CHAPTER

5

HOW SHOULD FLOOD CONTROL FACILITIES BE PLANNED AND DESIGNED?

How Should Flood Control Facilities be Planned and Designed?

Irrigation more widely consists of two main components, irrigation facilities and flood control facilities. This chapter deals with the planning and design methods applied in flood control facilities. The purpose of flood control facilities in the PMS method irrigation project is to protect irrigation facilities from flooding, rather than flood control of the river. Combining dikes and stone spur dikes, the PMS method irrigation project is planned and designed to meet the following conditions.

- The dikes are planned to protect farmlands, residential areas, and irrigation canals along the river from flooding at or below plan level.
- Assuming flooding and dike breaching due to floods beyond plan level, the sections where dikes are installed are minimized. As a general rule, the plan provides escape routes for flood water, without installing dikes on both the left and right banks in order to prevent the flood water level from rising excessively.
- Areas behind the dikes (inland areas) that have flooded in the past will be used based on the assumption that they will experience flooding beyond plan level and are therefore not used for residential purposes.
- Stone spur dikes are planned to prevent scouring of dikes and river banks and to play a role in stabilizing the main channel of the river.
- The plan adopts semi-overflow nontransparent stone spur dikes based on the need to prevent river bank erosion and ensure the resistance of the spur dikes themselves against the water flow.
- Stone spur dikes require continuous monitoring of damage and erosion to the surrounding area. They are planned to facilitate maintenance, including the resupply of gabions and boulders.
- The plan takes into consideration the social environment of the area, such as land acquisition following the installation of the dikes and the impact on the opposite bank due to changes in the flow of the river following the installation of the spur dikes.

With a structure that is easy for local residents to maintain and that utilizes boulders, cobble, soil, vegetation, and gabion wire that can be procured locally, flood control facilities are designed as follows.

- The dikes are arranged in a smooth alignment along the main channel, avoiding existing facilities in the inland area as much as possible.
- The profile of the crown of the dike is set by adding the freeboard according to the flow rate at the design flood water level.
- The standard cross section of the dikes shall be the slope gradient and shape required to ensure the stability of the dikes.
- Revetments of dike are designed by calculating the boulder diameters that will not be washed away or eroded by the flow of the river.
- Vegetation works and drainage works are also considered as ancillary facilities for the dikes.
- The shape (width, height, and gradient) of the stone spur dikes is designed based on conditions such as river width, river alignment and design flood water level.
- As with the dike revetments, the foundation and main body of the stone spur dikes are designed by calculating the diameter of boulders that will not be washed away or eroded by the flow of the river.
- When designing dikes and stone spur dikes, it shall be designed so as not to narrow the width of the river channel so that it does not obstruct the flow of water in the river.

The following pages give commentary on the above contents:

5.1 Layout Planning and Design Process of Flood Control Facilities

5.1.1 | Layout Planning of Flood Control Facilities

Based on the basic concept formulated jointly with local residents, river conditions, and the layout plan and design of irrigation facilities, the flood control facilities in the PMS method irrigation project—that is, dikes and stone spur dikes—are planned with the following in mind.

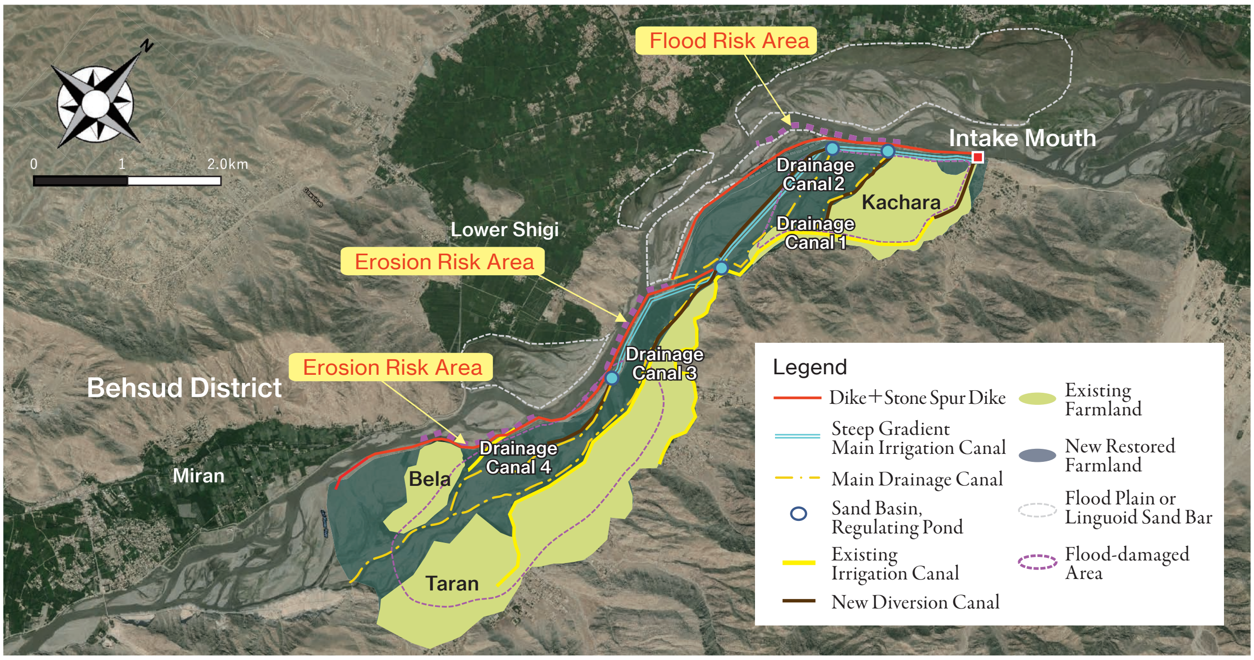


Figure 5.1 Example of the Layout of Irrigation Facilities, Dikes, and Stone Spur Dikes [2)]

(1) Layout Planning of Dikes

Field surveys are conducted to better grasp existing structures such as farmlands, houses, roads, and canals that must be protected from flooding, with satellite imagery and land use maps used to gain more in-depth insights. Dikes are arranged to protect these inland area assets. Our understanding of the relation between the elevation of the inland areas and the design flood water level is based on the results of a river cross section survey. Dikes are placed in sections where the elevation of the inland area is lower than the design flood water level. This plan strictly avoids dike plans that confine flood water flow by placing dikes on both banks of the river. If a dike is planned on one bank, existence of retarding basin area must be confirmed on the opposite bank. If placing dikes on both banks cannot be avoided, instead of applying a continuous dike, an open levee is applied to provide a retarding basin to which flood water flow can escape.

(2) Layout Planning of Stone Spur Dikes

High-speed currents form in the outer curved parts of river channels. There, water colliding fronts form and scouring and erosion are likely to occur, increasing the risk of the dike collapsing. Stone spur dikes are placed in these sections. In addition, a stone spur dike is installed for the purpose of controlling the direction of flood flows and stabilizing the main channel and sandbars. If the length of a spur dike is excessively long with respect to the width of the river, the main channel will shift away from the river bank more than necessary, which may lead to scouring on the opposite bank. A layout is planned with consideration toward the installation ranges and lengths of the stone spur dikes.

5.1.2 | Design Process for Flood Control Facilities

Flood control facilities for the PMS method irrigation project— namely dikes and stone spur dikes—are designed according to the design process shown in Figure 5.2. The method for designing flood control facilities is described in detail in Sections 5.2 and 5.3.

In a plane design, specifications design, and profile and cross section design of the dikes and stone spur dikes, the location of farmlands, residential areas, and irrigation canals along the river as well as the safety of irrigation facilities in the river against flooding is taken into consideration. The design gives consideration to land acquisition restrictions, workability, economic feasibility, and maintainability. Depending on whether land acquisition is possible and requests from residents, the layout design of the dikes and stone spur dikes is flexibly reviewed as necessary upon consulting with the various parties concerned.

