26.4 Channel stabilization plan

26.4.1 Basic policy of stabilization countermeasures

The following are the basic directions of the channels stabilization measures:

1) To maintain the present route of the mainstream to secure water depth at the existing and planned ports, waterways, existing irrigation water intakes, and other vital infrastructure including the Duong River. As the expected route of the main stream, **Figure 26.4.1** shows the basic sinuosity of the Red River channel.
2) To construct stabilization facilities step by step, confirming the effect of the facilities, assessing the necessary measures to be executed in the next step. Monitoring bathymetric/topographic surveys, at least twice a year, are prerequisite to this planning and execution works,
3) To laid aside facilities, which are to be executed carefully or not necessary for the waterway.
4) To give priority to the facilities identified to be urgently required, and
5) Others.

26.4.2 Intensions of countermeasures

The fundamental data and results of analyses include the recent change of morphology from 1999 to 2002 shown in **Figure 26.4.2**, trend of erosion/accretion predicted by numerical simulations, for example, shown in **Figure 26.2.5 (2)**, dredging requirement shown in **Figure 26.3.1**, and others.

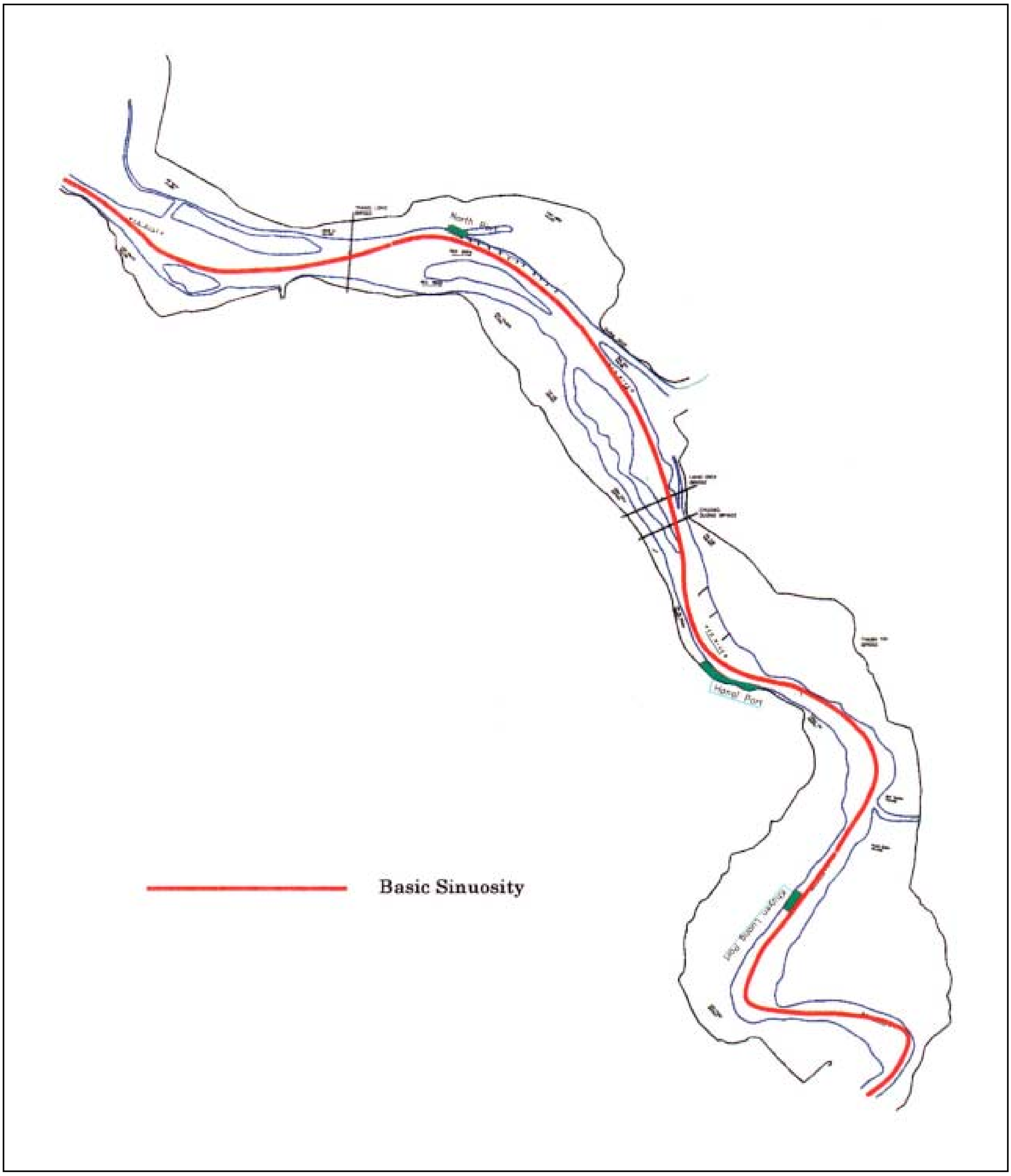
The following are the basic issues in relation to the planned the proposed countermeasure facilities:

1) To guarantee a safe and stable IWT navigation channel according to the design depth (d = 2.5 m and d = 3.6 m) and width (w = 150 m)
2) To secure water supply to the Liem Mac Culvert
3) To secure water depth in front of the new Hanoi North port and to prevent sediment accumulation in the channel behind Tam Xa bank
4) To secure the discharge distribution between the Red River and the Duong River

5) To stabilize the channel between Tu Lien-Trung Ha Sand Bar and Bac Cau Commune, and prevent cut of Tu Lien-Trung Ha Sand Bar
6) To secure water depth in front of the Hanoi Port and protect neighboring upstream portion form failure of slope
7) To secure water supply to the Bat Trang Culvert
8) To avoid excessive increase of water level during the flood season
9) To avoid excessive current speed, specifically in front of Hanoi Port, Khuyen Luong Port and the new Hanoi North Port, which does not hinder efficient operations of berthing and un-berthing
10) Others

For long-term subject, the following issues are taking into consideration:

1) To train the direction of incident current direction upstream the Thang Long Bridge by streamlining the current along the Right Bank (near Lien Trung Village) Vong La Sand Bar,
2) To protect the Hanoi Port from intrusion of Thach Cau Sand Bank,
3) To prevent the water flow to concentrate into the secondary channels (e.g. South of the Phu Xa sandbank or West of Tu Lien sandbank)
4) To stop further meandering at downstream below Khuyen Luong Port, and
5) Others



