velocity of current a river can keep in suspension and carry off materials of a certain specific gravity and size of grains, those that are of a small specific gravity and fine grained, for instance clay, are kept in suspension, even in still waters, for some time. As the fall on a river as a rule decreases from the hills towards the sea, we must expect to find stones and gravel close to the mountains, coarse sand further down, and on the lowest part of a river fine sand or clay.

These common-place remarks are necessary in order to understand the remedies that might be employed for improving the drainage and navigation, and of which I shall speak below.

In the Huei-ho, Kaoliang straw and reeds are much used for protecting the slopes of the embankments, which need it very much, as they are as a rule too steep, which makes it difficult to preserve them intact.

Very little has been done towards producing a grass vegetation on the slopes, though it is one of the cheapest and most efficient protections.

In the Sao-san Canal a piece of flat land, between the embankments and the channel, a little above the low water level, is planted with willows, which have been allowed to grow up to big trees, while they ought to have been cut near the ground, so as to yield shoots that might be employed in the construction of fascines; and besides the wind shaking the heavy tops of the trees, tends to loosen the earth round the roots.

Nothing better can be recommended to the Chinese than the planting of willows in all places where the soil is suitable, because enormous quantities will be required if in future any improvement of the present state of the rivers should be undertaken.

The usefulness of fascines would soon be recognized by the Chinese authorities if they only once had employed them when closing a breach in an embankment.

At the present time when an embankment is broken, nothing can under the usual circumstances be done before the water from the river has risen over the adjoining plain to a height when the difference of levels of the water on the plain and in the river is less than one foot.

As breaches during the recent floods mostly occurred while there was a differ-

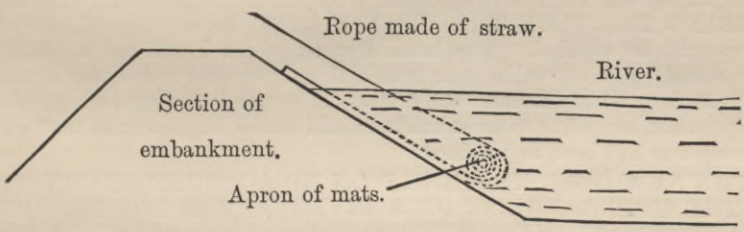
ence of four feet, enormous quantities of water must run out before anything could be done.

At present a breach in an embankment is closed in the following way. Two rows of poles are driven into the ground reaching from one end of the breach to the other, fascines made of Kaoliang or reeds are placed on each row of poles from the bottom of the water up to the surface, and the intervening space is filled with earth. For ramming the poles a stone is used, the men working, standing on a ricketty scaffolding, and ropes are attached to the poles to keep them in position during the ramming. It is easy to comprehend that this operation can only be performed when the current is not too strong, or in other words, when the difference in levels is not more than some inches, or in any case less than a foot.

When breaches occur, people are hurried to the spot, but they have the choice of patiently awaiting the moment when the difference of levels of the water over the plains or in the river has decreased to less than a foot, or of beginning work that will be washed away.

What one must wonder at, is not that so little is done, but that with the few and primitive means available breaches are so speedily closed as they are.

A most ingenious invention of the Chinese for protecting the slope of an embankment that is begining to give way during floods is the following. Mats of Kaoliang straw long enough to reach from the foot of the slope up above the surface are made. To the lower end some stones are secured, the whole is rolled up and ropes made of straw passed round it. The upper end is secured to the slope above water and by means of the ropes it is now lowered, rolling down under water until it reaches the foot of the embankment.



Similar aprons made of canvas weighed down at the lower end by lead, stone or other heavy materials have in hours of danger been made use of in Europe, but that the same thing can be successfully done with straw, shows that the Chinese with the scanty materials at their disposal, have known how to make the most of them.

At present the Chinese are much hampered in their movements when in time of floods men and materials have to be sent from one place to another to secure some imperilled part of the embankments, because as a rule these are not kept in sufficiently good order to serve as a road; if they had depôts where materials were stored; at certain intervals along the river, and had all these places connected with telegraph or telephones, help could at once be given to any place where it was required.