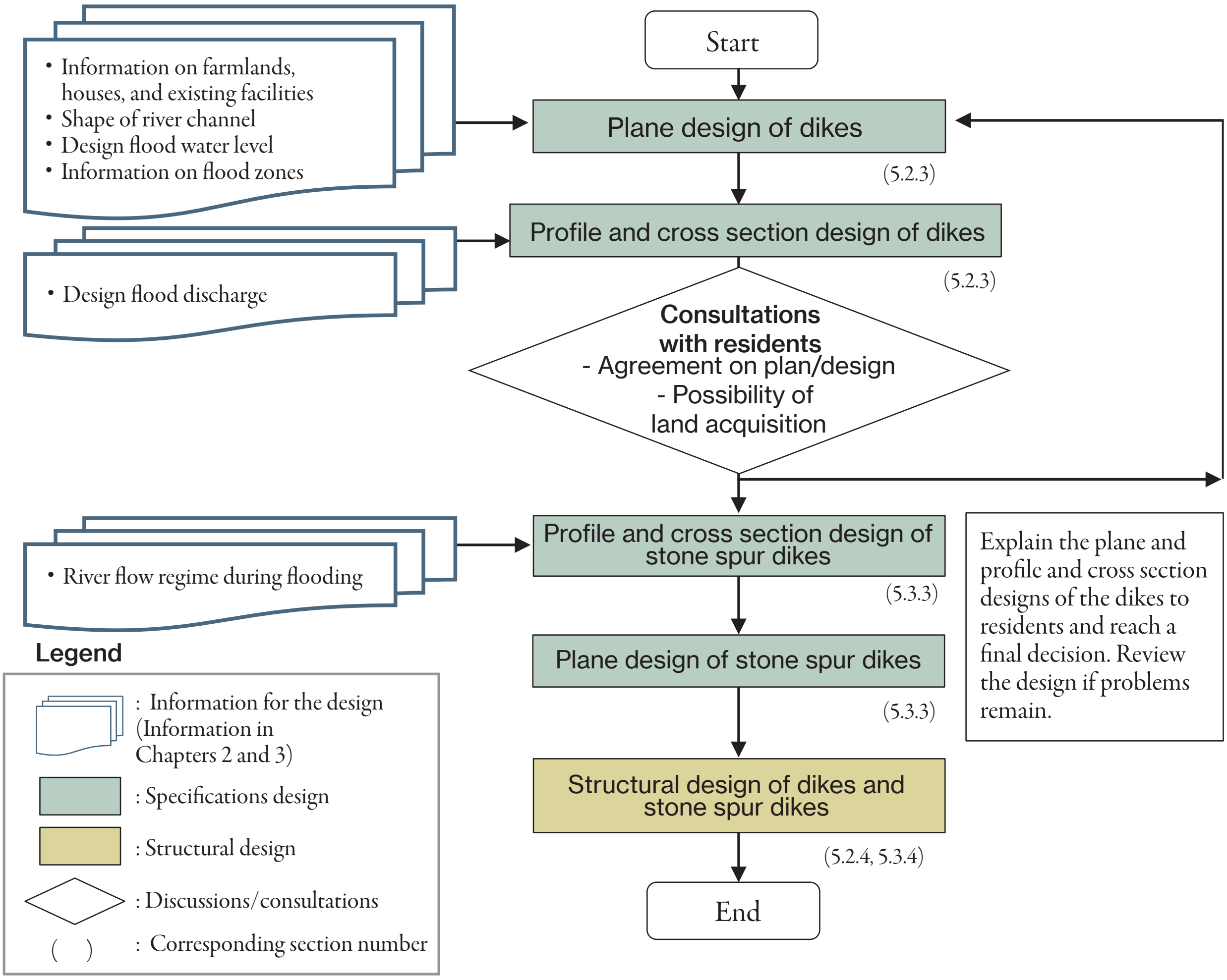


Figure 5.2 Design Process for Flood Control Facilities [2)]

5.2 Dike Design

5.2.1 | Basic Design Policy of Dikes

The dikes are embankments constructed from local surplus soil to protect inland areas from flooding. Important points to be observed when designing the dikes are as follows. In addition, the process of designing the dikes is as shown in the Figure 5.3 design process figure.

- The alignment of a dike shall be linear, with a smooth radius of curvature that follows the shape of the main channel so that a water colliding front resulting in erosion of the dike does not occur.

- The dikes use revetment works and foot protection works to prevent the dikes from collapsing due to scouring at the dike foot. However, stone spur dikes are installed in sections where erosion is significant, such as curved river channels.

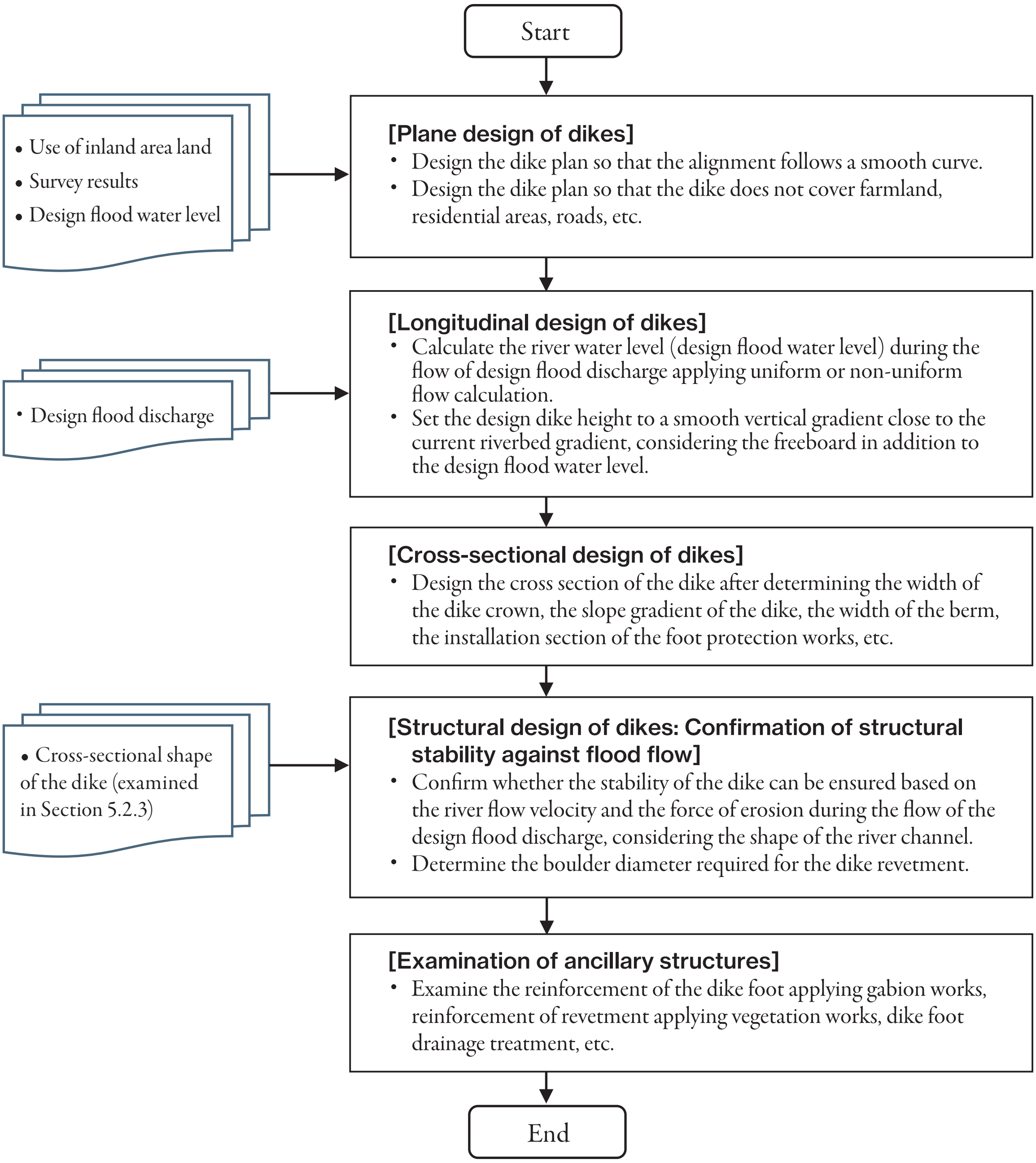


Figure 5.3 Design Process for Dikes [2)]

5.2.2 | Type and Design Policy of Dike Revetments

(1) Type of Dike Revetments

The dikes are formed by heaping sandy soil and consolidating the load, while mainly applying local surplus soil, with erosion preventive measures in the form of revetment (slope protection works, foot protection works, etc.). A concrete (block) lining revetment is preferable because of its good appearance, but with the PMS method irrigation facilities, a revetment will be provided by boulders, gabion works and vegetation works, and foundation with a foot protection by boulders is adopted.

