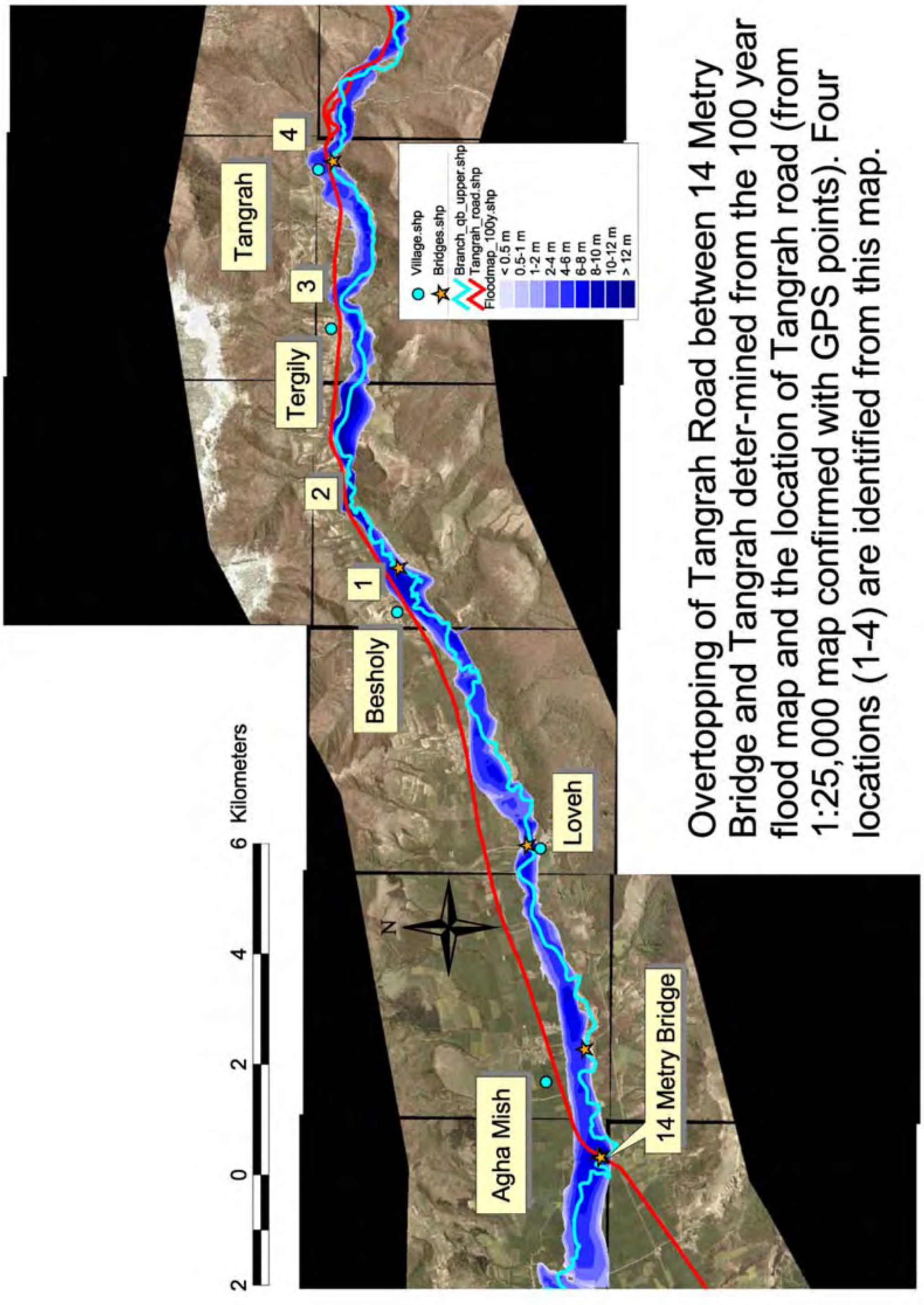
APPENDIX B ROAD OVERTOPPING 14 METRY BRIDGE TO TANGRAH

Area 1: Near Besholy

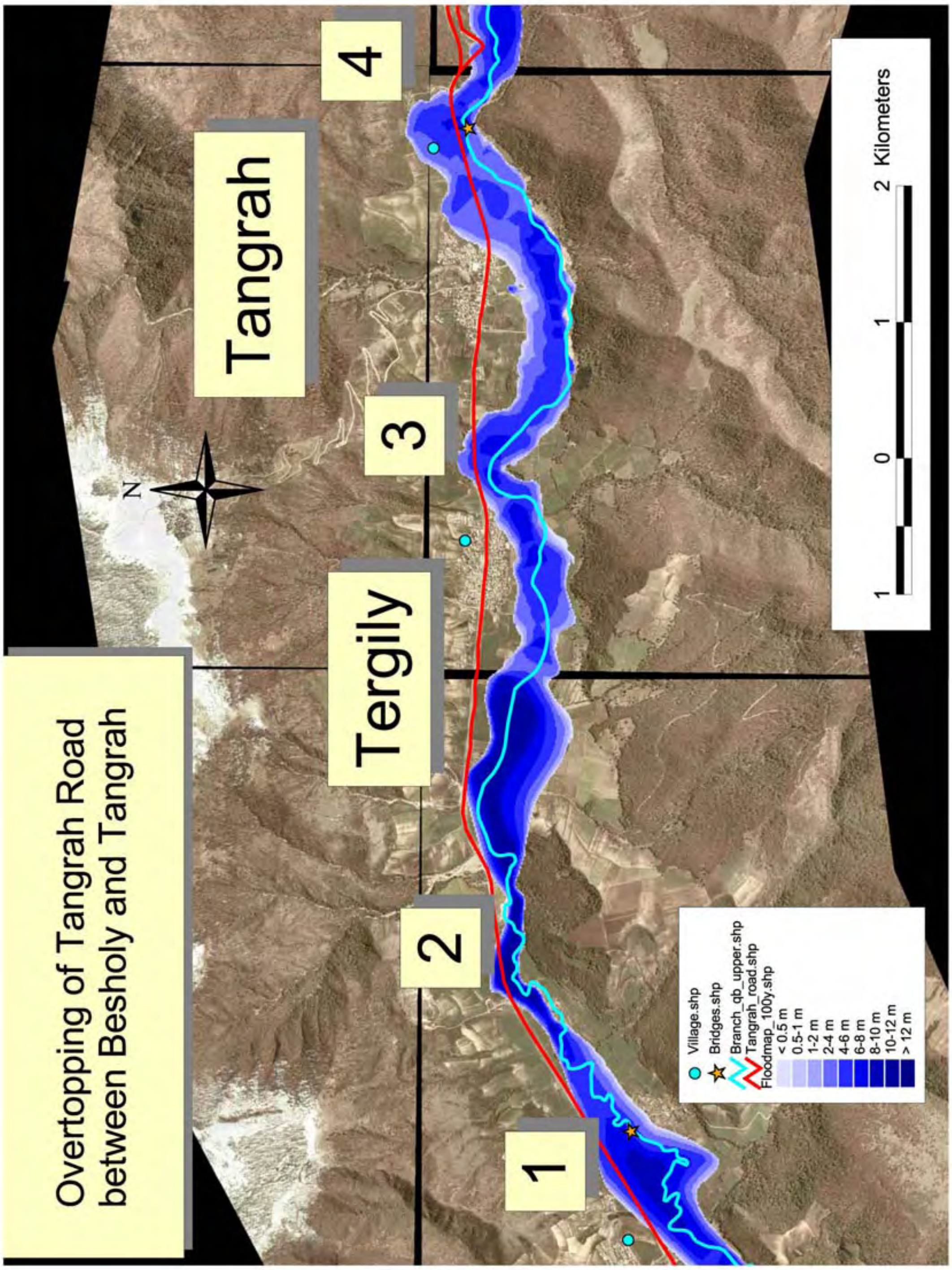
Area 2: Between Besholy and Tergily

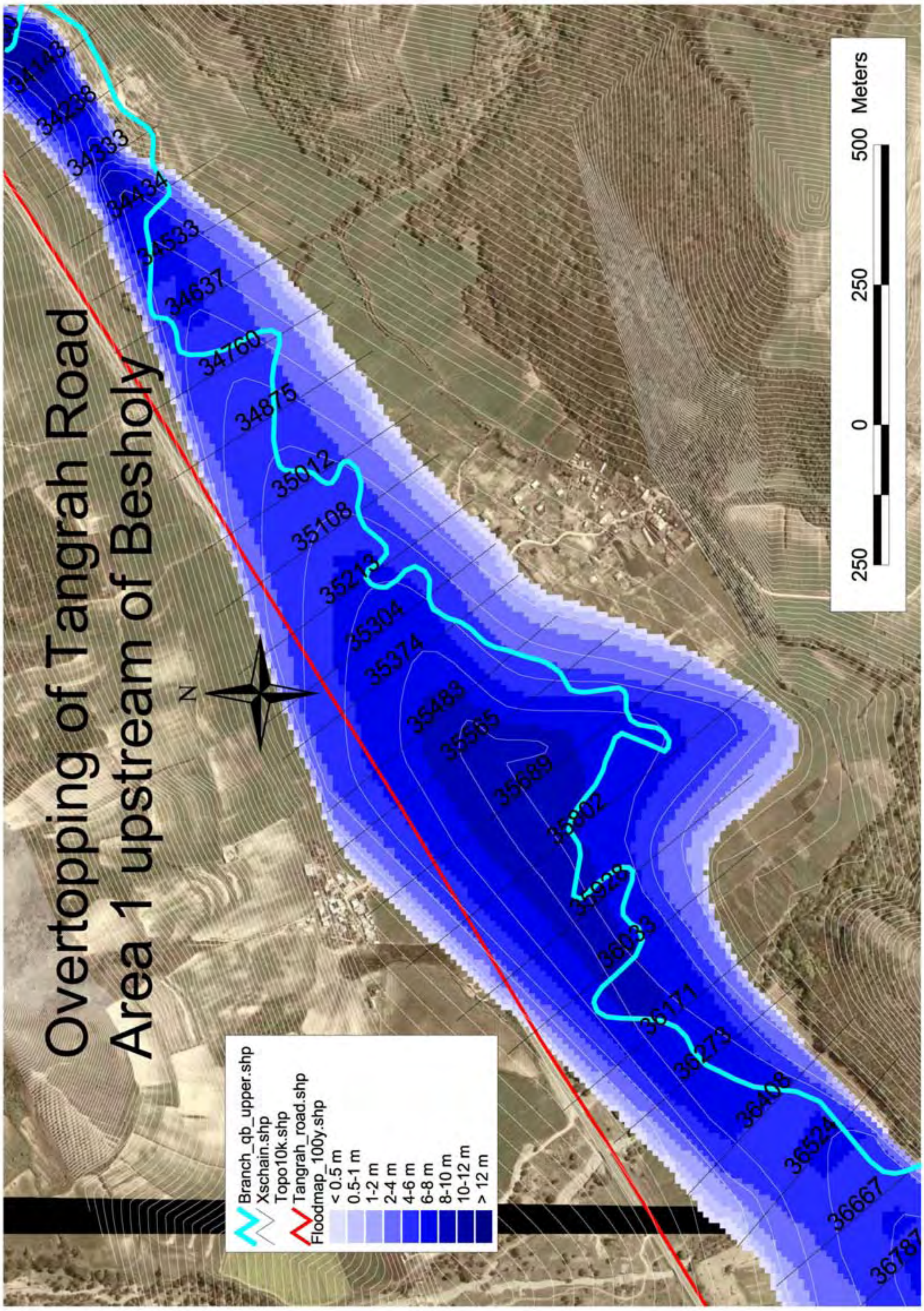