The few statistics that we have about the rainfall in the Provinces of Pechili and Shan-si seem to indicate that in most places there is twenty to thirty inches a year, and that much the greater part of that amount falls during one or two Summer months; as there is not much snow it is natural that the supply of the river varies considerably during one year. The Channels of the several rivers often are only capable of discharging a quantity that is considerably below the maximum requirement; new outlets to the sea or to the lower course of other rivers have been constructed. The Sao-san Canal

connecting the Huei-ho with the Pei-ho near Taku, and several canals between the upper part of the Pei-ho and the Pe-tang-ho have no doubt done some good in relieving the Huei-ho and the Pei-ho in time of floods, but nevertheless they are all of them failures. In the next chapter treating of improvements in the drainage, I shall discuss this matter at greater length.

(V.) REMEDIES FOR IMPROVING THE DRAINAGE SYSTEM.

The channels of the rivers of Pechili are no doubt inadequate for the discharge of the Summer floods, and it must be the object of future improvements to provide new outlets.

As a rule the policy is to avoid the construction of new branches, but to improve the existing ones or even close some in order to send the whole volume of water through one only, because it can be proved theoretically and has been proved by actual experiment that the resistance to the movement of a certain quantity of water is greater when passing through two channels than through one only.

In the present case, though the theory is of course equally correct, it can not advantageously be applied, because there are other circumstances that demand with more force that more than one outlet should be provided. The necessity of this is caused by the irregular supply to the rivers during the year; if only one channel capable of discharging the maximum quantity is maintained, it must necessarily silt up during low water, while if ONE CHANNEL OF THE CAPACITY REQUIRED FOR THE ORDINARY QUANTITY OF WATER, AND ANOTHER ONLY TO BE OPENED DURING THE TIME THE FLOODS LAST be constructed, the danger of silting up will be avoided. The latter channel which I will call a "Flood Canal" must be closed by a moveable weir which is only opened when the ordinary river channel is inadequate to discharge the floods. If it was left open during low water the silting up would, according to what has been said above, be greater in the two channels than if only one had been maintained.

THE NEW OUTLETS SHOULD ON NO ACCOUNT BE CONSTRUCTED FROM THE UPPER COURSE OF A RIVER TO THE LOWER COURSE OF THE SAME OR ANOTHER RIVER, as has been done in the case of the canals on the left bank of the Pei-ho connecting this river with the Pe-tang-ho, or the Sao-san Canal between the Huei-ho and the Pei-ho; but must be carried DIRECT TO THE SEA.

The water discharged into the Pei-ho by the Sao-san Canal, raises the level of the former, and diminishes the fall on this river above the point of confluence.

It is of course more convenient for navigation to have these flood canals or canals of relief connecting two navigable rivers instead of their leading out to the sea, but the same object might be attained without a great outlay if a branch with a lock was constructed between the canal and the river.

At present there is a canal from a point above Ho-shi-wu on the Pei-ho, another near Yang-tsun and a third a little above Tientsin. They have waste weirs which ought to be replaced by moveable needle weirs, because the level of the Pei-ho must rise considerably above the top of the weir before the quantity of water which the canals are capable of discharging can pass over the weir; it is true that this might be remedied by making the waste weir longer, but a moveable weir is for many reasons more desirable, for one thing because it admits a perfect control over the flow of the water.

Beginning with the Huei-ho I shall now state the measures that I consider

would materially improve the drainage and navigation; these two objects are so closely connected, that though I treat of the latter in a special chapter, it is impossible to avoid allusion to it when discussing the question of improved drainage.

We have seen above that the Huei-ho, even in a flooded state, kept its depth uniform for hundreds of li above Tientsin, and that the suspended matter in its water was fine silt, consequently it is of importance not only for the navigation of the Huei-ho, but also for the Pei-ho between Tientsin and the sea, both as regards the maintenance of a channel of the greatest possible discharging capacity, and for avoiding the formation of shoals, that any direct outlet between the Huei-ho and the sea should only be opened when the former is in a flooded state, but closed when there is low water.