The characteristics of both types of dike revetments and their applicability in Afghanistan are compared in Table 5.1. A boulder/gabion works revetment is cheaper than a concrete (block) lining revetment and can be constructed with materials (boulders, annealing wire for gabion) that can be procured locally in Afghanistan. This means it is easy for local residents to maintain.

Table 5.1 Comparison of Dike Revetment Types [2)]

Item	Boulder/Gabion Works (Adopted by the PMS Method Irrigation Facilities)	Concrete (Block) Lining (adopted in many countries)
Image	 Source of photo: 1)	 Source of photo: JICA
Type	- Constructed with stone masonry applying primarily boulders	- Constructed with precast concrete
Features	- Maintainability through use of materials that can be procured locally - Relatively low construction costs	- High durability due to concrete structure - Low maintenance frequency if the dike foundation and the dike itself are securely compacted Disadvantages
Due diligence points	- Regular maintenance required such as adding additional stones	- Time and labor required to repair in the case of damage; almost impossible for residents to handle repairs alone - High construction costs
Applicability in Afghanistan	- Easy for local residents to maintain - Structure utilizes stones that exist in abundance in many areas - Many track records with the existing PMS irrigation project	- Difficult for local residents to maintain - Government and donor track record

(2) Design Policy of Dikes

The design specifications of the dikes in the existing PMS irrigation project are as follows. The following dike components and the ancillary facilities shall be the standard design for the PMS method irrigation project. On the other hand, the dike height, dike slope gradient, dike crown width, and dike width are designed according to the conditions of each area, such as the design flood discharge and design flood water level, while also referring to the actual specifications below. An example of a standard cross section of a dike is shown in Figure 5.4.

- Dike components: The dike is composed of revetment and foot protection works with boulders of 0.5 to 2.0m diameter and/or stone spur dike.
- Ancillary facilities: Front slope of dike: Wicker works
  Front slope of dike: Wicker works, *shisham*
  Back slopes of the dike: *Shisham* or eucalyptus are planted to form a forest zone to strengthen the dike.
  Outer slope foot of dike: Drain installed

- Dike height: Design flood water level + 0.5–2.5 m (depending on the design flood discharge)
- Slope gradient of dike: In the case of stone masonry: 1:1–1:1.5
  In the case of an soil embankment slope by applying local surplus soil : 1:2.0
- Dike crown width, dike width: Crown width: 8.0 m or more
  Dike width: 12.0–15.0 m

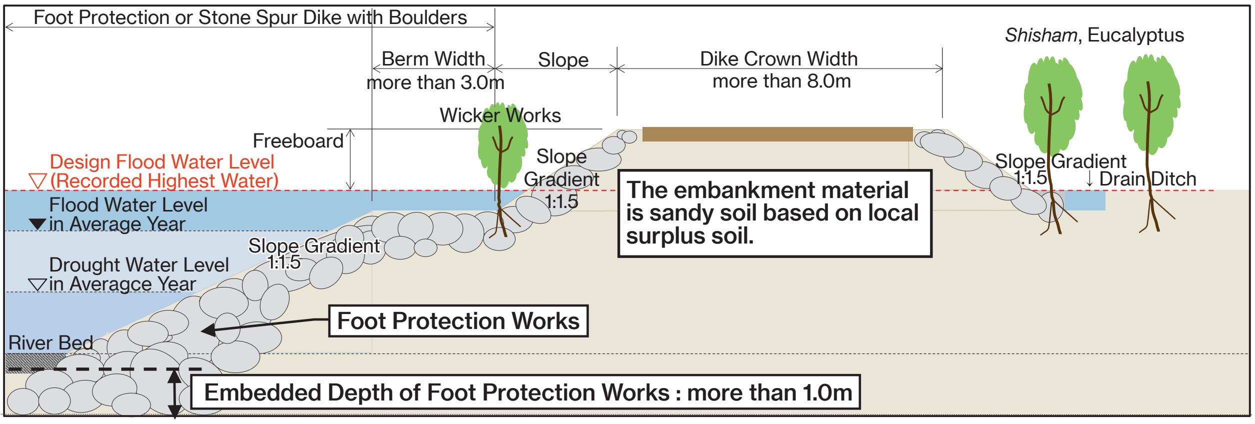


Figure 5.4 Standard Cross Section of the Kunar River Dike / Revetment in the Existing PMS Irrigation Project (Example of a Dike in the Behsud District) [2), see 3)]

5.2.3 | Specification Design of Dikes

(1) Plane Design of Dikes

The process for the plane design of the dikes is as follows. The image of plane alignment design of dikes is shown in Figure 5.5.

1) The standard cross section of the dike examined in Section 5.2.3 (3) is incorporated to a river cross section drawing acquired by topographical survey result. And provisional dike cross section drawing is created.
2) The positions of the center of the dike crown, the dike shoulder, and the dike slope foot incorporated on each dike cross section figure (provisional) is plotted in the plane drawing.
3) The plane alignment of the dike is determined so that the uneven lines connecting the points plotted on each cross section of the plane drawing form a smooth curve with a radius of curvature. It is necessary to make sure that the line connecting the dike slope foot does not overlap with farmlands, private houses, roads, and so on as much as possible.
4) The dike alignment determined in this way is re-added to the cross section of the river to confirm the cross-section shape and plane alignment of the dike.

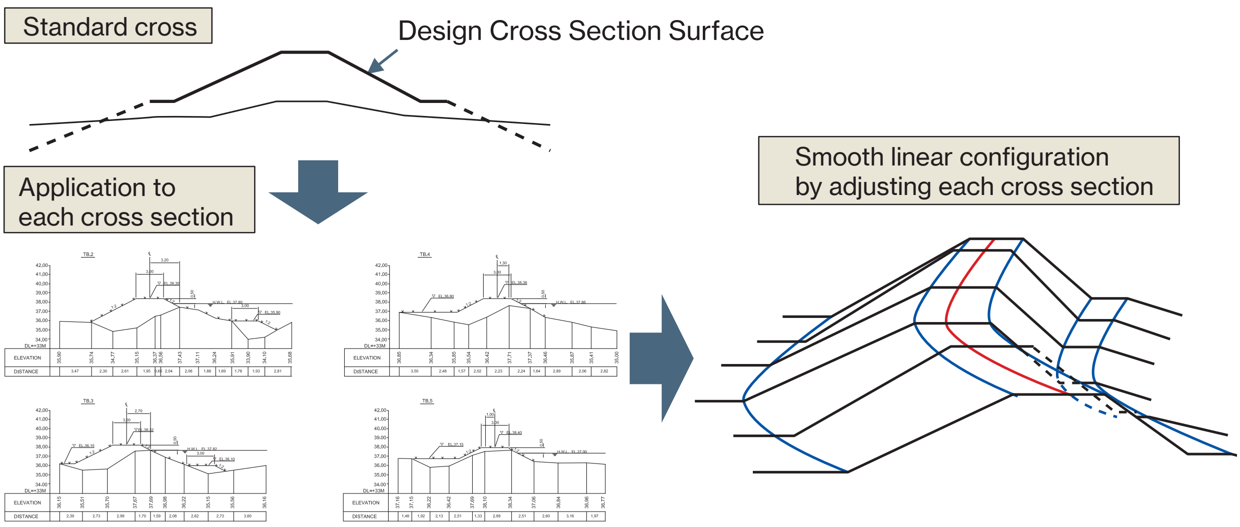


Figure 5.5 Plane Alignment Design of Dikes [2)]

The following points shall be noted in the plane design of dikes.