Source) JICA Study Team

Figure 26.4.1 Basic Sinuosity of the Red River Channel

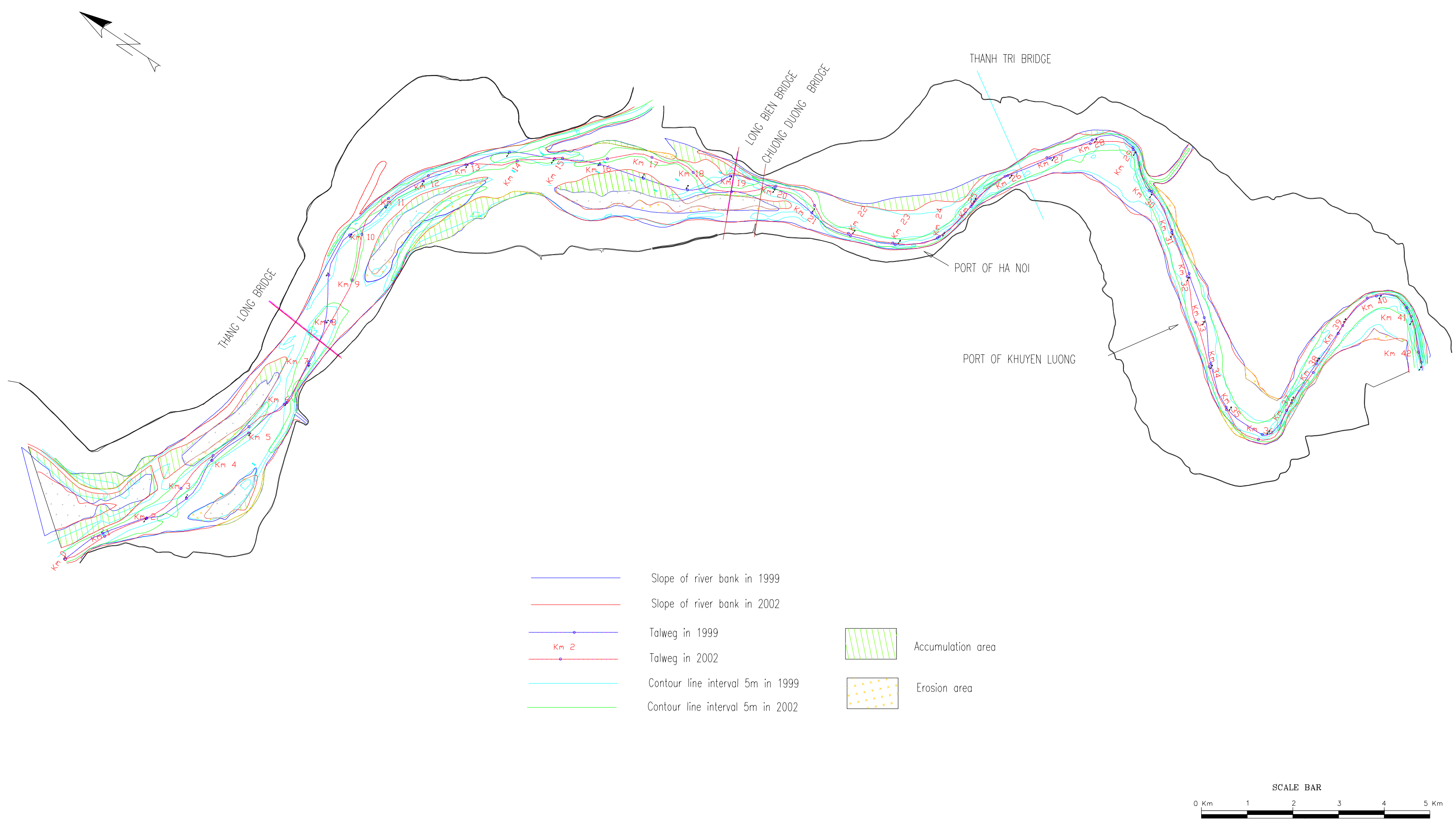


Figure 26.4.1 Trend of Erosion / Accretion from 1999 to 2002

Source) JICA Study Team

26.5 Means of river regulation works

26.5.1 River training facilities

(1) Groin fields

One of the methods of protecting a bank is the construction of series of groins or spur-dikes to guide the flow, thus avoiding strong currents along the bank. For this, the determination of the distances between the structures is of the utmost importance. Experience obtained from similar cases in the same river may be useful. Recent investigations have shown that the problem can also be treated theoretically.

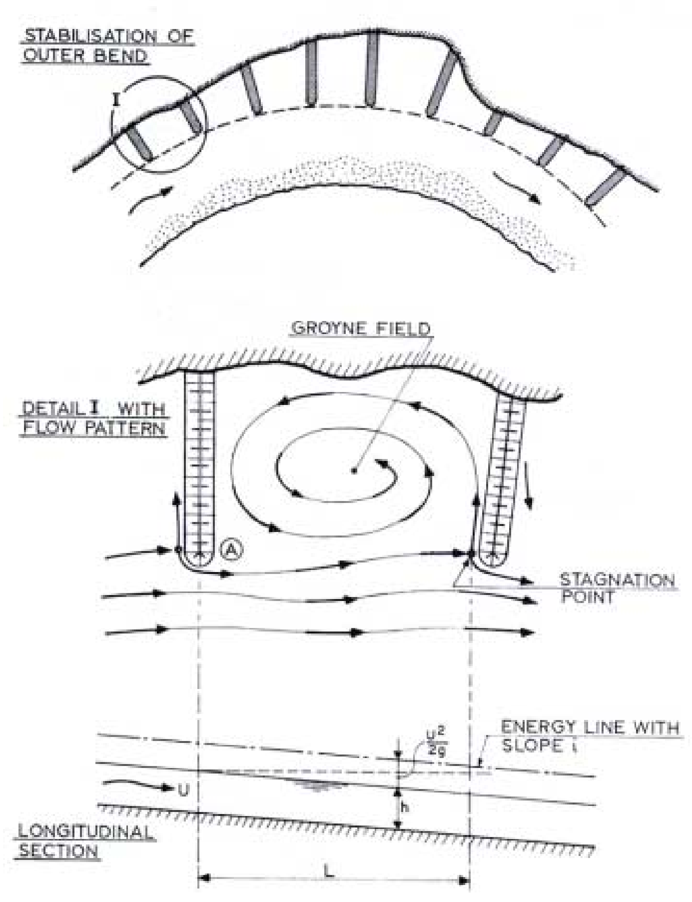


Figure 26.5.1 River Bank Stabilization with Groins

In **Figure 26.5.1** stabilization of an outer bend with series of local structures (groins) is shown. The application of these local structures rather than longitudinal structures is only economically justified if the distances between the groins are large, yet they retain their guiding function on the main flow of the river. This guiding function will be best fulfilled if there is one strong eddy between each pair of groins. This wish restricts the length L of the distance between the groins because the stability of one eddy is governed by the factor $2gL/C^2h$ in such a way that this factor shall never exceed unity. This rule follows from the assumption that the backward flow in a confined eddy is only possible if the level of the water surface in the stagnation point of the downstream groin is higher than the water level at point A of the upstream groin.

This means that the energy loss iL of the river flow between two groins (mainly due to bottom friction) has to be smaller than the velocity head $U^2/2g$. Hence it follows that

$$\frac{2gl}{C^2h} < 1$$

C : Chézy friction coefficient ($m^{1/2}s^{-1}$)

This rule has been tested by model investigations in circular basins. The tests gave values of $2gl/C^2h < 0.6$ for a strong eddy. (The depth h is that at mean discharge). For example, with a water depth of 5 m and a Chézy coefficient of 40 $m^{1/2}s^{-1}$ a distance $L < 240$ m should be chosen. Because of the rather idealized shape of the test basins, however, it is advisable to use a lower limit in practice. Other factors which influence the strength of the eddies are the bottom friction and depth in the basins between the supports (groin fields).

(2) Training walls

More complicated problems may be encountered when channel regulation is to be undertaken for a braided river in which series of bifurcations and confluences divide the flow into two or more channels which are separated by islands. Such a river is not stable; seasonal variations may result in fluctuating bed levels and shifting channel patterns. This instability may adversely affect navigation, water intakes, culvert outflows, etc. It would certainly be possible to stabilize each branch by channel fixation, but often it is preferred to concentrate the river into a single stable channel.

As in the previous example of the short-cut, two different methods can be applied. A direct but expensive method is dredging one of the channels to the depth and width of the unbifurcated reaches, giving it a suitable alignment, eventually stabilized by bank fixation, and immediately afterwards closing the other channel(s). This improvement will only generate morphological processes of a minor nature.

If low-water bed regulation is contemplated for a braiding river, in many cases there is no other option than to close one or more channels in order to pass all low-water discharge through the navigable (main) channel. Channels can be closed permanently by means of a closure dam but also partly by means of a weir construction. This weir acts as stage regulating device and it will be overtopped permanently or only part of the time.

A cheaper method consists of closing the channel(s) with a training wall to be abandoned and leaving the development of the remaining channel to natural scouring. During that process the eroded sediments will temporarily settle downstream of the reach, when in the reach and upstream of it the water levels will be raised until equilibrium is reached. This will cause aggradation in the reach influenced by backwater effects.

If it is anticipated that the morphological processes described will develop too fast and will hinder proper discharge, those processes can be retarded by closing the channel(s) gradually by placing open-pile clumbs or low weirs.

Channel regulation in a braided river where only one channel is abandoned, induce strong erosion of the remaining channel, resulting in substantial aggradation downstream. If this long-lasting process is not desirable, additional dredging may be an attractive alternative solution.

It is clear that a method must be selected from various alternatives. This means that decisions have to be made on whether or not additional dredging should be carried out, whether the channels to be abandoned should be closed directly or whether a slower process should be chosen making use of pile-clumbs or obstacles of that nature. To arrive at such decisions the various aspects – navigation, floods, speed of adaptation – have to be carefully weighed up.

(3) Sills and weirs

Sills are defined as low dams which will be overtopped regularly. Such a sill may consist of a filter construction comprising filter layers of different gradings; a bed protection mattress comprising geotextiles, fascines and stone ballast; a low broad-crested dam of rock placed on a bed protection mattress; a concrete slab or slab made of stone masonry.

The crest height of the sill or weir is determined by

- the requirements for stage regulation (rate of cutting off the secondary channels)
- the part of the overall discharge which should pass over it when the river is in spate.

A weir (or barrage) is normally built in a river for the purpose of stage regulation upstream. The extent of overtopping (duration, height) will depend on the hydrograph of the river, the dimensions of the weir and the water flow conditions. A fixed-crest weir can have the shape of a small gravity dam built of concrete or stone masonry. It can, however, also have the shape of a broad-crested dam built up of selected rockfill.

The crucial point is here the manner in which rockfill has been placed. If the weir has been constructed in the dry, an open-type revetment structure can be built in which stones are interlocked. More critical are weirs which are made of riprap. Here a very gentle downstream slope will be required as well as stones of more or less uniform size. Such weirs will be built in the dry when regularly-shaped stones are lacking.

When a weir has to be built in the wet, a low dam of dumped rockfill is the only possibility. It may turn out difficult to close such a dam unless the water can temporarily or partly be diverted. Usually such a weir of dumped rockfill, after construction, needs some reshaping. Care must be taken to use stones of more or less equal size all having a certain minimum weight. Smaller stones will be removed by the current and larger stones will roll down the slope as they stick out too much.