AT TSANG-CHOW about two hundred li up the Huei-ho there are at present several branches that connect the river with the sea. A CANAL OF SUCH CAPACITY THAT IT COULD DISCHARGE THE WHOLE SURPLUS OF WATER OF THE HUEI-HO AND THE SIA-HO SHOULD BE CONSTRUCTED DIRECT TO THE SEA, and in order that it should not silt up, it must be closed during low water by a moveable weir. This canal should not be made use of for draining the plains between Tsang-chow and the sea, as it then would be difficult to keep it in good order and prevent it from silting up; it might also be found necessary to close it near the sea, against the tide.

THE SIA-TZE-HO OR SIA-HO should be put in connection with this canal by another; on the map I have shown the proposed new Canals by a thick dotted blue line.

Similar canals have been constructed, but after a time they have proved failures, because they have not been put in direct communication with the sea, and they have been allowed to silt up, either from their not having been closed when there was low water in the rivers, or because the surface water from the surrounding plains had been admitted into the canals, and as such water washes down great quantities of alluvial soil, which owing to the slow current is deposited before reaching the sea, a gradual silting up takes place, and when exceptionally heavy floods happen the canal has not the required capacity for discharging the surplus water.

THE TA-CHING-HO (Chang-tze-ho or Pao-ting-fu river) which passes through several lakes where the suspended matter is deposited, has, to reckon from its confluence with the Hun-ho, twenty li northwest of Tientsin to within fifty li of Pao-ting-fu, a rather uniform depth; occasional shoals being only found in places where it receives the water of some small streams, or when, as was the case during the recent floods, water from the plains passes over the obliterated banks into it.

The water of the Ta-ching-ho being free from sand, except when the Hun-ho has brought a quantity down during a heavy flood, it is of the greatest importance that in any scheme for improved drainage and navigation that the Ta-ching-ho like the Huei-ho and Sia-tze-ho should not be diverted from its present course joining the Pei-ho at Tientsin. The water of the Pei-ho is for much the larger quantity due to the three above named rivers, and only a little part of it comes form the Pei-ho above Tientsin.

THE HUN-HO OR YUNG-TING-HO joins the Ta-ching-ho some twenty li from Tientsin and on some Chinese maps, other channels between the two rivers are shown, but owing perhaps to their banks being obliterated by the floods, I could find no trace of them.

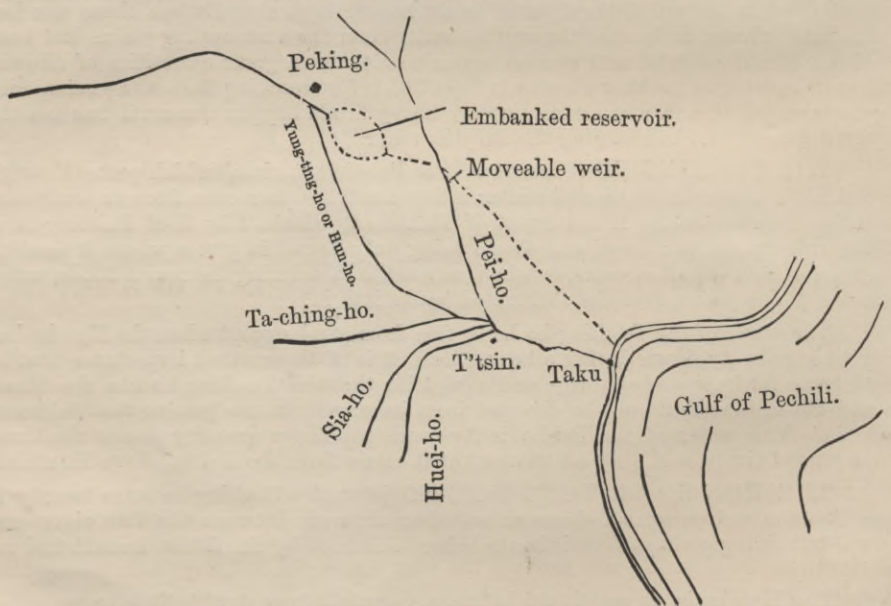
The Hun-ho is, as mentioned before, a mountain torrent with little or no water during much the greater part of the year; and immediately after heavy rains it becomes a roaring river, two to three thousand feet wide, bringing down from the hills enormous quantities of stones, gravel and sand.