- In river channel sections where the river is wide and meandering, **the river width shall not be narrowed easily.** Rather, the dike alignment is set after securing a width greater than the current width of the river channel so as to maintain and promote the flood regulation effect of the river channel.
- If the width of the river is narrow, or if it is determined that a certain degree of flooding is unavoidable, an open levee is installed to make a part of the dike discontinuous. An open levee is installed so that flooding in the river channel slowly flow back from the discontinuous section of the dike toward the upstream side of the inland area.
- When planning the open levee, signal with stacked gabions and so on along the boundary of the retarding basin to prevent people from living there. And while cultivation may be permitted in the retarding basin, it is necessary to make residents aware of the natural conditions, namely that flooding may occur.

An open levee has the following functions as shown below.

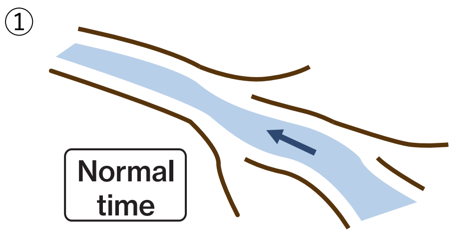
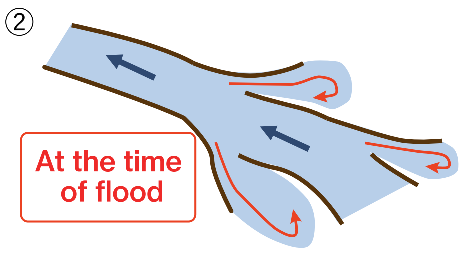
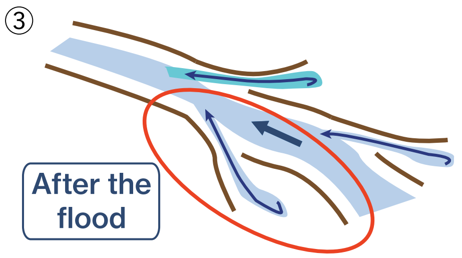
	In the normal condition, river water flows down the low water channel.
	Flood control (retarding basin effect): During flooding, flood water is temporarily allowed to flow from the openings to the inland areas to control the flooding.
	Returning floodwater to the river channel: Flood water that was retained during the flood or if a dike breaches upstream is returned to the river channel. Inland water and tributary drainage: Drains the tributary flowing into the opening and drains inland water.

Figure 5.6 Function of Open Levee [2)]

(2) Design of Dike Profile

Design of dike profile follows the process below. See Figure 5.7.

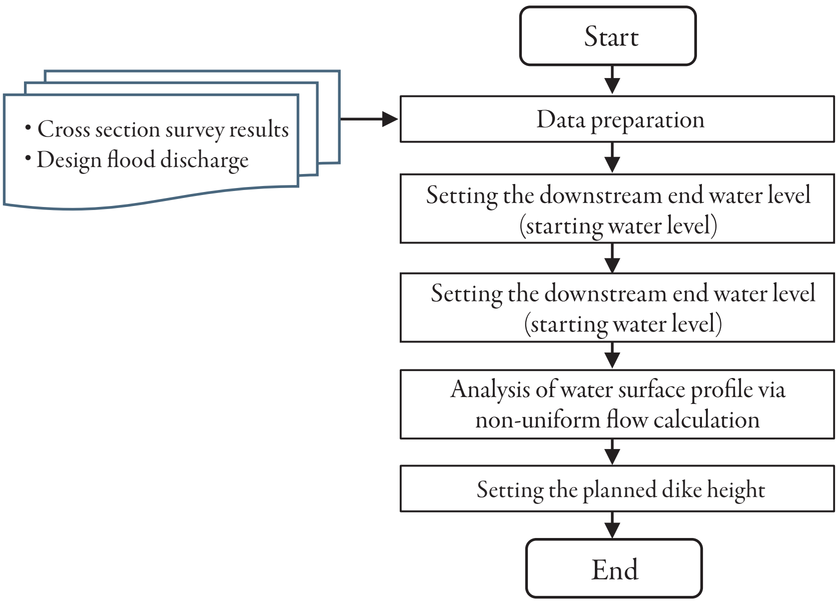


Figure 5.7 Design Process for Dike Profile [2)]

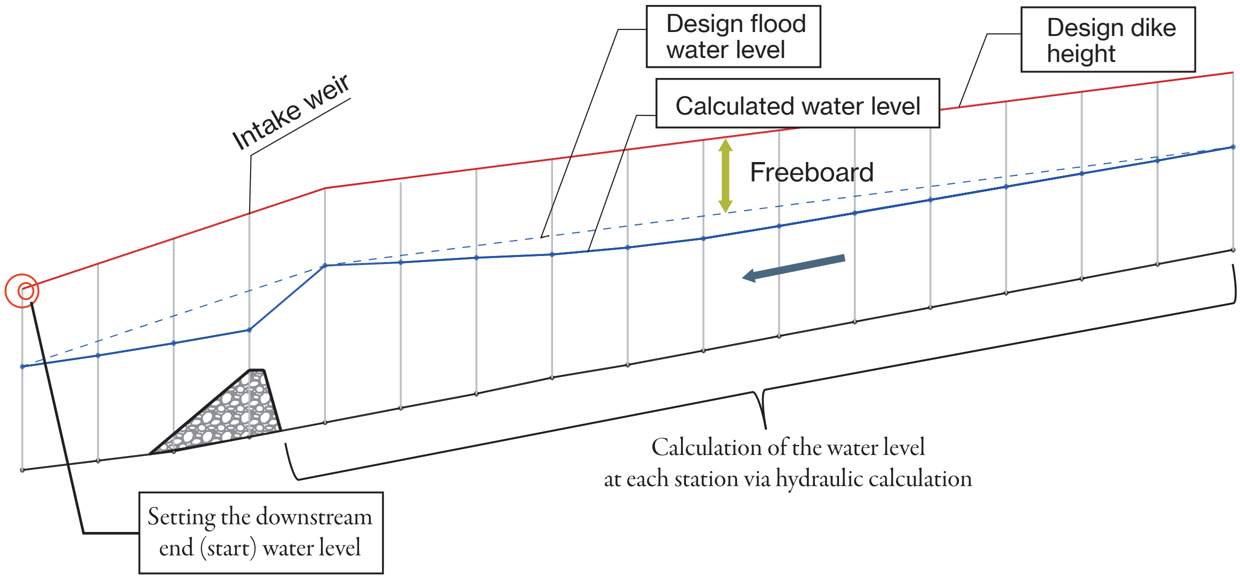


Figure 5.8 Visualization of Dike Height Determined by Hydraulic Calculation [2)]

1) The range of hydraulic calculation is from a few hundred meters downstream of the proposed intake weir location to the section where the flood control facility will be provided upstream of the weir location. The date required for hydraulic calculations includes the river cross section survey data and design flood discharge data obtained in Chapter 3.
2) Next, the downstream end water level, a condition for hydraulic calculations is set. The downstream end water level is set at a point where the water level is stable several hundred meters downstream of the intake weir point. After setting the starting point, the starting water level applying the Manning equation is calculated based on the riverbed gradient at the set starting point and other information. If the design flood discharge overflows from the intake weir and meets the conditions for a complete overflow shown in Chapter 4 (*4.2.5 (4) c) Calculation Method of Flow Velocity Immediately Downstream of Weir Apron Works*), the overflow formula indicated in Chapter 4 (*4.2.4 Design of Basic Specifications of Intake Weir and Intake Gate*) will be applied to find the overflow water level at the top of the intake weir. Hydraulic calculations may also be performed applying that water level as the starting water level at the weir station.
3) Hydraulic calculations are performed under the above conditions of the starting water level. The water surface profile is analyzed, and the design flood water level is set for each station (Sta. No) at regular intervals. While hydraulic calculations generally use non-uniform flow calculation, if the river cross section is generally constant and the changes in the cross section are limited, uniform flow calculation can be applied. In addition, if it is necessary to estimate the channel storage effect (flood regulation) during flooding, unsteady flow calculation is applied.