The increase of flow attack during construction in the wet of the sill/weir is accounted for by gradually using larger stones. Final closure can be realized by constructing closure bunds on top of the sill, simultaneously from both sides. During final closure the flow attack on the top layer of part of the sill still open increases. Therefore the largest stones will be necessary at the final stage, in the center of the gap.

26.5.2 Hydraulic characteristics and training philosophy

(1) General

For the Red River Ha Noi section the following can be observed and lays the basis for river regulation works w.r.t. IWT:

- Between the Thanh Long Bridge and the (planned) Thanh Tri Bridge the river is a double (or even triple) channels system. Upstream and downstream of this part, is a single-channel system;
- The hydraulic section downstream Thanh Long Bridge increases significantly to reach a minimum at the Duong River entrance.
- The ratio of the average hydraulic section, Sh (m^2), to the water discharge, Q (m^3/sec), or so-called "Sh/Q ratio", shows a progressive increase between the very upstream part (section 1) and the Phu Xa, Tam Xa area (section 3). (see **Figure 26.5.2**);

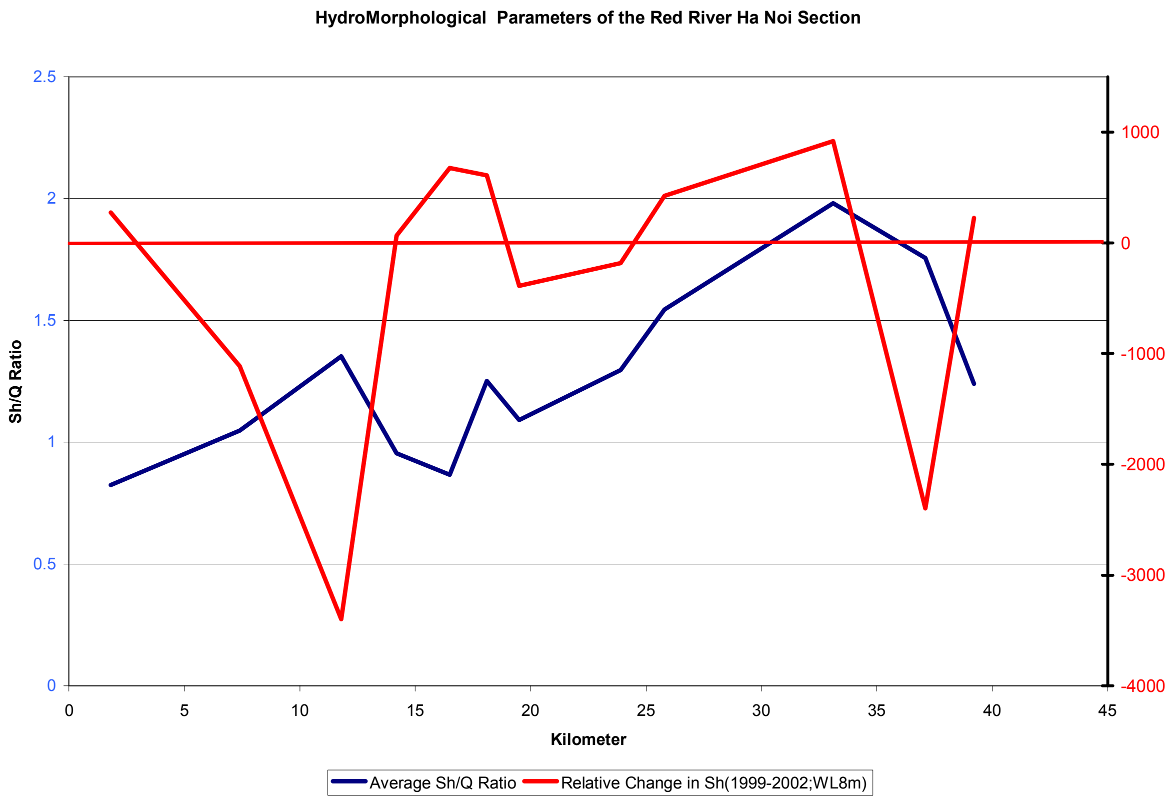


Figure 26.5.2 Hydromorphological parameters of the Red River Ha Noi Section

- A similar increase in Sh/Q ratio is observed downstream the Duong River Entrance (section 4) and the very downstream part (section 9);
- Parallel to this can it be observed – from the recent (1999-2001) morphological evolution – that the hydraulic sections at Phu Xa/Tam Xa (and to some extend at Ver Phuc) have been decreasing: this means sedimentation;
- The River Section in Ha Noi has historically yet been constrained within river banks, levees and various training structures without taking into account the natural meandering (amplitude and wave-length of the meanders);
- Hydraulically spoken, does the river hydraulic gradient exhibits at transition at Ha Noi (near the Chung Duong Bridge: "hydraulic jump")

It is assumed that the geology of the Red River bed in the Ha Noi section is quite uniform and that the morphodynamic is only governed by the interaction water flow/river-bed sediment.

In this respect it is considered that Section 1 and Section 2 are stable sections according to the historical morphological analysis: In these stable sections, Sh/Q ratios are close to 1. The larger this ratio the more unstable the morphological equilibrium is expected to be (see **Figure 26.5.2**).

Hence, river training works considered in this study will be designed to comply with the following 3 functionalities:

1) stabilize the river bed against lateral shifts of the channels;
2) stabilize or scour (locally) the natural depths in order to comply with the design criteria;
3) yield the desired morphological stability by reducing the hydraulic section in order to get the Sh/Q ratio as close to 1 as possible.

(2) Computation of hydraulic regime: discharge and average flow velocity

Based on previous hydraulic flow analysis (see **Chapter 14**), there are now estimates available of both discharge and hydraulic section for different water levels at the consecutive cross sections along the studied reach of the Red River. From that, it is possible to calculate the local mean velocity as the ratio of discharge and section. This velocity gives an idea about the equilibrium in the channel at a certain discharge. An increase in flow velocity may lead to an

erosive gradient in sediment transport, whereas a decrease of the water speed probably will result in sedimentation of the transported sediment load.
The developed calculation methodology to obtain a longitudinal variation in mean velocity U in the consecutive cross-sections along the river reach can be described as:

- For different water levels at the upstream boundary cross-section 1 (2, 4, 6, 8, 10 and 12 m above LSD), the corresponding discharge Q_{input} is calculated using the artificial rating curve for cross-section 1 (deduced from the rating curves (30 years of observations) at Ha Noi and Thuong Cat + hydraulic gradient).

- This discharge Q_{input} has to be transported through the whole river reach of the Ha Noi section and is therefore kept constant.
- As a consequence this means that the downstream water levels are adapted for the consecutive cross sections, based on the measured water profile of the January 2002 survey (Ref. "Progress Report (1) for the Study on the Red River Inland Waterway Transport System in the Socialistic Republic of Vietnam" (2002)).
- The available recorded water surface profile is only available for two particular flow situations during the dry and rainy seasons in 2002. In order to identify the water surface profile under different flow conditions (also during wet season), it is assumed that an identical hydraulic gradient of the water surface profile can be used for all flow situations.
- At the bifurcation with the Duong River, it is assumed that a constant proportion of the flow (27.2%) will go to the Duong river and the rest flows further downstream in the Red River.
- This percentage is based on a graph (**Figure 26.5.3**) where the discharge in Tuong Cat station (Q_{TC}) is depicted with regard to the discharge in Ha Noi Station (Q_{HN}).