This river presents the greatest difficulties, mainly because the distance from the

point where it issues from the hills to the sea is so great that it is scarcely possible to prevent the gravel and sand from being deposited before it reaches the sea, and if it be allowed to pass into other rivers they will be polluted.

There are only two remedies that can advantageously be employed, PLANTATIONS ON THE HILLS through which the river flows, by which if it is done on an extensive scale, the rainfall would be more equally distributed throughout the year, and the protection of the slopes of the hills by vegetation; the rain would not wash stone, gravel and sand down into the river, at least not to such an extent.

If such plantations are not practicable or insufficient, a large EMBANKED RESERVOIR must be constructed, probably somewhere south of the Imperial Park, in which gravel and sand could be deposited before it reaches the Ta-ching-ho and the Pei-ho. That at present the bad effects of the Yung-ting-ho on the Pei-ho are not much more felt is due to its nearly always breaking through the embankments and emptying itself into the plains where the sand and gravel are left behind; to construct an embanked reservoir is in fact nothing but restricting the water when running over the plains to a certain area. From this reservoir the Hun-ho should not be allowed to join the Ta-ching-ho, as it does now, twenty li from Tientsin because the Pei-ho below Tientsin is not capable of discharging the united supply from the Ta-ching-ho and the Hun-ho, when they are both in a flooded state. It is true that if the reservoir was made of a sufficiently large area it would to some extent equalize the flow of the Hun-ho or Yung-ting-ho, and the effect of this might be such as to render unnecessary a new outlet to the sea, which could only be made by leading the Yung-ting-ho, when issuing from the reservoir, over to the Pei-ho and connecting both directly with the sea.



On the above sketch the embanked reservoir is shown south-east of Peking, but the exact spot where it should be constructed is a matter that would require levelling operations not yet undertaken. It is superflous to say that the dotted line represent-

ing the new canal over to the Pei-ho and thence to the sea is merely drawn to illustrate the idea. The moveable weir on the Pei-ho would always remain open, except during floods, when the weir on the canal from the Pei-ho to the sea should be opened, while being closed the rest of the year.

Unlike the Huei-ho, Sia-tze-ho and Ta-ching-ho the Pei-ho after heavy rains brings down as far as Tientsin and further sand that forms shoals, so if the above proposal was found practicable the weir on the Pei-ho would exclude the water containing sand in suspension from reaching the lower course of this river, while during the greater part of the year the water containing only fine mud would be admitted and would, during the low water season, contribute to the maintenance of the proper size of the bed of the Pei-ho between Tientsin and Taku.

The canals on the left bank of the Pei-ho which connect more or less directly this river with the Pei-tang-ho, should, for the reasons stated above, be put in direct communication with the sea, and all of them should either have moveable weirs constructed across them, or the existing weirs should be arranged so that it should not be necessary for the water of the Pei-ho to rise much above the top of the weirs before the canals were taxed to their full capacity. If it was desired that they should be used for navigation, the weirs could be supplied with locks.

A little above the confluence of the Huei-ho and the Pei-ho there is a canal from the latter to the Pei-tang-ho; this canal has no weir across it, and therefore during low water its effect is bad, as it absorbs a good deal of the water from the Pei-ho which otherwise would serve to maintain the channel of the latter between Tientsin and the sea; this canal ought therefore also to have a weir and lock constructed, somewhere near its junction with the Pei-ho.

The course of the Pei-ho is very tortuous; and with regard to the part that is above Tientsin and not influenced by the tide on the bar any cutting of bends would tend to increase the current and consequently lower the average depth in the river, and might also contribute to endanger the stability of the banks, and as the traffic with boats is very considerable the improvement in draining capacity that would be obtained by cutting some of the bends would probably be more than counterbalanced by the other inconveniences that would result therefrom.

(VI.) IMPROVEMENTS IN THE NAVIGATION OF THE TA-CHING-HO AND THE PEI-HO.