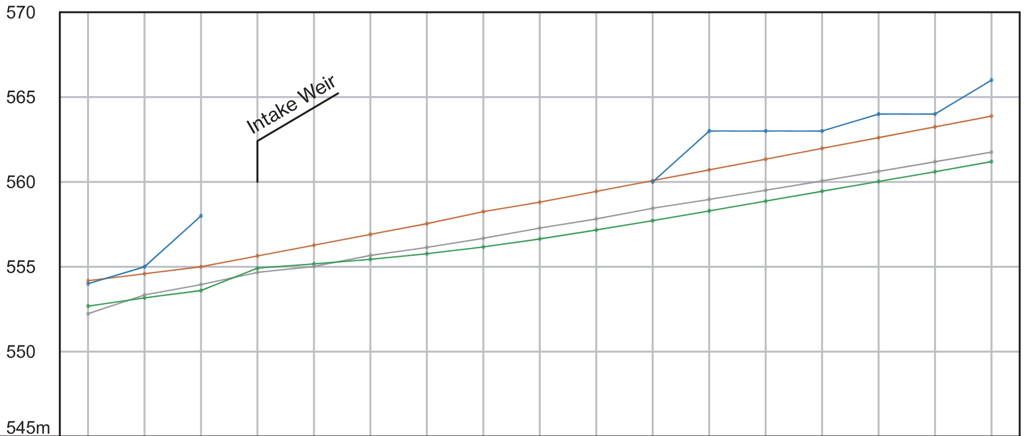
The design dike height is determined by adding the freeboard to the water surface profile from above 3). For the freeboard, the values indicated in Table 5.2 according to the design flood discharge is referred.

Table 5.2 Design Flood Discharge, Freeboard and Dike Crown Width [4)]

Design flood discharge (m³/s)	Freeboard (m)	Dike Crown Width (m)
Less than 200	0.6	3
200–499	0.8	3
500–1,999	1.0	4
2,000–4,999	1.2	5
5,000–9,999	1.5	6
10,000 or more	2.0	7

If the inland area elevation is higher than the design flood water level, the freeboard can be reduced to 0.6 m.

4) A longitudinal profile based on the above information is created. In principle, a) design dike height gradient, b) design dike height, c) ground elevation, d) design flood water level, e) distance, etc. are indicated on the dike profile. In addition, the locations of major structures in the longitudinal direction of the river such as intake weirs, intake gates, and the confluence of tributaries are clearly indicated. See Figure 5.9.



Design Dike Gradient	554.2							L=3200 i=1/330									563.9
Design Dike Elebation (m)	554.2	554.6	555.0	555.6	556.3	556.9	557.5	558.3	558.8	559.4	560.1	560.7	561.3	562.0	562.6	563.3	563.9
Ground Elavation (m) (google earth)	554	555	558								560	563	563	563	564	564	566
Ground Elavation (m) (Survey Data)	552.2	553.3	554.0	554.7	555.0	555.7	556.1	556.7	557.3	557.8	558.5	559.0	560.0	560.0	561.0	561.2	561.8
Design Flood (m)	552.7	553.2	553.6	554.9	555.2	555.4	555.8	556.2	556.6	557.2	557.7	558.3	558.9	559.5	560.0	560.6	561.2
Distance (m)	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200

Figure 5.9 Example of Dike Longitudinal Profile [2)]

(3) Cross-sectional design of dikes

The procedure for the design of dike cross-section is as follows.

1) Because it is assumed to be utilized as a construction (maintenance) road, the width of the dike crown should have about 4 m or more ensured for one-way traffic and about 8 m or more for two-way traffic.

2) The slope gradient of the dike shall be a gradient that can ensure the stability of the slope. A gradient of 1:1.5 is standard for stone masonry slopes, and 1: 2.0 is standard for embankment slopes.
3) If the height of the dike is high, a small berm with a width of 3 m or more is installed on the slope. The installation criteria for small berms shall be as follows. The purpose of small berm installation is to prevent the load of the upper embankment from being applied to the lower embankment, and to set back the load of the upper embankment to ensure the stability of the slope. In the existing PMS irrigation project, small berms are set slightly above the normal flood level.
- River side (river side area): Berm is installed 3–5 m down from the crown when the dike height is 6 m or greater.
- Land side (inland area): Berm is installed 2–3 m down when the dike height is 4 m or greater.
4) The dike itself shall have a depth of at least 1 m from the deepest riverbed elevation at the foot protection works installation site.
5) The dike cross section clearly indicates the basic specifications such as the external dimensions of the dike and the applied materials (sandy soil, boulders, vegetation, gabion works). See Figure 5.4.

5.2.4 | Structural Design of Dikes

(1) Structural Characteristics of Dikes in the PMS method irrigation project

The structural characteristics of dikes in the PMS method irrigation project are as follows.

- The dikes are constructed from materials that can be procured locally, and shall provide foot protection works by installing riprap works on the river side with stone masonry consisting of boulders of a size of 1 m or more. Stone pitching are provided to small berms and the upper slopes of the small berms to reinforce the dike. See Photo 5.1 and Figure 5.4.

Photo 5.1 Stone Pitching on a Continuous Dike, Small Berm, and the Upper Slope of the Small Berm [2)]

- Foot protection works that employs not just boulders but a combination of boulders and gabion works is applied on the dikes along the river side as shown in Photo 5.2. There are two types of gabion works—1 m wide x 2 m long x 1 m thick, and 1 m wide x 2 m long x 0.6 m thick—and multiple gabions are connected and installed.

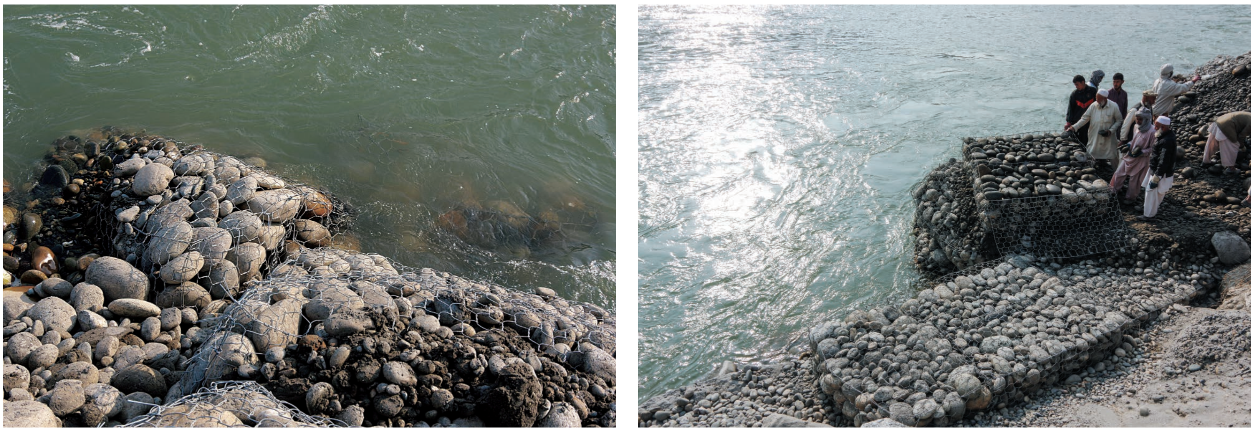


Photo 5.2 Foot Protection Works applying Combined Gabions [3)]