Area 3: Upstream of Tergily

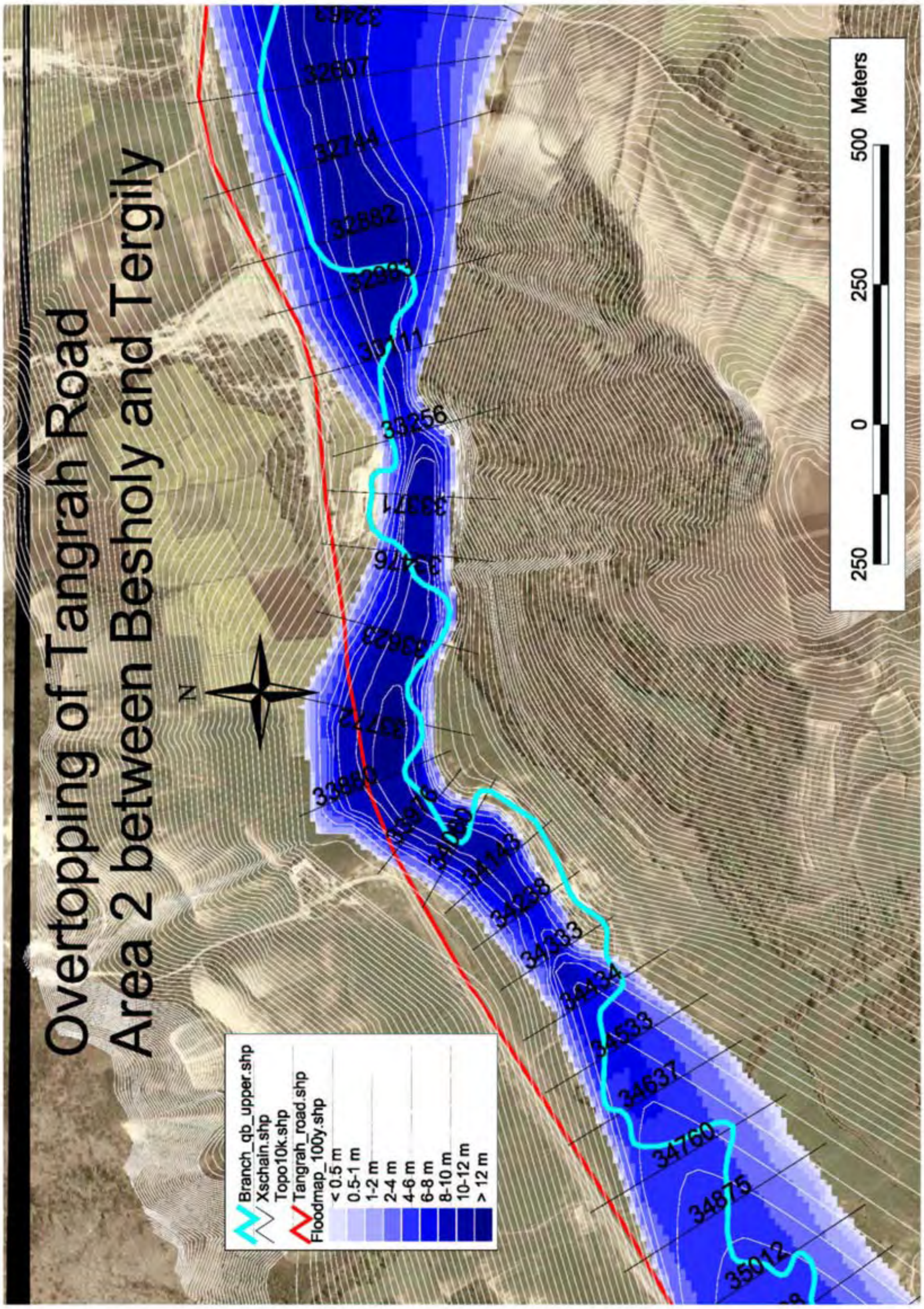
Area 4: Upstream of Tangrah

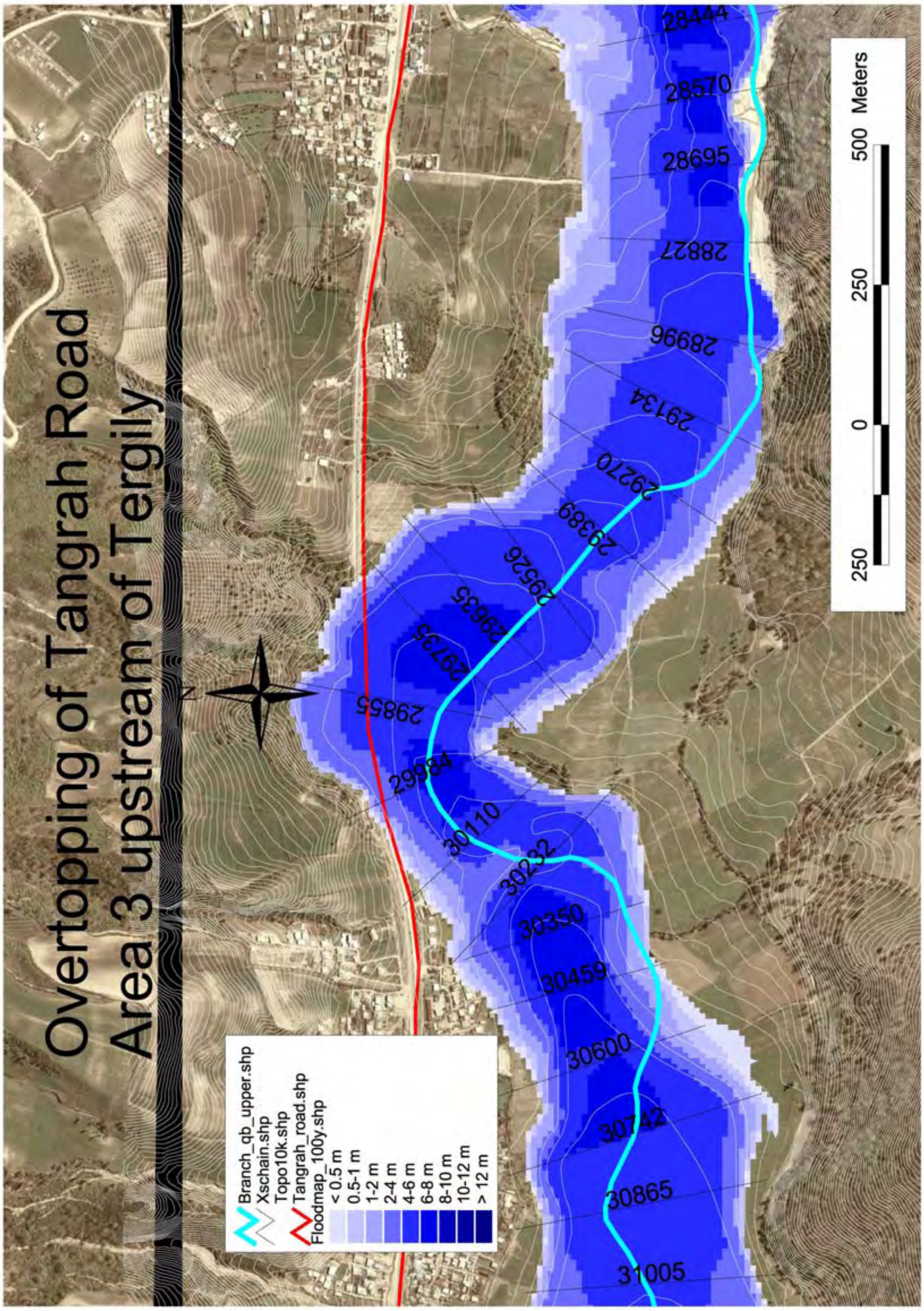


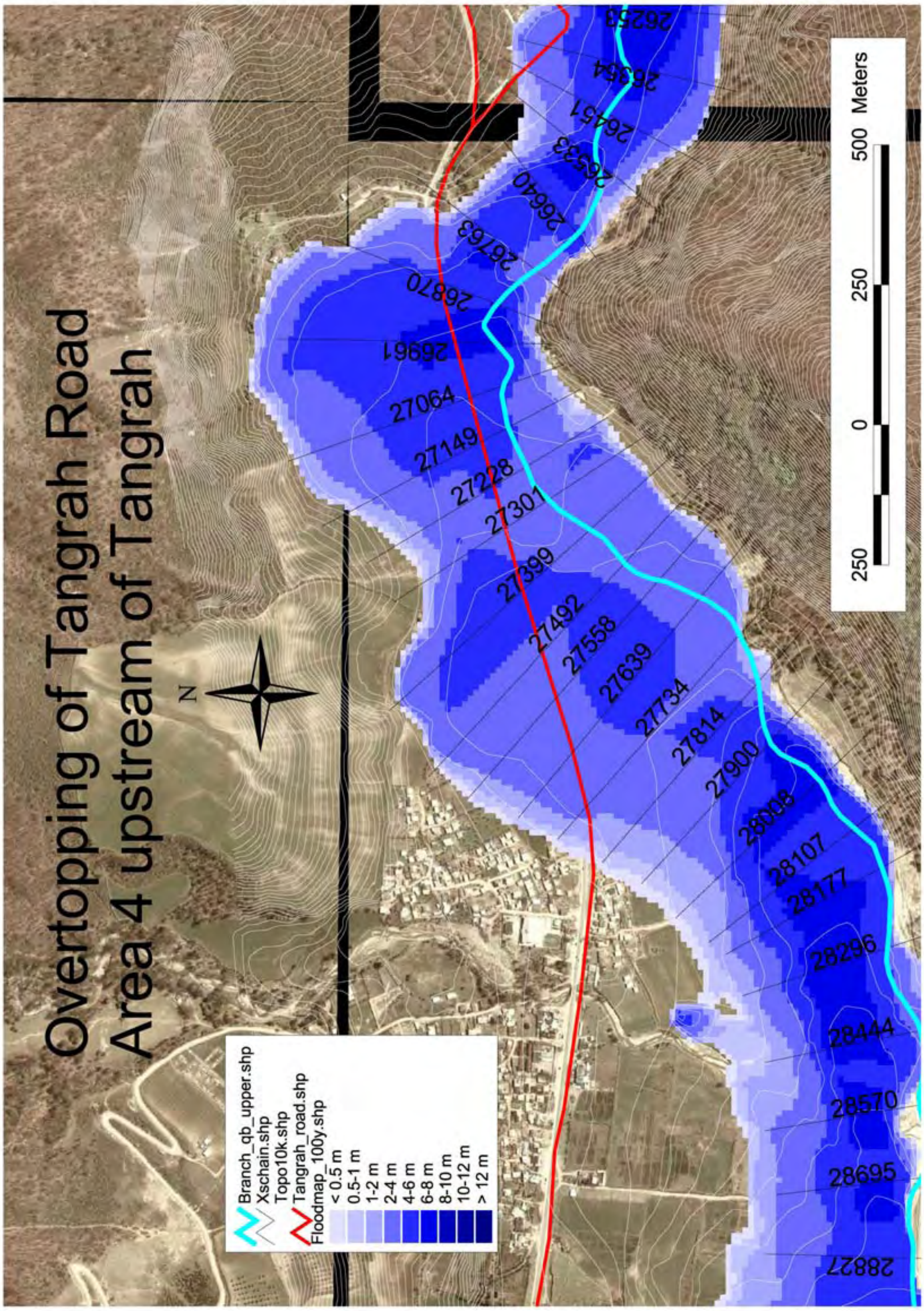
Overtopping of Tangrah Road between 14 Metry Bridge and Tangrah deter-mined from the 100 year flood map and the location of Tangrah road (from 1:25,000 map confirmed with GPS points). Four locations (1-4) are identified from this map.