The Ta-ching-ho connects Pao-ting-fu with Tientsin, and most of the goods traffic between the two places goes by boat. From its confluence with the Pei-ho just above Tientsin the Ta-ching-ho is for some twenty li shallow and full of shoals owing to the Hun-ho which joins the former twenty li from Tientsin; but as soon as the mouth of the Hun-ho is passed the navigation is easy with five to ten feet of water and a weak current.

So it goes on until the so called Pao-ting-fu lake is reached; this lake is merely a low marshy ground which is more or less dry according to the season of the year. The river has its proper channel through the lake, and which is always followed by the larger boats.

From the lake and to within fifty li of Pao-ting-fu the river is from five to seven feet deep, with a weak current. From here the country is undulating and the river flows between banks twenty feet high. From the end of the rainy season there

is very little water in this section, and the water is retained by seven sluices of the usual Chinese pattern. At certain times of the day, or rather when the basin above the sluices has enough water, the timber forming the sluice gate is removed to allow the boats to pass, the passage down being rather dangerous, and the passage up very toilsome, as the difference between levels above and below is sometimes as much as two feet.

Of course the opening of the sluice for half an hour or so nearly empties the basin above, and it is therefore necessary to replace the timber, and wait for several hours before any boat can pass again, and even then two feet of water seems to be the maximum depth attainable with the present system.

Properly constructed locks would avoid this waste of water, the passage of boats would become easy, and it would be very easy to maintain a minimum depth of six feet or even more, no embankments would be required even when raising the level of the river another ten feet, as the natural banks of the river are over twenty feet high. Boats could pass through at any time; and a single man would be able to work the gates of each lock of which only three or four would be required, while with the present system a dozen or so are necessary for the removal of the timber put across the opening.

A proper towing path should also be constructed and kept in repair; at present there is a path for some part of the way, but as a rule none, or a very inadequate one.

If some arrangements be made for putting the twenty li of shallow water near Tientsin in proper order, which could be done by separating the channel of the Ta-ching-ho from that of the Hun-ho, and an occasional dredging on some part of the upper course of the former river, an excellent communication by water with Pao-ting-fu would be created without any great outlay.

Before adopting any measures tending to improve the navigation of the PEI-HO it must first be decided whether it is intended to undertake works that would simultaneously benefit the drainage and the navigation; in fact whether any of the above mentioned proposals have any chance of ever being carried out. If this was intended we have seen that the sand from the Hun-ho and the upper course of the Pei-ho when in a flooded state would not reach Tientsin, while by closing all the canals on the left bank of the Pei-ho above Tientsin, especially the one from Tientsin to Pei-tang-ho, and the Sao-san Canal during low water, the quantity of water of the Pei-ho would be considerably increased during the low water season, and all of that water would contain no matter in suspension except fine silt. If the occasional inrush of sand from the Yung-ting-ho or Hun-ho, and from the upper course of the Pei-ho into the lower course below Tientsin was permanently stopped the formation of shoals would be a thing of the past, and if furthermore the whole quantity of water rightly belonging to the Pei-ho was led into it, a depth in excess of what is required, the desired depth being dependent upon the height of the tide over the bar, could be obtained.

The Pei-ho below Tientsin receives or ought to receive the drainage of an area of over fifty thousand square miles, and though the supply owing to the unequal amount of snow and rain that falls is rather irregular it is quite sufficient for maintaining a channel eleven feet deep.

No important changes in the bends of the Pei-ho (when speaking of the Pei-ho I mean now, and in the following pages, the river between Tientsin and the sea) have taken place during this century. Comparing a map made by the surveyors accompanying Lord Macartney's embassy in the last century I could scarcely see any difference at all, and all changes in the bottom could in every case if properly investigated be shown to be the immediate result of a change in the condition of the rivers that have their confluence above Tientsin.