$$\frac{Q_{HN}}{Q_{TC}} = 2.68 = \frac{Q_{input} - Q_{TC}}{Q_{TC}}$$

$$Q_{input} = 3.68\ Q_{TC} \text{ of } Q_{TC} = 0.2718\ Q_{input}$$

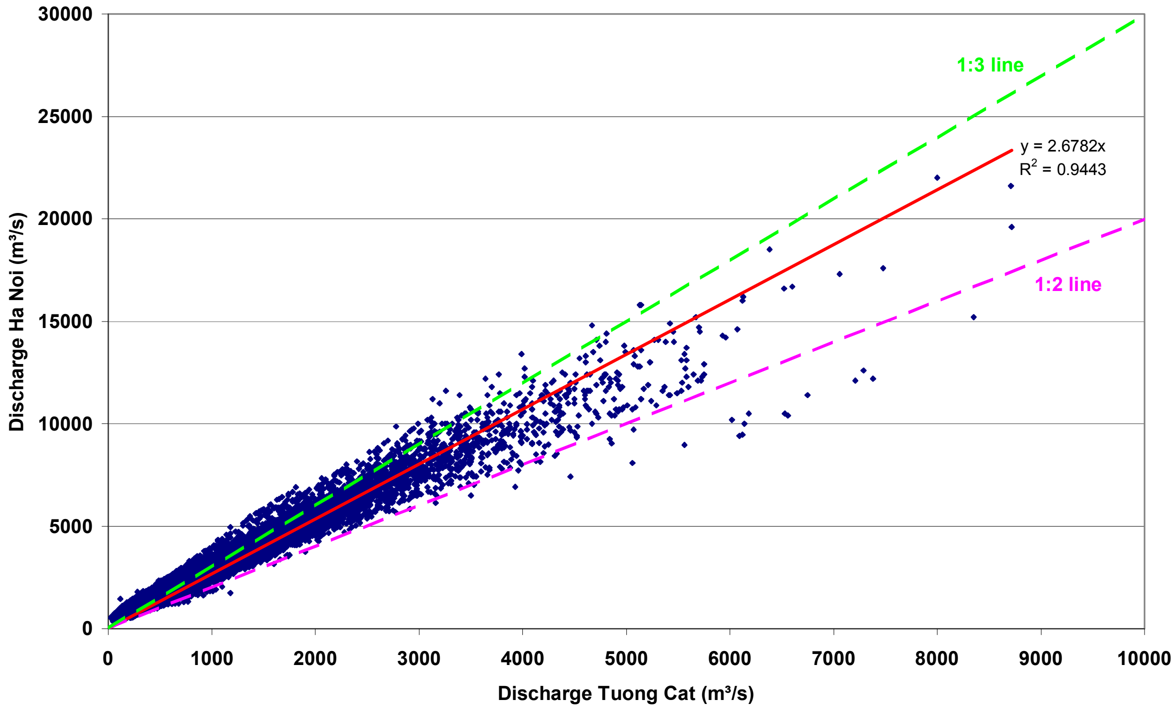


Figure 26.5.3 Comparison of Discharge in Ha Noi Station in the Red River and Discharge of Thong Cost Station in the Duong River

- Starting from section 4, the discharge in the Red River is decreased by the above percentage. This way, the initial discharge Q_{input} in cross-section 1 is transferred consequently through the studied river reach, whereas the corresponding water levels were found by the interpolation of the water surface profile.
- Downstream, at Ha Noi station, a validation could be made of the stage-discharge relationship by using the measured one. The deviations of the water level were acceptable, within the initial rough estimations.
- Finally, the hydraulic sections corresponding to the calculated water levels are determine. In combination with the discharge, the mean velocity at the consecutive river cross-sections at different flow conditions could be calculated. This in shown in **Figure 26.5.4** for the year 2002.

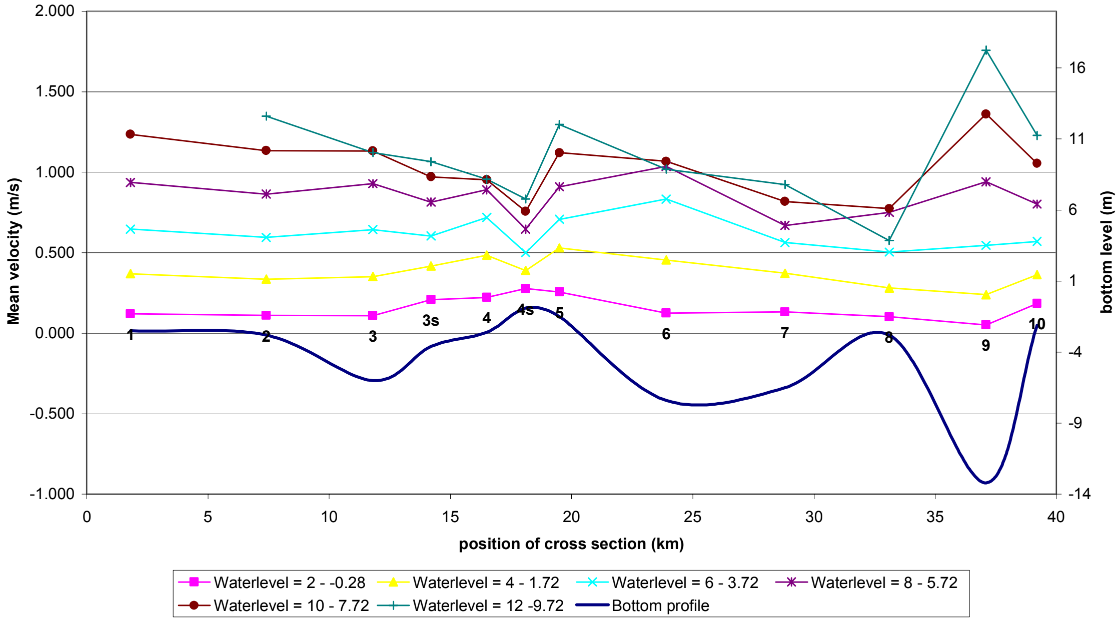


Figure 26.5.4 Mean Velocities at Different Initial Water Levels at Section 1 (Existing cross-sections with an indication of bottom profile of the Study area)

In the legend of **Figure 26.4.5**, for each initial upstream water level at cross-section 1 (associated with a constant flow situation along the river reach), the corresponding theoretical downstream water level (at cross-section 10) is also indicated.

Again, an upstream water level of 6 m can be indicated as a critical threshold from where significant variations in mean flow (and possibly associated sediment transport gradients) are noticed. A sharp decrease in mean water flow velocity is seen in cross-sections 4s and 8. This significant drop in flow velocity is explicitly reflected in a local (sand)_bank development (high river bottom level due to local sedimentation) along the main river channel. At cross-section 4s, this drop in flow velocity can be linked with the actual developing lateral cut of the Tu Lien-Trung Ha sand bar at the right bank.

(3) Hydraulic impact of river training works

The designed river training works – apart from their stabilization function of banks – will also constrict the water flow.

Based on the above analysis of the mean flow evolution along the Hg Noi Red River reach, the impact of some particular river training works as described in the next paragraph is studied an evaluated. A first exercise is developed for a full closure of the secondary channels in cross sections 3, 4 4s and 5 in order to obtain a single-channel river system. The calculated results are shown in **Figure 26.5.5**.

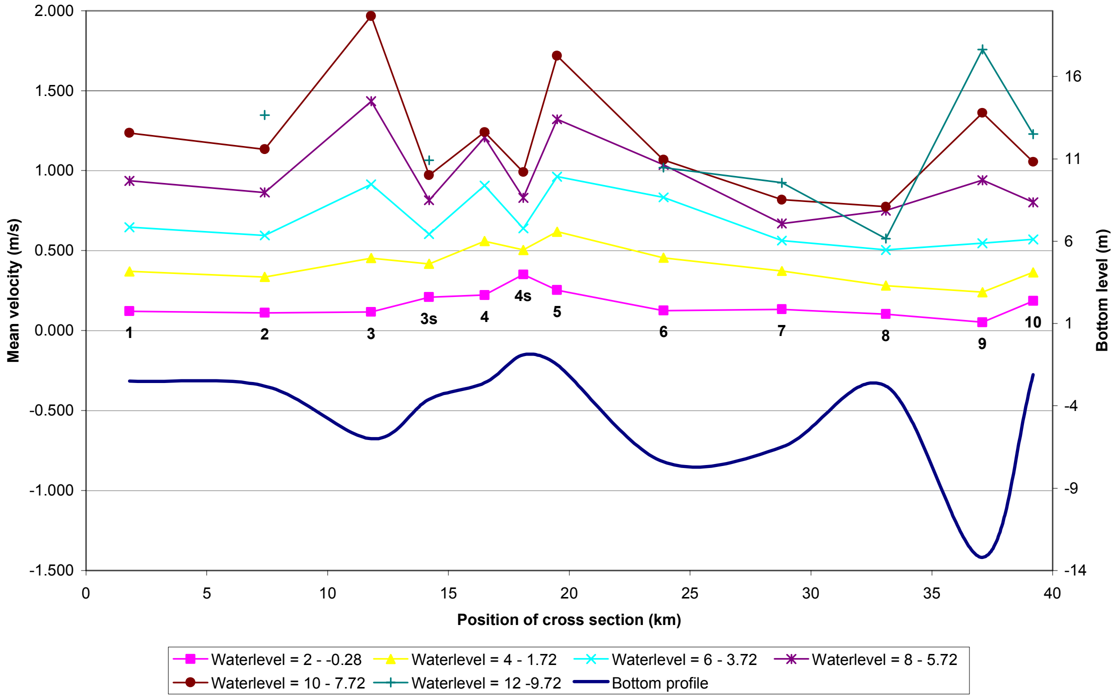


Figure 26.5.5 Mean Velocities at Different Initial Water Levels at Section 1 (Full closure of the secondary channels in cross section 3, 4, 4s and 5, with an indication of the bottom profile of the Study area)

It is clear that a full closure of the secondary channels will lead to a much too high flow velocity of the water in the main channel at higher water levels. Still, the effect of this drastic intervention remains minor up to the upstream critical water level of 6 m. At higher upstream input water levels, the increase in mean water flow velocity becomes unacceptable. Especially, at cross-section 3 the cut off of the secondary channel Phu Xa will focus the flow too much towards the outer river bend. The remaining narrow flow channel will certainly erode and the transported river bed material will deposit downstream at cross-section 3s, where the flow drops to the normal value. The cut off of the secondary channel at the upstream side of Tu Lien sandbank (Tay Ho District) induces a less significant increase of mean flow velocities at cross-sections 4 and 5. A local increase of the mean flow velocity in the main channel of the river can reach up to 30% of the initial value under the actual river configuration.