Overtopping of Tangrah Road
between Besholy and Tangrah
Tangrah
Tergily
1
2
3
4
N
Village.shp
Bridges.shp
Branch_qb_upper.shp
Tangrah_road.shp
Floodmap_100y.shp
< 0.5 m
0.5-1 m
1-2 m
2-4 m
4-6 m
6-8 m
8-10 m
10-12 m
> 12 m
1
0
1
2 Kilometers


Overtopping of Tangrah Road
Area 1 upstream of Besholy
Branch_qb_upper.shp
Xschain.shp
Topo10k.shp
Tangrah_road.shp
Floodmap_100y.shp
< 0.5 m
0.5-1 m
1-2 m
2-4 m
4-6 m
6-8 m
8-10 m
10-12 m
> 12 m
N
250 0 250 500 Meters


Overtopping of Tangrah Road
Area 2 between Besholy and Tergily
Branch_qb_upper.shp
Xschain.shp
Topo10k.shp
Tangrah_road.shp
Floodmap_100y.shp
< 0.5 m
0.5-1 m
1-2 m
2-4 m
4-6 m
6-8 m
8-10 m
10-12 m
> 12 m
N
250
0
250
500 Meters


Overtopping of Tangrah Road
Area 3 upstream of Tergily
Branch_qb_upper.shp
Xschain.shp
Topo10k.shp
Tangrah_road.shp
Floodmap_100y.shp
< 0.5 m
0.5-1 m
1-2 m
2-4 m
4-6 m
6-8 m
8-10 m
10-12 m
> 12 m
250 0 250 500 Meters
N
28444
28570
28695
28827
28996
29134
29270
29389
29526
29635
29735
29855
29984
30110
30232
30350
30459
30600
30742
30865
31005


Overtopping of Tangrah Road
Area 4 upstream of Tangrah
N
Branch_qb_upper.shp
Xschain.shp
Topo10k.shp
Tangrah_road.shp
Floodmap_100y.shp
< 0.5 m
0.5-1 m
1-2 m
2-4 m
4-6 m
6-8 m
8-10 m
10-12 m
> 12 m
250
0
250
500 Meters
26258
26364
26451
26533
26640
26763
26870
26961
27064
27149
27228
27301
27399
27492
27558
27639
27734
27814
27900
28008
28107
28177
28296
28444
28570
28695
28827

SUPPORTING REPORT I (MASTER PLAN)

<u>PAPER XVIII</u>

River Planning

THE STUDY ON FLOOD AND DEBRIS FLOW IN THE CASPIAN COASTAL AREA FOCUSING ON THE FLOOD-HIT REGION IN GOLESTAN PROVINCE

SUPPORTING REPORT I (MASTER PLAN)

PAPER XVIII RIVER PLANNING

TABLE OF CONTENTS

CHAPTER 1 GENERAL PROCEDURES OF FLOOD CONTROL PLANNING

1.1 NECESSITY OF THE FLOOD CONTROL PLAN

When the catchment area and/or flood-prone area is considered large and very important to the national or regional economy, it should be necessary to formulate a flood control plan. The flood control plan shall be formulated from the basin-wide viewpoint, and requires proper coordination with the following related plans:

- Irrigation Development Plan;
- Road Network and Bridge Improvement Plan;
- Watershed Management and Sediment Control Plan; and
- Environmental Management Plan.

It is necessary to incorporate the effects and influences of other development plans into the flood control plan to be formulated. For instance, the height of levee will affect the design of the height of bridge and road. Likewise, the design riverbed profile will affect the design of irrigation intake/canal and other related facilities.

1.2 CHANNEL IMPROVEMENT IN FLOOD CONTROL PLANNING

For establishment of the flood control plan, various surveys, research works and analyses are needed. Fig. 1 shows the general procedures to formulate the flood control master plan.

In the process of flood control planning, the designing of channel improvement is conducted as alternatives for comparative study to select the optimum plan. After formulating the master plan, the feasibility study and detailed design for channel improvement shall be made if the channel improvement scheme is selected as the optimum plan components.

Set-up of Objectives and Flood Control Strategy, and Determination of Safety Level (Design Flood Return Period)

↓

Collection of Meteo-Hydrological Data and Hydrological Analysis

↓

Set-up of Design Rainfall and Computation of Design Discharge through Rainfall-Runoff, Flood-Routine and Flooding Simulation

↓

Determination of Design Discharges at Control Points

↓

Comparative Study among Alternatives of Flood Control: Storage Reservoirs, Retarding Basin, Channel Improvement Works, etc.

↓

Determination of Optimum Plan from Technical, Environmental, Social and Economical Points of View

Fig. 1 General Procedures of Flood Control Planning (Master Plan)

CHAPTER 2 CHANNEL IMPROVEMENT PLANNING

2.1 OBJECTIVES

Channel improvement planning has three (3) major objectives:

(1) To increase the flow capacity of river channel for the protection of flood-prone area from over-bank flooding by: (a) construction of dike/levee, (b) widening of the waterway, and/or (c) dredging/excavation, as illustrated in Fig. 2.

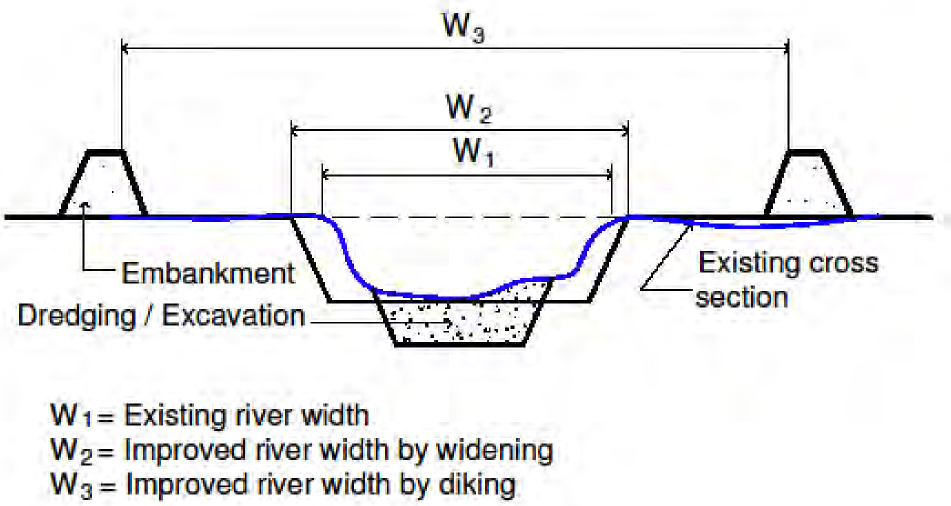


Fig. 2 Channel Improvement Works to Increase Flow Capacity

(2) To prevent bank erosion and harmful riverbed degradation by: (a) construction of revetment, (b) construction of spur dike, (c) alteration of water course/cut-off channel, and (d) construction of groundsill to prevent channel degradation, as presented in Fig. 3.