In a memorial to the throne His Excellency Li Hung-chang reported that when in the spring of this year the snow in the mountains melted, the water in the Yung-ting-ho or Hun-ho at once reached a depth of seven to eight feet and a breach in the embankment was only prevented by great exertions on the part of the authorities. I have above mentioned that the width of the Yung-ting-ho is, at a little distance from the point where it issues from the hills, between two and three thousand feet; fortunately for the inhabitants of the plain near the river, but unfortunately for the navigation of the Pei-ho, this enormous quantity of water was prevented from running into the plains where the sand would have been deposited; instead of which it reached by way of the Ta-ching-ho the Pei-ho and caused all the trouble there.

If anybody wishes to see the result of this flood they need only pass into the Ta-ching-ho a little above Tientsin and go on for about twenty li when one of the branches of the Hun-ho or Yung-ting-ho is reached; on these twenty li there was (22nd August) in some places next to no water while in 1889 when I passed the same way there was certainly not plenty, which there never will be as long as the Hun-ho or Yung-ting-ho is left in it present state, but much more than this year.

The new shoals formed could not be due to the recent floods because the Yung-ting-ho or Hun-ho broke through its embankments into the plains south of Peking.

As a rule the channel of the Pei-ho is deepened when in the early spring the ice is broken up, in other years the silting up begins at that time; this seems strange. The popular theory is that the ice covering the surface produces a scour by keeping the water down and preventing it from rising, this is of course absurd as the specific gravity of the ice is less than that of the water and any rise of the water would have the same effect on the ice.

The facts are of course the same here as in any other river that receives part of its supply from the melted snow. If great quantities of snow fall during the winter and then in the early spring there is a sudden change from frost to mild weather a torrent carrying gravel and sand down from the mountains is at once created; if the banks of the rivers are broken the water runs into the plains, sand and gravel are deposited and the water comparatively pure will when reaching the Pei-ho strengthen the current and produce a scour; if the embankments of the Hun-ho or Yung-ting-ho remain unbroken sand is necessarily carried into the Pei-ho and deposited in the first place where the current is weak, for instance in any widening of the river where owing to a too large section the velocity of the current has decreased.

If on the other hand no great quantities of snow have fallen during the winter and the change from cold to mild weather has been gradual, there will be a more gentle stream running down from the hills, less coarse materials and a smaller quantity of sand will be carried down the river and before it has reached Tientsin it will have been deposited; because with the smaller quantity of water the current is weaker in the Yung-ting-ho. All that has here been said about the Yung-ting-ho or Hun-ho applies also but on a much smaller scale to the upper section of the Pei-ho above Tientsin.

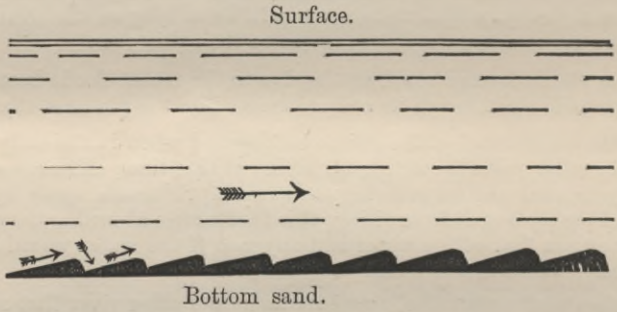
We now come to the question: "How to improve the navigation of the Pei-ho without having any regard to the other rivers." We need then not trouble ourselves about causes, but simply take the facts as they are, viz: The Pei-ho is for years navigable for sea-going steamers of eleven feet draught and then suddenly in the early spring or after the rainy season shoals consisting of fine sand are formed in some parts of it reducing the depth of water sometimes to about seven feet. I have no information at my disposal from which I can draw any conclusions as to whether on the whole length of its course there is a decrease of depth, or only in certain places, but remembering the

way in which the shoals were formed I am inclined to believe that investigations would show that there is no such general silting up.

Looking at the matter superficially only, it might have been expected that the increased current caused by the recent floods, in any case during the first part of it, would have removed the shoals.

Suppose that the first shoal was formed when the velocity of the current near the bottom of the river was half a foot per second, and then when the floods came it increased to say five–eights of a foot, no real scour would take place, but the following would happen.