Based on previous calculations, it is already clear that it is better not to work with a full closure of the secondary channels, but with a kind of underwater berm. This weir construction fully deviates the water flow to the main channel during dry season, but can be overtopped and becomes a submerged weir at higher water levels (floods during wet season). The crest level of this submerged weir is actually suggested at 6.5 m above LSD for the Phu Xa weir and at 6.0 m above LSD for the Tu Lien underwater berm.

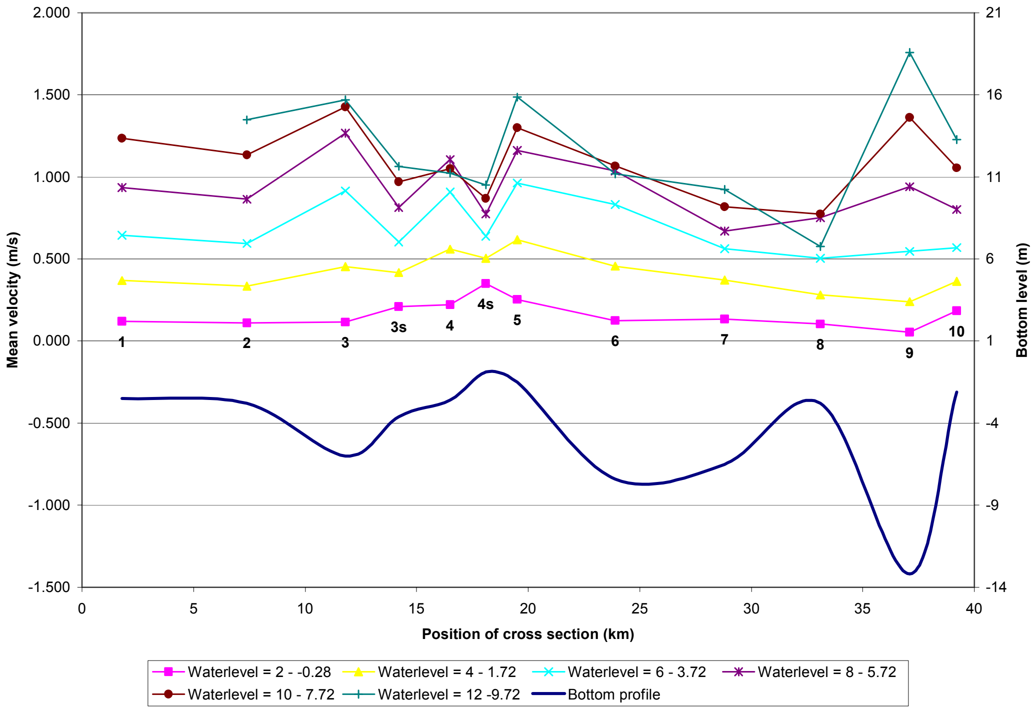


Figure 26.5.6 Mean Velocities at Different Initial Water Levels at Section 1 (Partial closure of the secondary channels in cross section 3, 4, 4s and 5, with an indication of the bottom profile of the study area)

The resulting mean flow velocities for this river training works (submerged weir to cut off the secondary channel) clearly show a less pronounced increase of the mean flow at cross-section 3 and 5 at high water levels due to the overflow of the submerged weirs and the associated flow redistribution over the river section (see **Figure 26.5.5** and **Figure 25.5.6**). Doing so, the morphological impact of extreme flood events on the main channel is controlled and do not greatly interfere with the global river training philosophy under normal flow conditions.

In order to prevent the further development of the cut of the Tu Lien and the Trung Ha sand bank, a river training wall is foreseen at the right bank of the Red River main channel, along the left side of the sand bank. Near cross-section 4s, it is suggested to construct a training wall that does not follow the actual river bank anymore; but fix a constant hydraulic flow section.

This will lead to a local constriction of the actual main flow channel, therefore causing the local mean flow velocities to rise. The present river bed morphology clearly shows a sand sill in the main channel at this location. The local increase in mean flow velocity results in a natural scouring of the river bottom, thus lowering the sand sill in the main channel and improving the navigability of the channel. The results for the mean flow velocity in the consecutive cross-sections along the river reach under this additional training work can be seen in **Figure 26.4.8** below.

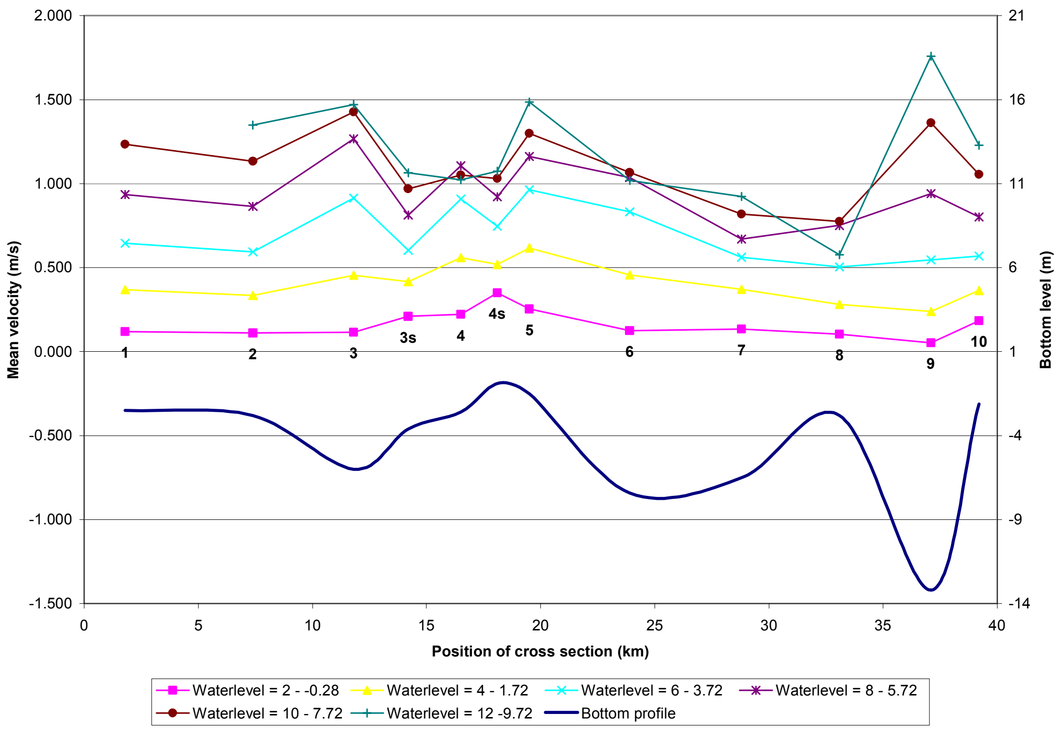


Figure 26.5.7 Mean Flow Velocities over the Red River Reach with Channel Constriction at Section 4s by the Training Wall of Tu Lien – Trung Ha Sand Bank (together with the submerged weirs at the secondary channels)

By comparison of **Figure 26.5.7** with respect to **Figure 26.5.6**, a slight increase in mean flow velocity can indeed be noticed near section 4s. Although the difference is rather small, it can be expected that some local erosion will initiate the (natural) removal of the sand sill in the main channel of the Red River.

Even though, the actual (short-term) evolution at cross-section 9 shows a quite stable hydraulic flow section, special focus should be drawn to the development of the upstream outer bend towards the Van Phuc District. Cross-section 9 shows a deep and narrow single channel, inducing a local increase in flow velocity. The plan view indicates a very sharp bend upstream. Due to this actual sudden change in flow direction, intensive erosion of the outer bank can be expected, threatening the land. Together with a close monitoring of the local morphological development under the above mentioned river training works upstream the Red River, a river stabilization with upstream groin fields should be kept in mind.

Similar features and river training suggestions can be identified and expressed for the next river bend, downstream cross-section 10.

Model simulations are needed to study the effects of the weir height concerning flow velocities. This will be done at a later stage of the study.

26.6 Preliminary analyses on the effect of essential river training works

Preliminary analyses are carried out to evaluate the effect of primary river training works by means of computer simulations. The river training works taken up here are most essential ones, and the analyses are limited to the dry season.

26.6.1 Arrangement of essential river training works

The essential river training facilities examined here are shown in **Figure 26.6.1**. They include the following facilities:

(1) Group of groins

1) Groins on the left bank at upstream and downstream of the new Hanoi North Port (Urgent)

(2) Training walls

1) left side of Tu Lien-Trung Ha Sand Bar (Urgent),
2) Head and left side at Nhat Tan Sand Bar (Urgent),
3) Left bank of Thac Cau Bank in front of Hanoi Port (Long term), and
4) Right side of Vong La Sand Bar (Long Term).