- On the river side, willow trees, etc. are densely planted in the gravel on the slope of the dike at a density of about 4–5 trees/m^2 (vegetation works) to reduce the velocity during flooding and reinforce the revetment to prevent the dike from collapsing. However, in the case of planting trees on the river side, the installation of vegetations with thick long roots should be avoided because it causes water piping formulation inside the bank embankment
- On the land side, eucalyptus and *shisham* trees are planted at a density of about 1 tree/ m^2 to slow down floodwater (dikes with tree belts). However, tree roots growing inside the dike weaken the embankment. Planting trees on an embankment that is higher than the ground elevation of inland side should be avoided. An example of strengthening the embankment by planting tree is shown in Figure 5.10.

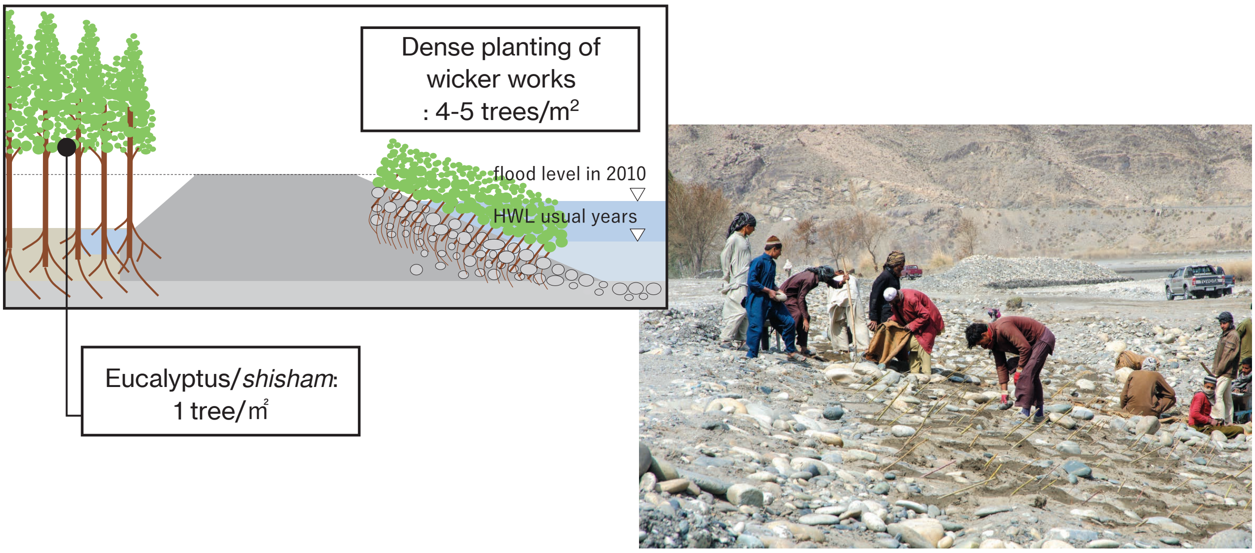


Figure 5.10 Strengthening Dikes by Planting Trees [1)]

- Dike crowns shall be utilized as access roads and maintenance roads. Dike crowns shall have a width of two lanes, or about 8 m or more, so that construction vehicles can pass in both directions as shown in Photo 5.3

Photo 5.3 Dike Crown utilized as Access Road [1)]

After determining the shape of the dike based on the above considerations, a specific dike structure is examined. In addition, as water inside the dike leads to it weakening, separate structural studies are considered and drawings created, such as drainage at the bottom of the dike slope foot to quickly drain water, and a structure of the part where the floodgate and the embankment are connected to each other.

(2) Examining the Stability of Boulder Revetments on Dikes

As dikes in the PMS method irrigation project are reinforced by boulder stone masonry revetment works, boulder size must be set by confirming the stability of the boulders on the dike revetment against the flow of the river.

The stability of the boulders on the dike revetment can be examined by knowing the critical particle size for sediment movement of the boulder for a certain design flow velocity. The following formula is a calculation criterion for riprap size at the U.S. Army Corps of Engineers. It is a formula derived from the balance between the tractive force acting on the material (natural stone) and the threshold of sediment movement. The sizes of stable boulders (cobble) on dike revetments are determined to be a particle size equal to or greater than the average particle size calculated applying the following formula.

$$D_m = \frac{1}{E_1^2 \bullet 2_g \left[\frac{\rho_s}{\rho_w} - 1\right]} V_0^2 \quad \cdots\cdots (5.1)$$ [2), see 5), 6)]

where, D_m: Average particle size of boulder (cobble) (m), V_0: Characteristic flow velocity (m/s), ρ_s : Stone density (kgf･s^2/m^4) , : Gravitational acceleration (m / s^2) , ρ_w : Water density (kgf･s^2/m^4), ρ_s / ρ_w: Generally about 2.65, E_1: Experimental coefficient indicating the strength of turbulence (Generally 1.2).

The above formula is obtained for riprap on a horizontal plane. When riprap is installed on a slope with a slope angle θ , the slope correction factor K obtained from the following formula is calculated for the particle size D_m, Let the multiplied $K \bullet D_m$ be the size of the boulder (cobble).

$$K = \frac{1}{\cos\theta \sqrt{1 - \frac{\tan^2\theta}{\tan^{2\Phi}}}} \quad \cdots\cdots (5.2)$$ [2), see 5), 6)]

where, Φ : Internal friction angle in water stone material (about 38° for natural stone and 41° for crushed stone), and θ : Slope angle.

In a curved river channel, the flow velocity is increased by the free vortex generated inside and the forced vortex generated at the outer downstream end as shown in Figure 5.11. The flow velocity is further increased by erosion in the outer bank of the curved part. Therefore, the design flow velocity used for the stability analysis of the dike revetment in curved parts of the river channel is calculated applying the following formula, adding the correction factor to the average flow velocity of the river channel.

$$Vo = \alpha \cdot Vm \qquad (5.3)$$ 2), see 5)

Inside of curved river channel:

$$\alpha = 1 + B/(2 \cdot r) \quad (\textit{Considering only curvature correction}) \qquad (5.4)$$ 2), see 5)

The section from the outside of the curved river channel and the downstream end of the curve to twice the width of the river:

$$\alpha = 1 + \Delta Z/(2 \cdot H_d) + B/(2 \cdot r)$$
$$(\textit{Consider both crosssection correction and curbature correction}) \qquad (5.5)$$ 2), see 5)

where, Vo : Design flow velocity of revetment (m/s), Vm : Average flow velocity of the river channel (m/s), α : Correction factor due to the plane curvature and cross section of the river channel, B : River channel width (m), r : Radius of curvature (m), H_d : Design depth (m), ΔZ : Maximum scouring depth on outer bank of the curved part (m) (Calculated as the difference between the average riverbed elevation and the deepest riverbed elevation. See Figure 5.12.)