By actual observation it has been found that on a bottom covered with sand a current a little stronger than that at which the deposits were formed will not directly carry away the sand but will produce an onward movement along the bottom, as shown by the diagram.



The small arrows show the movement of the sand, the current carries it up the inclined plain, a couple of inches in length, thence it falls down, is again carried up the next incline and so on. As the current increases the movement is quicker and at last the sand is carried directly away in suspension. These ripples of sand I saw on the upper course of the Pei-ho when the floods had subsided.

At the same time as the current increased when the floods first came on last year the water kept coarser sand in suspension which was deposited when reaching a place where the current, owing to a too large section, had decreased, so at the same time as the level of the surface rose the bottom rose too; and it is only now that the supply to the Pei-ho comes from the plains and consequently is clearer that improvement may be expected, and in order to assist the scour, the Sao-san Canal, and the canal from Tientsin to Pei-tang-ho should be closed at once.

Is the sand of which the shoals consist deposited again in a lower part of the river or is it carried out to the sea? If it goes out to the sea all is well as far as the river is concerned, if it does not we must examine whether anything would be gained by its merely being shifted from one place to another.

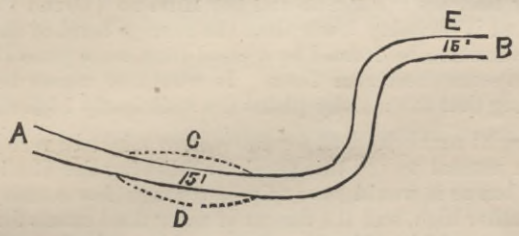
At first sight it seems that the obstruction had only changed place, but that is not so, the sand having been deposited on account of the current being too weak to keep it suspended it will if put in motion by a stronger current again form a shoal whenever the current, owing either to a too wide section of the river or to the direct loss of velocity caused by bends that force the water to take a new direction, is weakened.

Now the Pei-ho as far as Tientsin is influenced by the tide on the bar, and its action is stronger the nearer we are to the sea, therefore there is more reason to expect

that deposits formed lower down the river may be carried away again by the ebb current resulting from some tide when the difference between high and low water was exceptionally large, which again would produce a strong ebb current; there are other reasons why it is easier to deal with shoals lower down the river, but the explanation of which would lead us into calculations which are out of the scope of this paper.

Suppose there was a scour of one foot in the Tientsin reach and that the sand was deposited again in some other place where there was formerly say twelve feet of water, which now was reduced to say eleven feet, it is then evident that the area of the section of the river bed must in the latter place decrease, and as the same quantity of water as before must pass an increased current would result and a velocity would soon be reached where the strength of the current would prevent any more deposits from being formed; if this limit was reached before the place became too shallow something would be gained.

The river has generally depths considerably in excess of twelve feet, and there is every indication of the shallow places being due to local defects; it need not be feared that that part of the river which is now say fifteen or twenty feet deep would in turn be obstructed if the shoals were removed. Suppose a certain part of a river has a uniform width from A to B, and a depth of say about fifteen feet.



If the river is widened at C-D according to the dotted lines and the current carries matter in suspension that at a lower velocity is deposited, the depth of fifteen feet in this place cannot possibly be maintained, because the current will, owing to the larger section, decrease, the quantity of water that passes remaining constant.

If now again we reduce the width at C-D to the normal one the state of the river is the same as before the widening of the channel, consequently the shoals at C-D will be carried away and not be deposited anywhere else between A and B. In order that new shoals could be formed it would be necessary that the suspended matters of the current should be of a coarser quality or that a general reduction in the velocity of the current should take place.

We now come to treat of the Pei-ho as a tidal river. The effect of the tide on the bar is felt as far as Tientsin causing a rise and fall of a foot or somewhat more. The consequence is that when the ebb tide begins running it is considerably stronger and produces a stronger scour than if the current was due to the water of the Pei-ho alone.

The distance from Tientsin to Taku is about fifty miles by river while in a straight line it is only thirty or less; the effect of the tide would be more felt for each bend that was cut, because not only the distance would be reduced, but the resistance of the tortuous river to the movement of the water would also be less.