(3) Ban Slope protection

1) Upstream portion of Hanoi Port (Urgent),
2) Left bank of Bac Cau Commune (Urgent),
3) Head of Bac Cau Commune (Long Term), and
4) Meandering Comer at the down stream of Khuyen Luong Port (Long Term)

26.6.2 Expected effects of essential countermeasure facilities

The effects of the above urgent facilities are assessed by means of the numerical simulations for the dry season. The results are shown in **Figures 26.6.2 (1)** to **(3)** on current vectors, ratio of current speeds after and before construction of the facilities, and change of riverbed after construction of the facilities, respectively.

It is noted that two cases for the training wall along Tu Lien-Trung Ha Sand Bar are discussed, i.e. one is a continuous training wall and the other is intermittent training wall with length of 300 m and intervals of 100 m. The former is considered more suitable than the latter because of the effect to protect the sand bar, and the above figure shows the result of the former one.

The current field indicates rather streamlined flow owing to the training facilities. They creates, however, two places where current speeds increase considerably compared with the present condition, i.e. at the tail of Nhat Tan San Bar and in the middle of Trung Ha Sand Bar. They are the effects of groins (2) at Tam Sa and Tu Lien-Trung Ha Sand Bar, respectively.

These characteristic changes in the current field are not reflected on the seabed field. The erosion/accretion is relatively small.

Lastly, a comparison is made for the riverbed variations, or erosion/accretion, between the cases of the present conditions and artificially created conditions. Difference of the variations between the case of the present conditions and the case of the planned river stabilization facilities is shown in **Figures 26.6.3 (1)**. The difference between the present conditions and the cut of Tu Lien-Trung Ha Sand Bars (Case-A) is presented in **Figure 26.6.3 (2)**.

It is clearly demonstrated in **Figures 26.6.3 (1)** that there is no difference between the present conditions and the case of the planned stabilization facilities, which suggest that the arrangement of the stabilization facilities does not harm the present hydraulic and morphological conditions.

On the contrary, the case of the cut of the sand bar shown in **Figure 26.6.3 (2)** indicates a possibility of harmful effects at Vung La Sand bar, Hanoi North Port, the exit of the Cut, and Hanoi Port and other places.

In summary, the above results of simulations imply that the present river channel is rather stable during the dry season. The proposed channel stabilization measures can streamline the current field.

There is another characteristic location that is the stagnant pool behind the training wall in between Tu Lien and Trung Ha Sand bars where a cut of the bars is worried. The current speed in the pool has still tens of cm/sec. This is because of the supposed pile structure, which has 40% of permeability.

Paying attention to the above three characteristic locations created after construction of the stabilization measures, the discussion will be deepened during the course of the Study for the flood season.