(3) To maintain the secured flow capacity against channel aggradation due to sedimentation/siltation, by construction of sediment control structures, and/or by channel excavation/dredging as regular maintenance works.

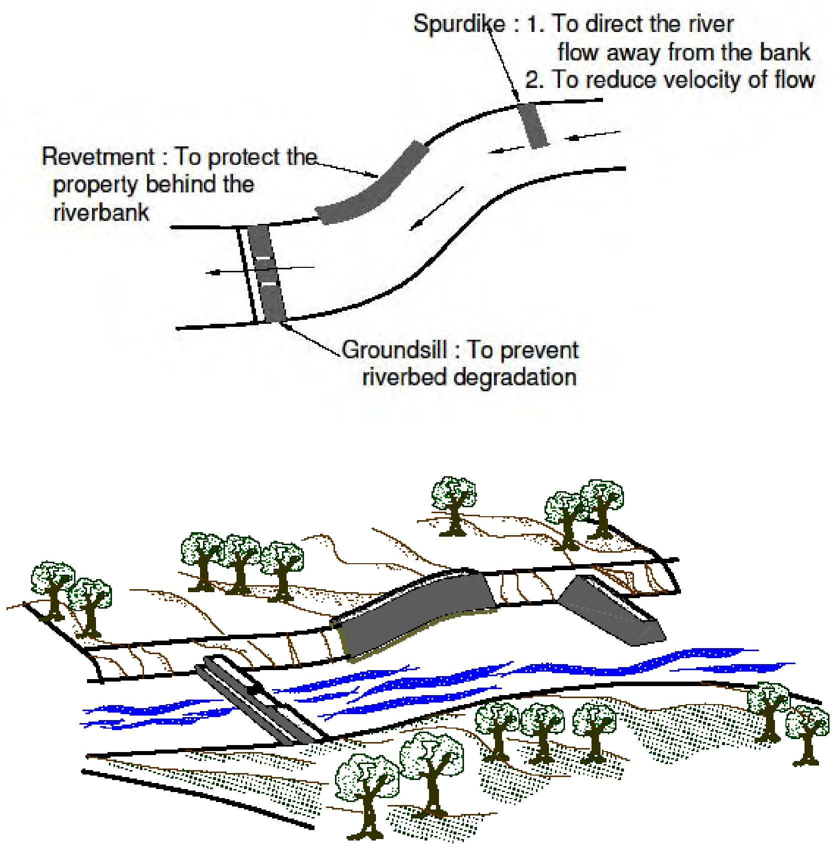


Fig. 3 Countermeasures of Bank Erosion and Channel Degradation

2.2 PLANNING PROCEDURES

Prior to designing any flood control structure, the following planning components shall be determined or clarified:

(1) River stretch to be improved;

(2) River channel route;

(3) Channel alignment plan;

(4) Riverbed gradient plan and longitudinal profile; and

(5) Channel cross-section plan.

Channel alignment, riverbed gradient and longitudinal profile, and channel cross-sections shall be planned in combination with each other.

2.2.1 River Stretch

The river stretch to be improved shall be determined considering the existing issues such as inadequate flow capacity, obstructions to the smooth and safe conveyance of floodwater, bank erosion and scouring. In addition, both sides of the riverbank shall be planned in an integrated manner.

If the priority area to be protected is located only on one side of the riverbank, the appropriate countermeasures shall be considered primarily for the establishment of a well-balanced flood control plan. Fig. 4 shows that both banks are located in the flood-prone area but in different conditions. In this situation, the safety level against floods shall be set up carefully in due consideration of economic, social and environmental effects. Sometimes, different safety levels are adopted for each bank in accordance with existing and future land use.

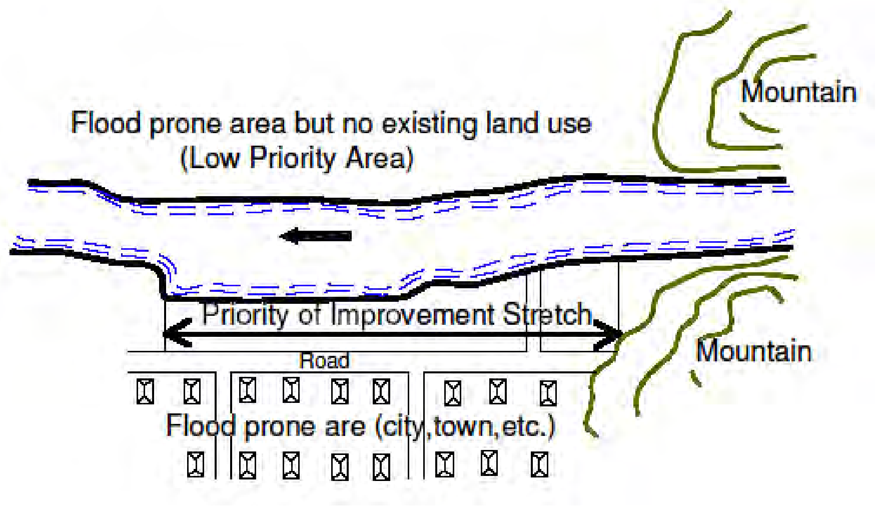


Fig. 4 Prioritization of River Stretch for Improvement Works

2.2.2 River Channel Route

Common channel improvement works are widening, dredging, and embankment in and along the existing river course. In addition to these common works, construction of floodway (flood diversion channel) also shall be considered if it is difficult to widen the existing river course in densely congested urban areas due to high cost of land acquisition, difficulty of relocation, and large-scale adverse effects on social environment. If the sharp meandering causes some problems, such as discontinuance of land use and flow disturbance, cut-off channel also shall be discussed.

Among the alternative routes, the optimum river channel route shall be determined through comparative study, taking the following factors into consideration:

Topographic and geologic reasonableness;

Consistency with present and future land use;

Effects on irrigation and drainage system;

Influences to the upper and lower reaches of the river channel;

Validity of project cost; and

Easy maintenance.

The following are brief explanations on: (1) Floodway, (2) Cut-off Channel, and (3) Open Dike System.

(1) Floodway

A Floodway is a diversion channel branching out from the existing river course by the excavation of a new man-made waterway, which will divert floodwater of the existing river into the sea, lake, or another river system. This scheme is usually selected in order to divert the floodwater from dense urban areas in rural areas to avoid the enormous cost of land acquisition and relocation.

The floodway project will require particular attention to the following:

The longitudinal profile of the floodway shall be carefully designed to avoid any unexpected channel degradation/aggradation in the new watercourse of the floodway. For this purpose, a detailed sediment balance study will be necessary, covering the entire susceptible river stretch of the original river course as well as the floodway.