In order to get the full advantage of the tide the river ought to become wider as gradually it approaches the sea, as this form is the most advantageous for the propagation of the tidal wave.

The many canals constructed from the left and right bank of the Pei-ho absorb of course a part of the tidal water, whereby they diminish the scour in that part of the river which is above the mouth of the Canal. It will require an exact survey of each canal before it is possible to say anything definite as to how far they are detrimental to the maintenance of the depths of the Pei-ho.

Another thing that must be done is to study the influence of the different tides on the rise and fall of the Pei-ho all along the river, whereby it will be possible to arrive at an approximate idea of what increase in the rise and fall may be expected by shortening the course of the river a certain number of miles. The difficulty in making the Pei-ho navigable is not that of engineering, but the selection of improvements that will cost the smallest amount, and to come to a result in this matter it is all-important to find out whether the shoals now in existence are due to local defects such as a too large section of the river, defects that could be remedied by local improvements such as training walls etc., etc., or whether a stronger ebb current is absolutely necessary to keep the river free from shoals in which case some bends must be cut and the canals closed. Probably a scheme containing some works that would locally improve some parts of the river and others that would produce a stronger ebb current will be found the best remedy.

The country between the Pei-ho and the Huei-ho (Grand Canal) in which the Ta-bo lake is situated is probably lower than the average level of the former river near Tientsin, it should therefore be drained by a canal from some place above the Ta-bo lake direct out to the sea somewhere near Taku. It would of course be necessary first to ascertain by levelling that the marshy plains are sufficiently high above the sea.

By such a canal much land fit for cultivation might be reclaimed. It might at the same time seem natural to use this canal for relieving the Huei-ho (Grand Canal) in times of floods, but as it would have to pass through low country its embankments would have to be rather high, and the danger of using flood canals for draining purposes or rather the reverse, would be objections that would require investigations on the spot before such a scheme could be adopted.

RESUMÉ OF PROPOSED IMPROVEMENTS.

1° To relieve the Huei-ho (Yü-ho or Grand Canal) and the Sia-ho (Sia-tze-ho) a flood canal from the latter to Tsang-chow on the Huei-ho and thence direct to the sea should be constructed. This canal should be closed when the floods were over in order not to silt up during low water. The canal should for the same reason not be used for draining the country through which it passes.

2° No canal, for instance the Sao-san Canal, should be allowed to be open when there is low water, but all the water from the Huei-ho and the Sia-ho which is exceptionally free from sand should be kept together until it reaches Tientsin because it will contribute to keeping the Pei-ho free from shoals.

3° Two of the bridges on the Sao-san Canal should because of their obstructing the passage of the water be replaced by two more suitable.

4° The Ta-ching-ho (Chang-tze-ho or Pao-ting-fu river) should be made navigable as far as Pao-ting-fu for boats of at least six feet draught by the construction of three or four locks on the section of the river next to Pao-ting-fu.

5° A large embanked reservoir should be constructed through which the Yung-

ting-ho should pass and where the enormous quantity of stones, gravel and sand brought down from the mountains might be deposited.

6° If a survey showed that it would not be attended with great difficulties the Yung-ting-ho should be led over to join the Pei-ho somewhere above Tientsin and thence a direct outlet to the sea should be made, and in order not to get the sand from the Pei-ho when in a flooded state down into the lower course of the same river, a moveable weir should be placed across the Pei-ho immediately below the point of confluence.

7° The canal from Tientsin to Pei-tang-ho should be closed by a moveable weir and a lock.

8° The construction of embankments should be improved and vegetation produced on the slopes.

9° Planting of willows should be undertaken.

10° An arborization of the hills should be attempted.

If it is not contemplated to execute any other works than putting the Pei-ho between Tientsin and the sea in such a condition that the steamers could get up to Tientsin, the following are the measures proposed.

1° By cutting some of the bends and thereby shortening the distance and reducing the resistance to the propagation of the tidal wave up the river to increase the effect of the ebb tide.

2° To construct training walls in places where the river is too wide.

3° To close the canals (Including the one previously mentioned under section seven) the extent to which these measures should be carried out to depend upon and to be determined by a detailed survey.