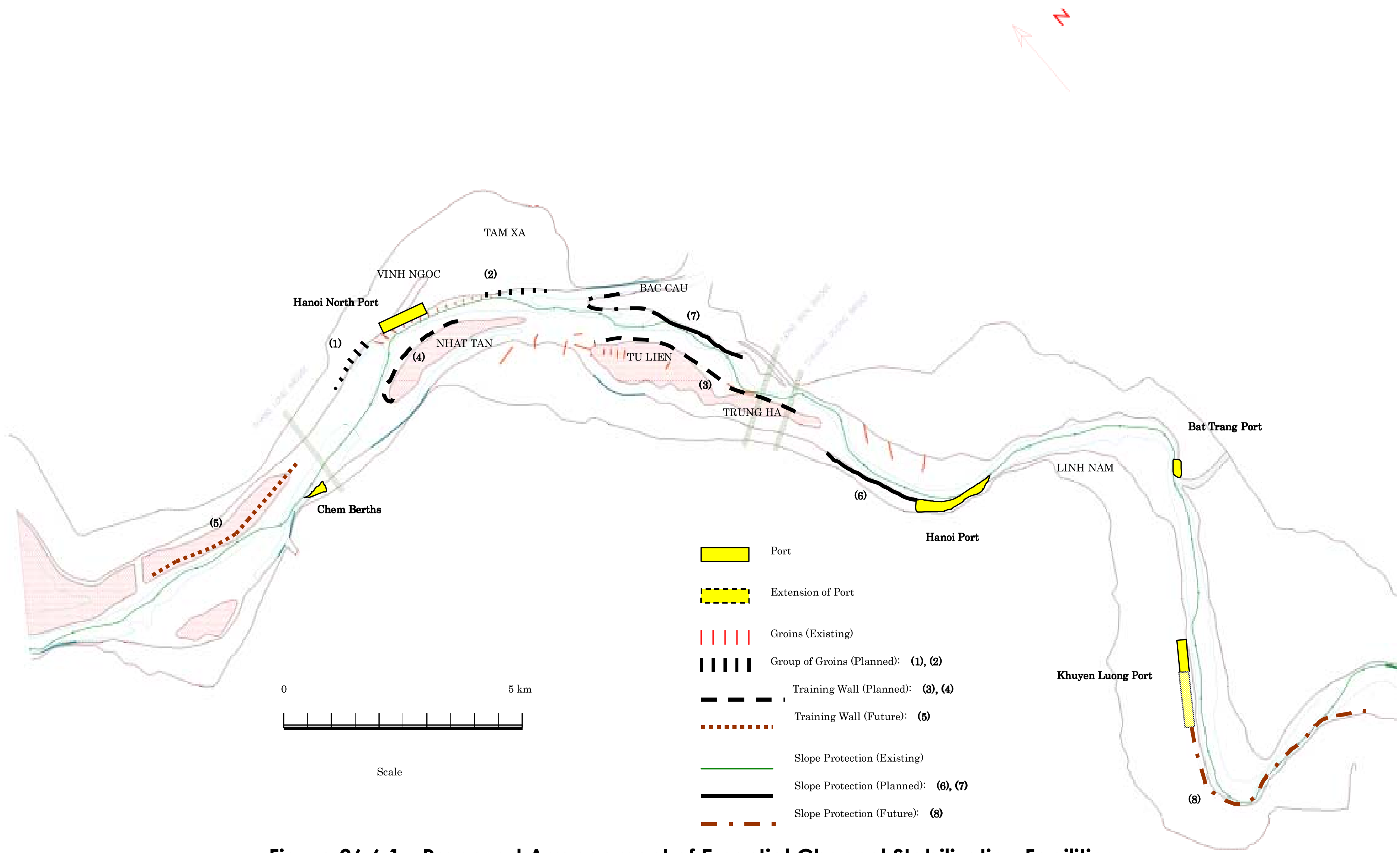


Figure 26.6.1 Proposed Arrangement of Essential Channel Stabilization Facilities

Source) JICA Study Team

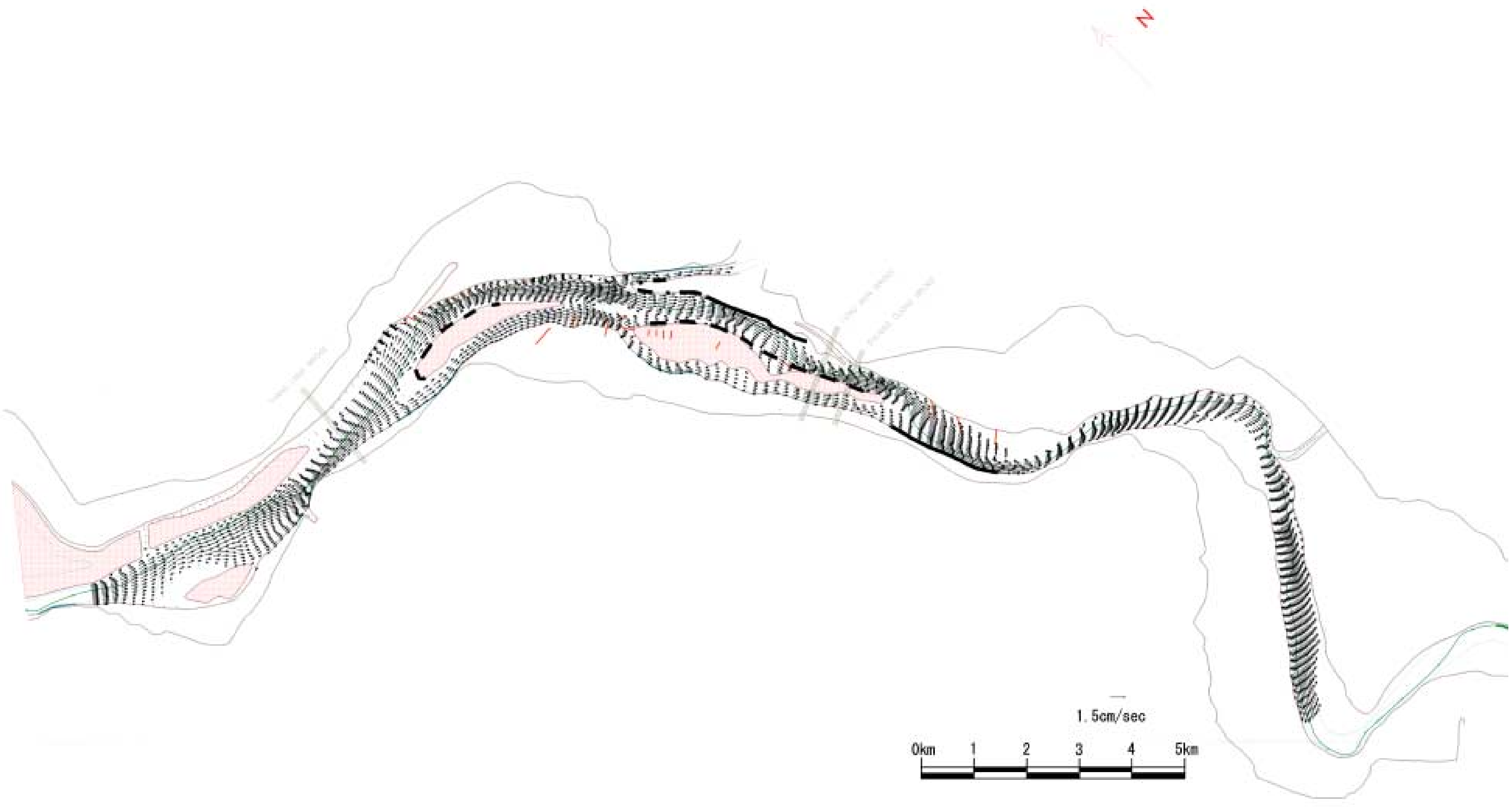


Figure 26.6.2 (1)   Current Vectors (After Construction of Urgent Stabilization Facilities)

Source)   JICA Study Team

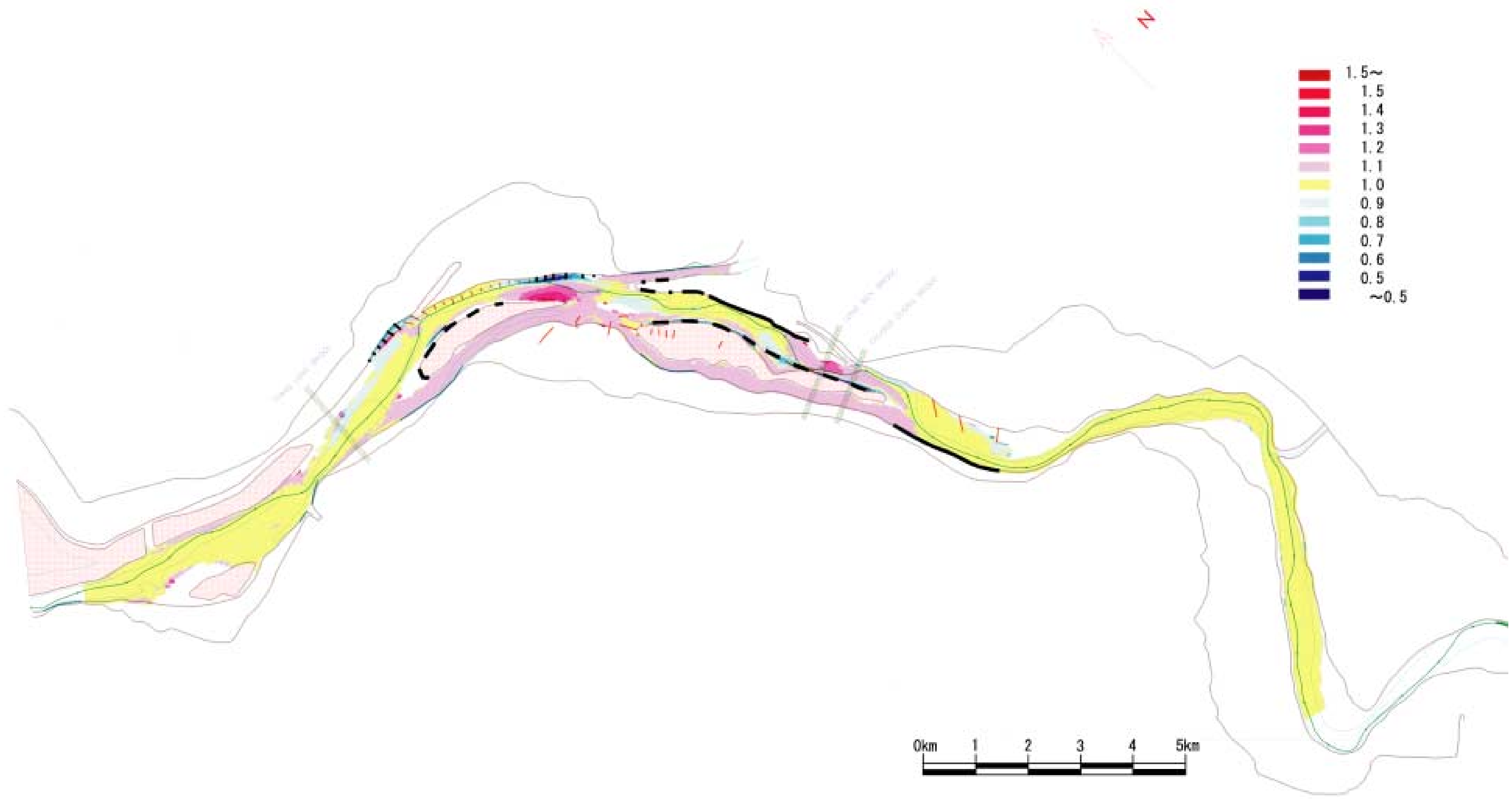


Figure 26.6.2 (2) Ratio of Current Speeds (Before and after Construction of Urgent Stabilization Facilities)

Source) JICA Study Team

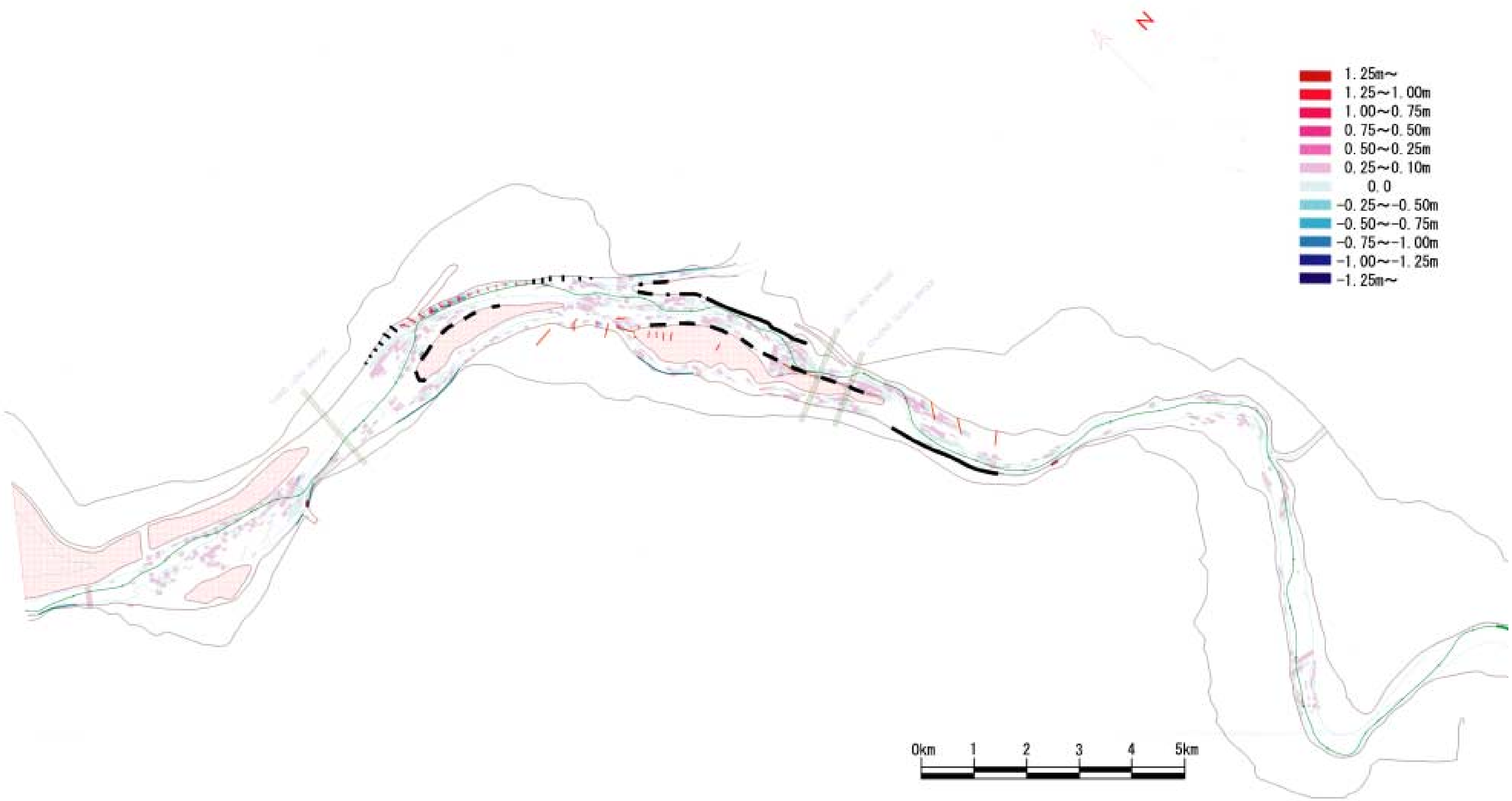


Figure 26.6.2 (3) Change of Riverbed (After Construction of Urgent Stabilization Facilities)