Maintenance of flow in the floodway shall be studied for the purpose of keeping the balance between water use and water requirements in the existing river and new requirements in the floodway in rainy seasons as well as in dry seasons.

(2) Cut-off Channel

A cut-off channel is a shortened waterway made by excavating a new channel to straighten the bending portion in the meandering river course. Conspicuous meandering causes insufficient flow capacity and bank erosion. Designing of cut-off channel requires meticulous deliberation on the riverbed behavior, and proper maintenance works will be necessary once flood control structures are constructed on the meandering portion.

The constructed cut-off channel normally makes the riverbed gradient steeper due to the shortening of channel stretch. It may cause riverbed degradation because of increase of flow velocity in the upper reaches, and riverbed aggradation in the lower reaches. Therefore, the cut-off channel planning shall pay careful attention to the lower and upper stretches of the channel as well as the cut-off stretch. For this reason, a basic investigation shall be made on river morphology such as riverbed planform, riverbed gradient, bed materials, sediment transport, and flow regime.

(3) Open Dike System

The open dike system has been constructed mainly along braided river channels in the alluvial fan, where the floodwater velocity is high and floodwater conveys an enormous amount of sediment. To minimize flood disasters due to excessive floodwater, sediment deposits and dike breach, the open dike system shall function well to control floodwater and sediment as far as it does not provide a hindrance to the land use in the hinterland of the dike system.

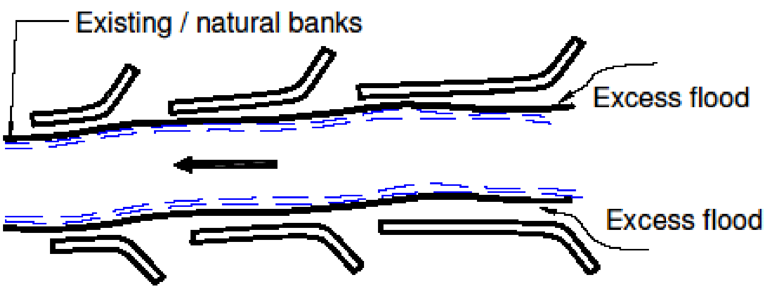


Fig. 5 Open Dike System

2.2.3 Channel Alignment

For determining the channel alignment, the following factors and mechanisms shall be considered:

(1) The existing river width shall be maintained as much as possible, for preservation of the natural retarding functions.

(2) Flow mechanisms of floodwater shall be cautiously monitored during floods and examined by the mathematical model or laboratory test. In particular, the following mechanisms are important in planning bank protection works: (a) flow convergence zones along the undercut slope (concave bank in the bend); (b) flow convergence and divergence mechanism on the alternating sand bars; and (c) mobility of the sand bars downstream.

(3) The bank alignment of the low-flow channel in a compound cross-section shall be normally parallel with the dike alignment. The suitable alignment, however, shall be determined in consideration of easy channel maintenance and water utilization for navigation, irrigation and so on, if needed.

2.2.4 Riverbed Gradient and Longitudinal Profile

The longitudinal profile shall be determined using the existing average riverbed elevation, since the average riverbed could be considered most representative of the existing longitudinal profile of the river, as illustrated in Fig. 6. The deepest riverbed is also an important parameter for determining the design depth of the protective and control structures.

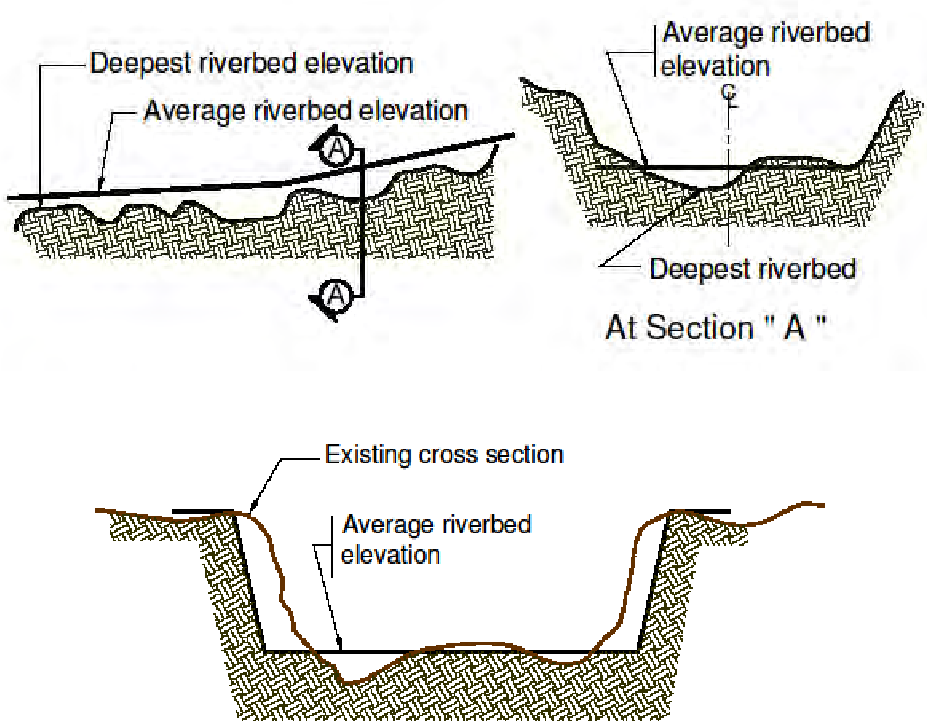


Fig. 6 Relationship between Deepest and Average Riverbed

To increase the flow capacity, the cross-sectional area has to be improved through widening, but without any change in the planned longitudinal profile (refer to Fig. 6). Furthermore, the riverbed gradient and the design flood level (DFL, or high water level: HWL) shall be primarily determined prior to determination of the required longitudinal profile and cross-sections of the river channel.

(1) Riverbed Gradient

The riverbed gradient, as one of the parameters in the computation of flow velocity, shall be planned on the basis of the longitudinal profiles of the existing average riverbed. In principle, the riverbed shall be designed as low as possible for conveying the floodwater. However, a much-lowered riverbed may cause a problem by lowering of the groundwater profile. Thus the riverbed gradient and longitudinal profile shall be determined in due consideration of various factors concerned, to attain a well-balanced water environment.

(2) Design Flood Level

Design flood level (DFL) means the high water level that corresponds to the design discharge. Basically the DFL shall be set at about ground height along the river. For rivers without embankment and diking system, it shall not be higher than the ground level.

In principle, the river channel could be planned as a non-embankment channel, because this type of channel could allow sufficient inflow of local runoff from the hinterland along the river course so that damage potential once over-bank flooding occurs would be minimal. On the contrary, when the floodwater rises, the embankment type would induce a higher pressure against the dike system of the river, and the damage potential would be larger once the dike system is breached.