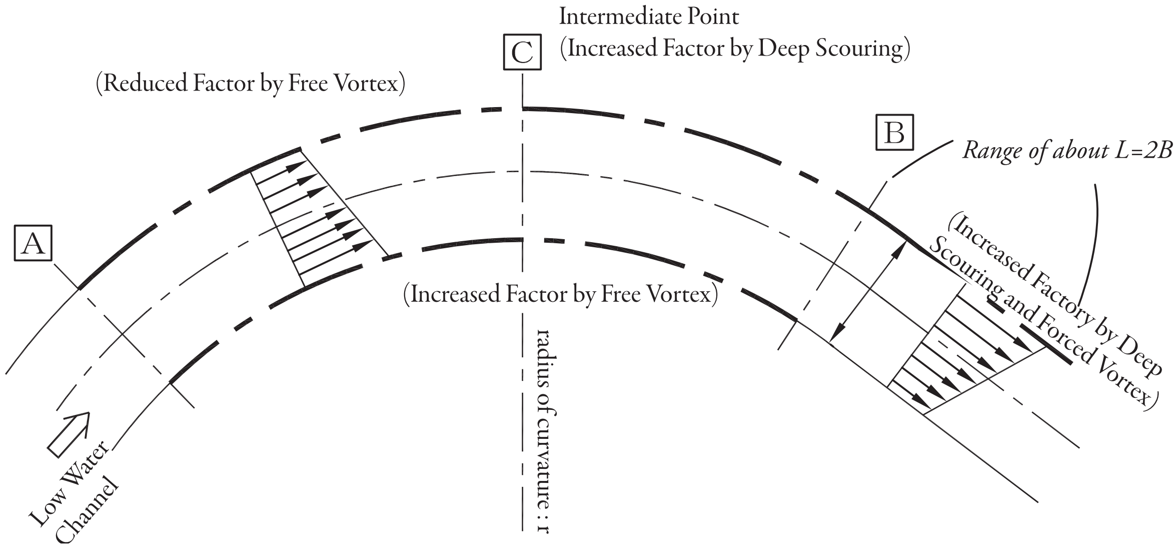


Figure 5.11 Flow Velocity Correction in Curved Waterways (Rivers) 2), see 5)

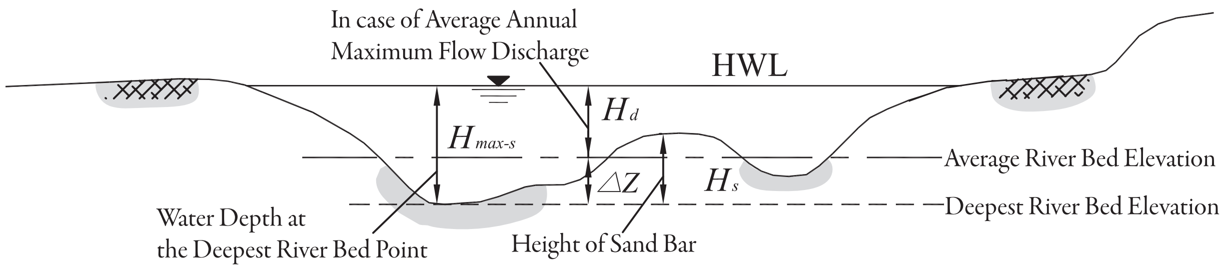


Figure 5.12 Average Riverbed Elevation and Deepest Riverbed Elevation in an Actual River 2), see 5)

5.3 Design of Stone Spur Dikes

5.3.1 | Basic Design Policy for Stone Spur Dikes

One function of a stone spur dike is to change the direction of the flood flow scouring the river bank to the opposite bank and is intended to stabilize the dike revetment as well as the main channel and sandbars. Important points to be observed when designing stone spur dikes are as follows. In addition, the process of designing stone spur dikes is as shown in the Figure 5.13.

- As a general rule, a stone spur dike is an upward spur dike, **and the application of a downward spur dike that causes scouring near the river bank should be avoided**.
- The length of a stone spur dike is set appropriately according to the width of the river channel to avoid scouring on the opposite bank and other impacts.

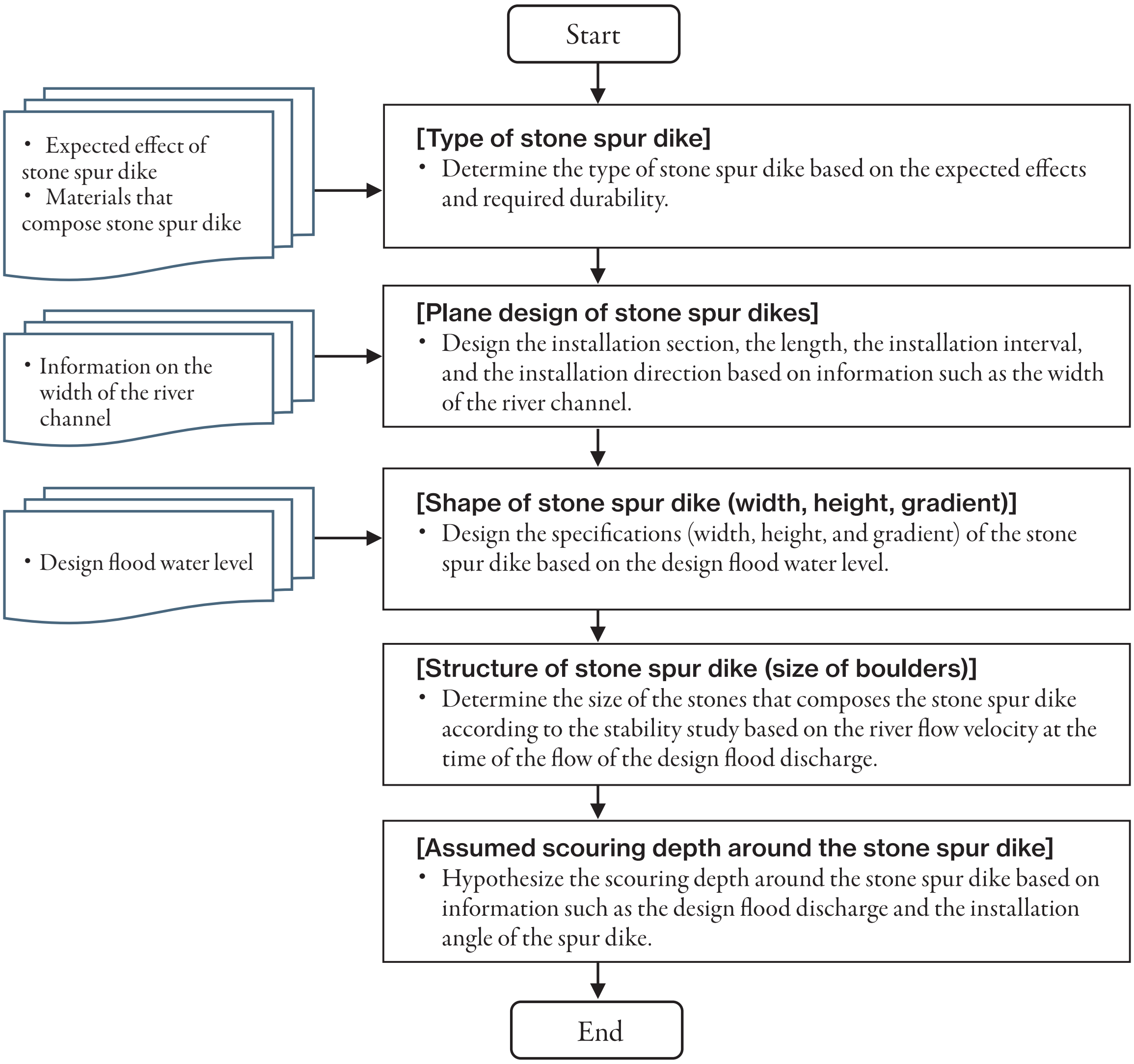


Figure 5.13 Design Process for Stone Spur Dikes [2)]

5.3.2 | Type of Stone Spur Dikes

(1) Spur Dike Components

Stone spur dikes are formed by stacking boulders from the dike slope foot to the river side, and has the role of protecting the dike embankment and the sandbar. In terms of dike embankment protection, erosion of the slope foot is prevented at curved parts of river channels. In terms of protection of sandbars, it has functions such as controlling the river flow direction, stabilizing the alignment of main channel, and securing the cross sectional area of the river channel at the narrow section and near the intake weir. Spur dikes are often applied precast concrete blocks as components in many countries, but the PMS method irrigation project adopts a type of boulders. Spur dikes applying boulders are relatively cheap when compared to precast concrete block types and can be constructed with materials that can be procured locally in Afghanistan. They are therefore easy for local residents to maintain. Table 5.3 shows a comparison of the types of spur dike.