Source) JICA Study Team

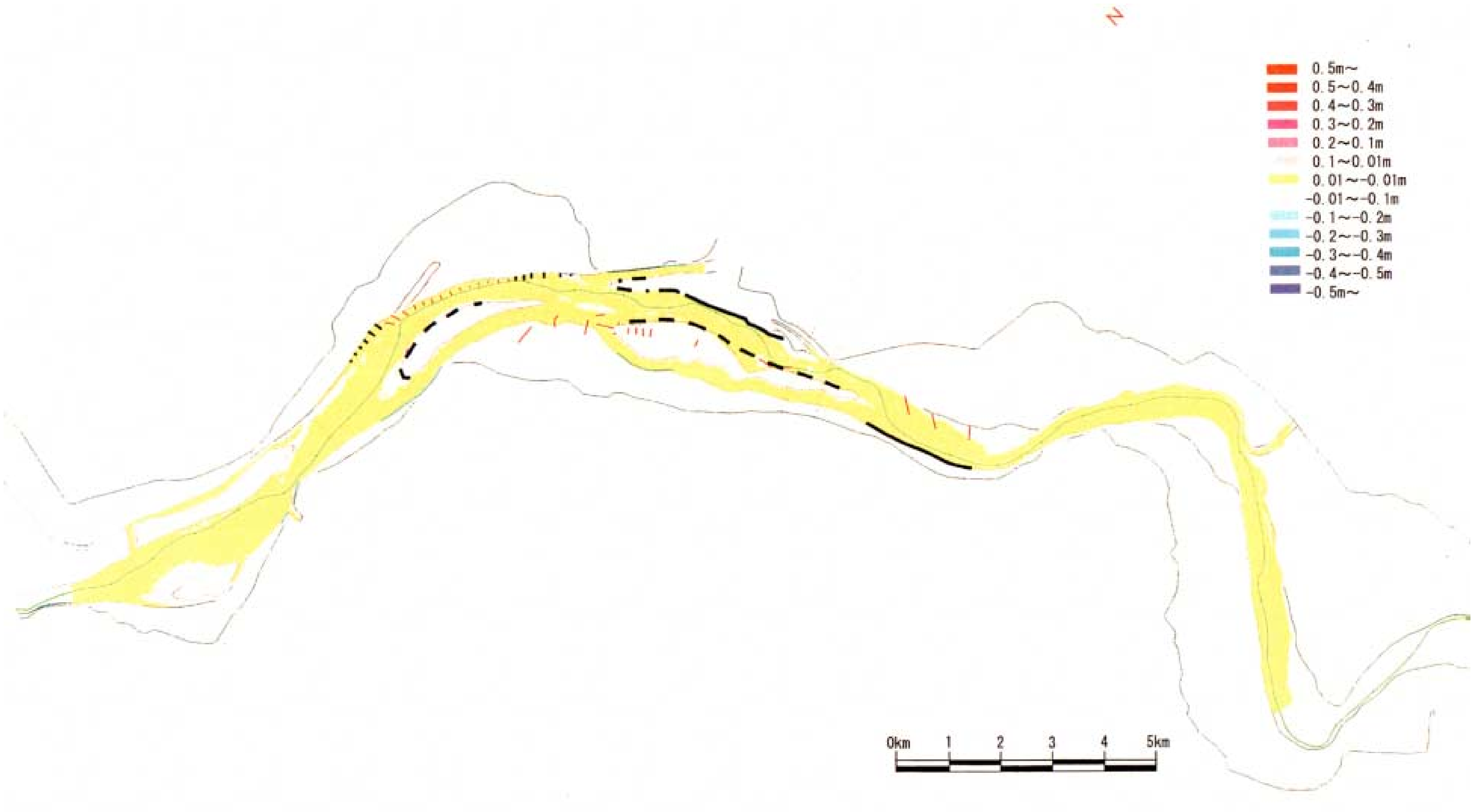


Figure 26.6.3 (1) Difference of Riverbed Variation (Present Condition versus Construction of Urgent Stabilization Facilities)

Source) JICA Study Team

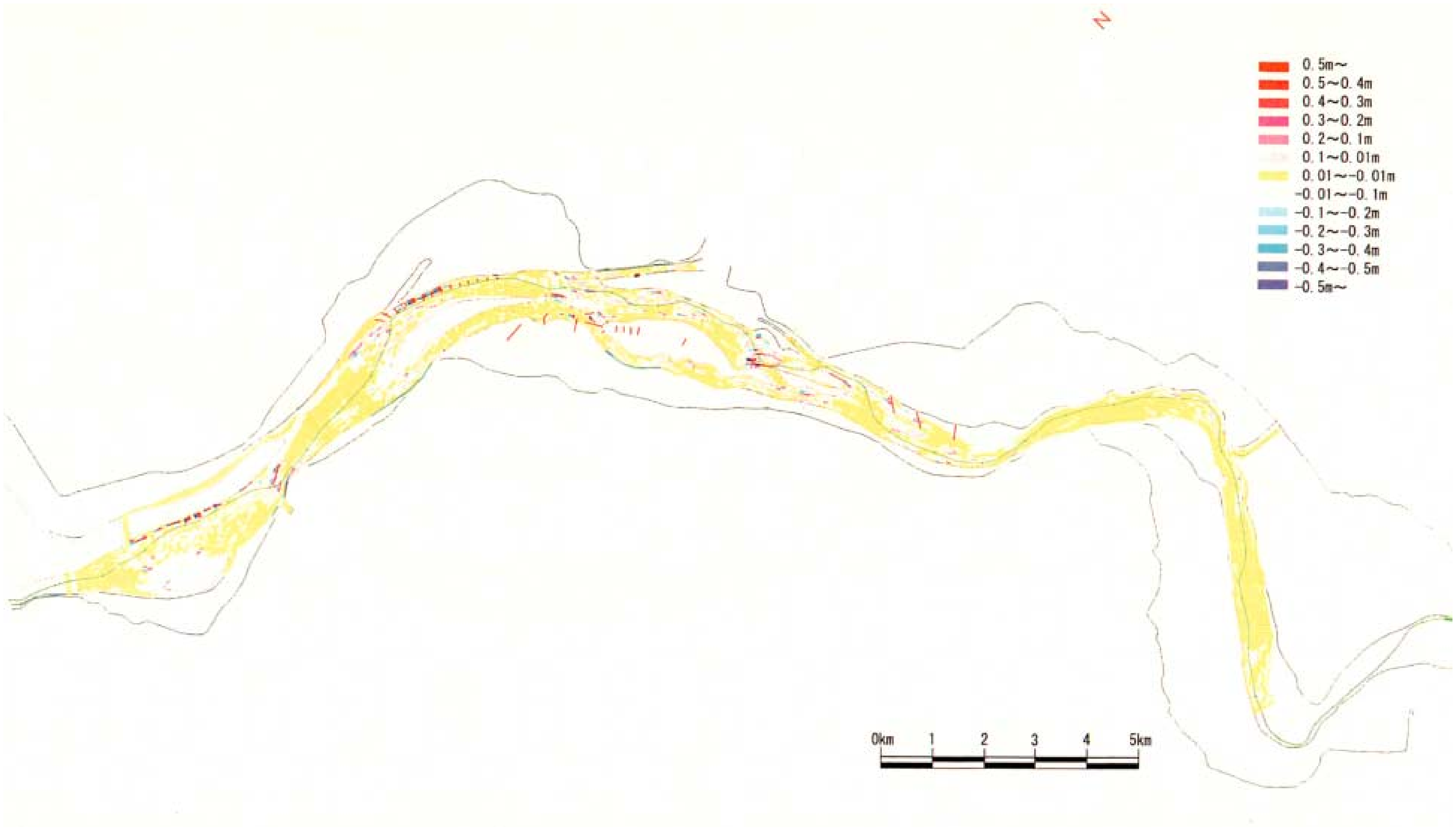


Figure 26.6.3 (2) Difference of Riverbed Variation (Present Condition versus Cut of Tu Lien-Trung Ha Sand Bar)

Source) JICA Study Team