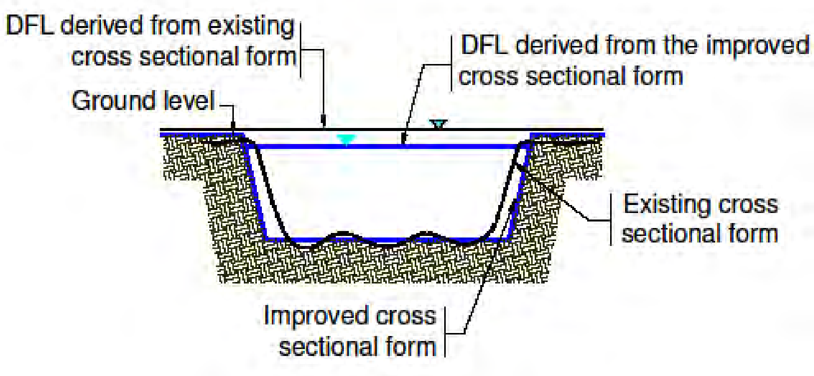


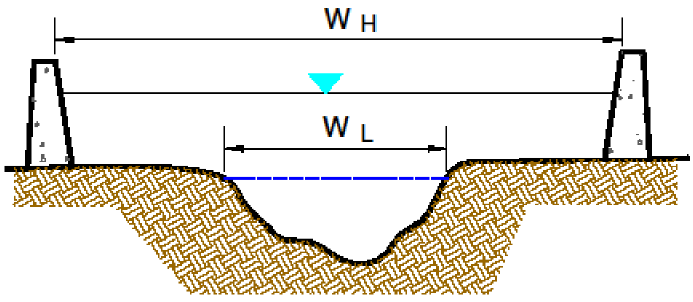
Fig. 7 Design Flood Level (DFL)

(3) Design Flood Level of Tributaries affected by Backwater of Mainstream

Peak flood discharges of the mainstream and tributaries do not usually occur at the same time due to the difference of drainage areas. In consideration of the relationship between the drainage areas of the mainstream and tributaries at their junction, the backwater effects shall be examined for the purpose of tributary channel planning in cases where two flood peaks appear simultaneously.

2.2.5 Channel Cross-Sections

In a large river, when the ratio of the design flood level to the normal water level is large, the design cross-section shall be a compound cross-section, if possible. However, it will be costly to maintain the low water channel because it is usually planned with revetment works to maintain the waterway. The major objectives of setting a low water channel are to secure and/or stabilize the waterway against meandering, and to protect the riverbank for maintaining a navigable waterway and water utilization structures.



Note: W_L – Width of low water channel
W_H – Width of high water channel

Fig. 8 Form of Compound Cross-Section

(1) River Width

The river width shall be determined in accordance with the magnitude of design discharge, simultaneously considering riverbed gradient, topographic features of the river, land use conditions along the river and so on. Even if the design discharges in both rivers have similar magnitudes, the differences in water depths, channel gradients, riverbed materials will result in different required river widths. Furthermore, river width planning depends on the conditions of land use along the river. For instance, the river width shall be strictly restricted due to difficulties of land acquisition if the river runs through densely congested urban areas.

(2) Low and High Water Channel

The height of a high water channel is to be discussed together with the width of the low water channel, since excessive high velocity of floodwater is not desirable for the maintenance of a high water channel. The velocity of less than 2 m/s on the high water channel may be desirable. If the design velocity is higher than 2 m/s, some bed protection works shall be designed, as shown in Fig. 9.

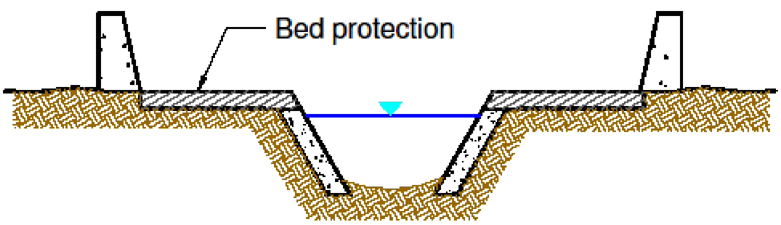


Fig. 9 Bed Protection for High Water Channel

The width of a low water channel is determined primarily on the basis of the existing low water channel, and the height of a low water channel is designed to accommodate floodwater in 2 to 3-year return period in the low water channel in principle. The flow capacity of the low water channel also depends on the demands for utilization of the high water channel bed.

(3) Cross-Section Form at Bend

At the bend of waterway, a turbulent flow occurs during floods, and water level along the concave bank rises and causes high local velocity threatening the protective structures. Considering that dead water area appears along the convex bank, the effective cross-sectional area decreases due to dead water area and occurrence of eddy. Thus the river width at the bend shall be designed at about 10 to 20% wider. If local scouring and erosion occurs frequently along the concave bank, further improvement works such as cut-off channel shall be considered.

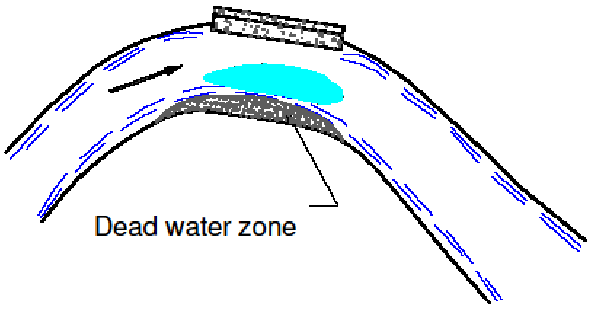


Fig. 10 River Bend

CHAPTER 3 MOUNTAIN STEEP CHANNEL IMPROVEMENT

3.1 CHANNEL IMPROVEMENT PROCEDURE

In principle, the procedures for mountain steep channel improvement are the same as the channel improvement in the common river systems described in Chapter 2. The major objectives to conduct improvement works in mountain steep channels are, however, to safely convey floodwaters containing much sediment and to stabilize the channel mainly using groundsills and revetment works.

The improvement procedure for the mountain steep channel is summarized in the figure below, and the major points are described following this figure.

PREPARATION OF TOPOGRAPHIC MAP, LONGITUDINAL PROFILE AND CROSS-SECTIONS
↓
DETERMINATION OF TYPICAL CROSS-SECTION OF CHANNEL WORKS
↓
DESIGN OF CHANNEL ALIGNMENT
↓
DESIGN OF LONGITUDINAL PROFILE OF RIVER CHANNEL
↓
DESIGN OF PROTECTIVE STRUCTURES

Fig. 11 Procedure of Improvement Works in Mountain Steep Channel

3.2 PROCEDURE OF DESIGNING CHANNEL WORKS

3.2.1 Determination of Typical Cross-Section of Channel Works

The typical cross-section of channel works shall be determined based on the following basic study results.

(1) Set-up of Upstream End

A sabo dam or a groundsill shall be designed at the upstream end as the starting point of channel works. The dam will function to check possible sediment runoff flowing into the channel works.

(2) Design Sediment Concentration

The design sediment concentration in the design discharge for planning of channel works shall be adjusted in accordance with the progress of the sediment control works in the headwaters. In Japan, the following rates are considered for the planning.

Table 1 Design Sediment Concentration Rate

Status of Sediment Control Works in Headwaters	Rate of Sediment Concentration
On-going	10%
Completed	5%

(3) Design Freeboard

The freeboard of channel works shall be set in accordance with the design discharge, as tabulated below.

Table 2 Design Freeboard of Channel Works

Design Discharge	Freeboard
Below 200 m^3/s	0.6 m
200 – 500 m^3/s	0.8 m
500 m^3/s or above	1.0 m

It can be assumed that the freeboard depends also on slope of riverbed. The ratio ($\Delta H/H$) of design flood depth (H) to freeboard (ΔH) shall not be lower than the values enumerated in the table below.

Table 3 Limiting Ratio of Design Flood Depth to Freeboard

Riverbed Slope	ΔH/H
< 1/10	0.5
1/10 – 1/30	0.4
1/30 – 1/50	0.3
1/50 – 1/70	0.25
1/70 – 1/100	0.20
1/100 – 1/200	0.10

In the case of a stream with steep slope, water surface fluctuation is higher than a stream with gentle slope due to streambed fluctuation, higher concentration of sediment runoff and higher flow velocity. Thus higher freeboard for design discharge is required.

(4) Bridge and Other Transversal Structures

Transversal structures such as bridges and pipes shall be minimized in the stretch of the channel works. When transversal structures are to be installed, it is necessary to have 0.5 m allowance to the freeboard in consideration of possible destruction by driftwoods or big boulders, as illustrated in Fig. 12.

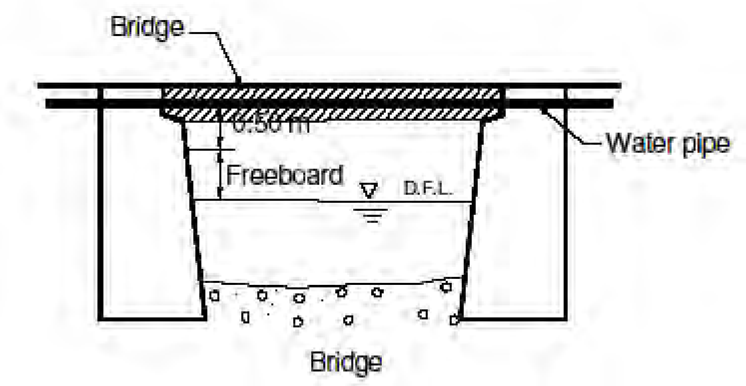


Fig. 12 Freeboard under Beam of Transversal Structure

(5) Streambed

In principle, channel works have no concrete bed lining. The concrete bed lining shall be avoided even if tractive force is greater than resistance force of riverbed materials. This also means preservation of natural environment of the stream.

(6) Transition of Streambed Slope

Where streambed slope changes, groundsill shall be planned at the transition stretch to minimize channel scouring. In addition, the groundsills shall be constructed at some intervals to prevent scouring at the foundation of revetment even if a constant slope continues over a considerable distance. The interval of groundsills shall be equal to the denominator of fraction expressing the target riverbed slope. For instance, if the riverbed slope is 1/100 (1%), the suitable interval of groundsills shall be 100 m.

(7) Water Utilization

When channel works is planned in the alluvial fan, water utilization around the channel works shall be investigated thoroughly in advance since the channel works may affect groundwater as well as surface water. Existing water use from spring water or groundwater could be affected by the construction of channel works.

3.2.2 Design of Channel Alignment

The alignment of channel works shall be straight to ensure the smooth flow of floodwater and to easily maintain the channel. In densely congested urban areas, the straight alignment is not practicable due to difficulties of land acquisition. In such a case the alignment is often planned following the existing channel. Even in the case of a sharp bend, the alignment shall be adjusted or alleviated as much as possible.

3.2.3 Design of Longitudinal Profile of River Channel

If streambed slope changes due to channel works, the works shall be designed in such a way that the design slope becomes gradually gentle towards downstream. Changes of the slope shall be limited within changes of 50% in the tractive force.

Sudden changes in streambed slope will result in heavy scouring or large amount of sediment deposits around the transition stretch. Maintenance work of the channel will be difficult due to unexpected scouring or sedimentation. Changes in riverbed slope and flood depth shall be restricted to the changes of tractive force of less than 50%.

3.2.4 Design of Protective Structures

For structural design, particular attention shall be paid to the following design of structures.

(1) Bend

Water level usually rises along the concave bank of the river bend during floods due to centrifugal force. The crest height of revetment along the bank shall be designed higher than the opposite convex bank. Furthermore, floodwater tends to converge along the concave bank so that proper reinforcement of the structures shall be considered.

It might be apprehensive that heavy local scouring also occurs along the concave bank. Thus stronger and more durable revetment works are required along the bank than those along the straight channel. In addition, sufficient embedment depth shall be considered and scouring protection works shall be provided along the concave bank.

(2) Connection with Sabo Dam

The opening of the sabo dam shall be calculated by the weir formula, while the section of channel works shall be calculated by the channel formula. When channel works are directly connected immediately downstream of sabo dam, the connection between channel works and sabo dam or vertical wall shall provide smooth flow of floodwater.

(3) End Protection Works of Concrete Lining

End protection works such as riverbed protection and groundsill shall be considered to protect the revetment foundation.

(4) Principle of Channel Works

For channel works, embankment shall be avoided and excavation shall be adopted as much as possible, as illustrated in Fig. 13. For instance, embankment shall be limited only to the connecting part to the mainstream with diking system.

Floodwater flowing through the channel works in the mountain stream usually has steep slope and high flow velocity. In such cases, embankment and diking system have a high possibility of breaching. Channel excavation shall be adopted for ensuring safety.

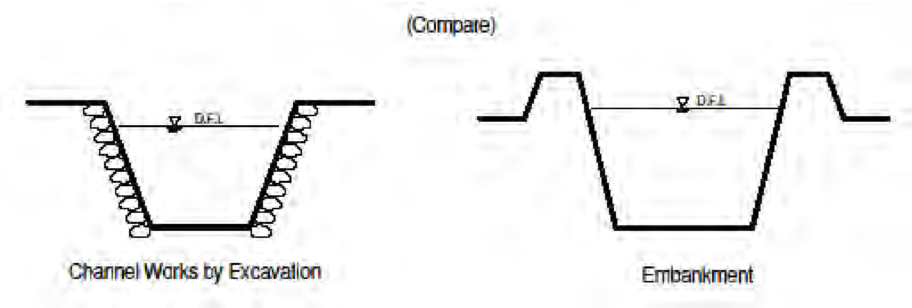


Fig. 13 Channel Works by Excavation

(5) Overlapping Height of Groundsill

The foundation of the groundsill for channel works shall be at least as deep as the crest of an adjacent downstream groundsill to obtain a sufficient overlapping height.

Stepping groundsills shall be used for channel works. When the streambed consists entirely or almost entirely of boulders, the foundation of the groundsill shall be as deep as the opening of the adjacent downstream groundsill. When the streambed consists of sand or gravel, the foundation of groundsill shall overlap with the opening of the adjacent downstream groundsill to protect the apron from scouring and channel degradation.

(6) Design Section

The design cross-section of channel works shall be determined from the existing channel width and shall not be smaller than the existing channel width.

River functions are adversely affected and design flood level increases if the channel width decreases. This means unsafe selection for planned structures.

Channel works of low water channel shall be adopted when the river width is wide enough to cause a turbulent flow or an extraordinary accumulation. If an adjacent area is free from river improvement, it is ideal to plan a buffer zone by making the area a natural forest. The wider portion of the high water channel shall be used as a sedimentation basin to accommodate unexpected sediment runoff, as shown in Fig. 14.

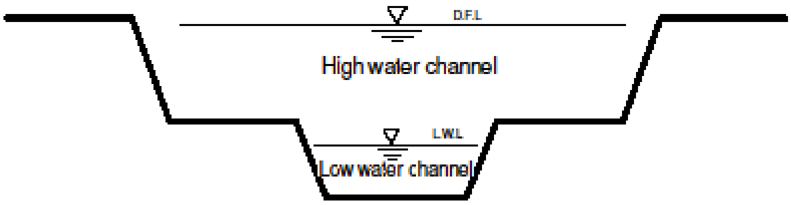


Fig. 14 Low Water Channel and High Water Channel