Table 5.3 Structural Types of Spur Dike

Stacked boulder type (Adopted by the PMS method irrigation facilities)	Stacked precast concrete block type (adopted in many countries)
 Source of photo: 1)	 Source of photo: 8)

(2) Structural type of stone spur dikes (Overflow type, semi-overflow type, non-overflow type)

The structural types of spur dikes include overflow types, semi-overflow types, and non-overflow types. Their characteristics are as shown in Table 5.4. The standard design of spur dikes in the PMS method irrigation project shall be a semi-overflow type, which offers intermediate functions of overflow and non-overflow types. A semi-overflow type stone spur dike has the following characteristics.

- It has a moderate hydraulic jump effect. In addition to the sedimentation effect on the installation part of the upward spur dike, it exerts an appropriate reduction in the force of water and prevents river bank erosion.
- As the impact of the force of water on the spur dike structure is slightly smaller than that of a non-overflow type spur dike, the structural burden on the dike itself is reduced. On the other hand, over time, partial damage and erosion occur, meaning monitoring and maintenance are necessary.

Table 5.4 Structural Types of Spur Dike [2)]

	Overflow type spur dike	Semi-overflow type spur dike (Standard design in the PMS method irrigation project)	Non-overflow type spur dike
Structure	- Low spur dike height; underwater during small and medium-sized floods	- Medium spur dike height; overflows when the flood level is high and flow rate and/or force of water is large	- Relatively high spur dike height; does not go underwater except in cases of high floods - Applied in areas with rapid flows

	Overflow type spur dike	Semi-overflow type spur dike (Standard design in the PMS method irrigation project)	Non-overflow type spur dike
Features	- The low spur dike height means it does not encroach on the cross-sectional area of the river - Low construction costs	- Moderate hydraulic jump effect; provides some resistance and river bank erosion prevention even during floods - Moderate effect in reducing the force of water; reduced load on structure from water flow	-High hydraulic jump effect; functions during flooding -High effect in preventing river bank erosion
Due diligence points	- Low hydraulic jump effect; there is concern about the impact of overflow water on the dike revetment	- The hydraulic jump effect to prevent river bank erosion is slightly inferior to that of the non-overflow type	- Reduced cross-sectional area of the river; becomes a large obstacle for flood water - Large impact from the force of water on the spur dike structure

The structural type of spur dikes can be further classified into transparent types and nontransparent types. The characteristics of these are shown in Table 5.5. Composed of boulders, the stone spur dikes in the PMS method irrigation project are nontransparent. Therefore, the stone spur dikes in the PMS method irrigation project—based on their structural characteristics—are considered semi-overflow, nontransparent types.

Table 5.5 Characteristics of Transparent and Nontransparent Spur Dikes [2)]

	Transparent spur dike	Nontransparent spur dike (Standard design in the PMS method irrigation project)
Structure	- Structure in which flowing water permeates the spur dike - Often adopted on gentle slope rivers	- Structure that does not allow flowing water to permeate the spur dike
Features	- Smaller impact on the spur dike compared to the nontransparent type; spur dike is less likely to be damaged - Simple structure means construction is easy and inexpensive - The spur dike is a factor that increases roughness and reduces flow velocity to prevent scouring	- Larger hydraulic jump effect when compared to transparent type spur dikes; large effect in reducing the force of the river flow
Due diligence points	- Smaller hydraulic jump effect when compared to transparent type spur dikes; less effect in reducing the force of the river flow	- Greater impact on the spur dike and greater scouring when compared to transparent type spur dikes; may result in damage to the spur dike itself
Example of construction method	- Pile dike, rock crib	- The structure shall be made of heavy objects such as stone and concrete blocks

(3) Installation Direction of Stone Spur Dikes

The stone spur dikes are often placed at the water colliding fronts on the outside of the curved parts of the river channel. The stone spur dikes make use of the characteristic that erosion and scouring occur due to flooding as a result of the hydraulic jump effect. The main course of the flood is kept away from the dike (river bank) to prevent scouring of the dike (river bank). It also works to stabilize the main channel.
There are vertical-angle, upward, and downward spur dikes depending on the direction of their installation. The characteristics of each are shown in Table 5.6 and Figure 5.14. Upward spur dikes shall be the standard design to prevent riverbank scouring, stabilize the main channel and the spur dike. Upward spur dikes protect the dikes (river bank) by causing scouring at the tip of the spur dike and sedimentation near the dike (river bank) installation.

Table 5.6 Classification of Spur Dikes by Direction of Installation [2)]

	Right-angle spur dike	Upward spur dike (Standard design in the PMS method irrigation project)	Downward spur dike
Characteristics	- Oriented at a right angle to the current - Sedimentation occurs near the center of the spur dike - Scouring occurs near the end of the spur dike - Does not significantly alter the direction of the current	- Angled upstream - Sedimentation occurs near the dike (river bank) - Scouring occurs toward the center of the river channel at the end of the spur dike - The current turns towards the center of the river	- Angled downstream - Sediment deposits occur near the end of the spur dike - Scouring occurs near the dike (river bank) - The current turns towards the dike (revetment)
Features	- The shortest spur dike lengthwise; low construction costs - The force of water at the end of the spur dike is not intense, meaning erosion at the end is limited	- Ideal for stabilizing revetments and forming new dike (river bank) alignment - Sediment is likely to occur immediately downstream of the root of the spur dike; the dike revetment is less likely to be eroded	- The force of water at the end of the spur dike is small; the scouring at the end is relatively small
Due diligence points	- As sedimentation occurs away from the dike (river bank), the effect of preventing erosion of the dike (river bank) is low.	- Long spur dike length; high construction costs - The force of water at the end of the spur dike is intense, and significant scouring is likely to occur at the end	- Long spur dike length; high construction costs - Due to the hydraulic jump effect and overflow water at the tip of the stone spur dike, scouring occurs at downstream section from the root of the spur dike.

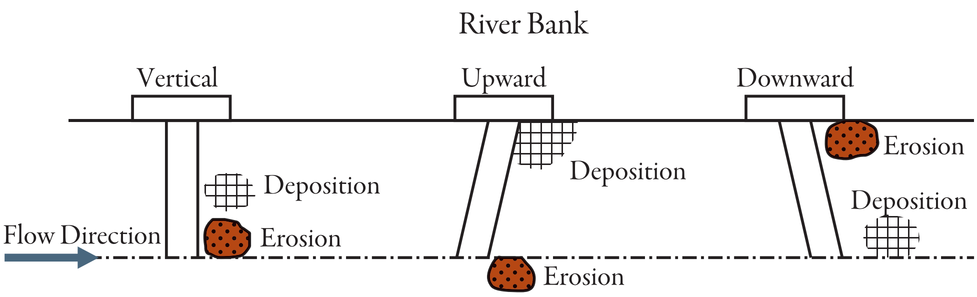


Figure 5.14 Installation Direction of Spur Dikes and Their Scouring and Sedimentation Characteristics[2),(see 7)]

(4) L-shaped Spur Dikes

In sections where the currents are particularly intense and where significant erosion occurs, L-shaped spur dikes are applied as a means to stop river bank erosion as quickly as possible and prioritize erosion countermeasures. As shown in Figure 5.15. L- shaped spur dikes are a type of nontransparent, semi-overflow spur dike. By making the spur dike into an L-shape, it becomes difficult for sediment between the spur dikes to flow out, making it possible to prevent scouring at the dike slope foot.

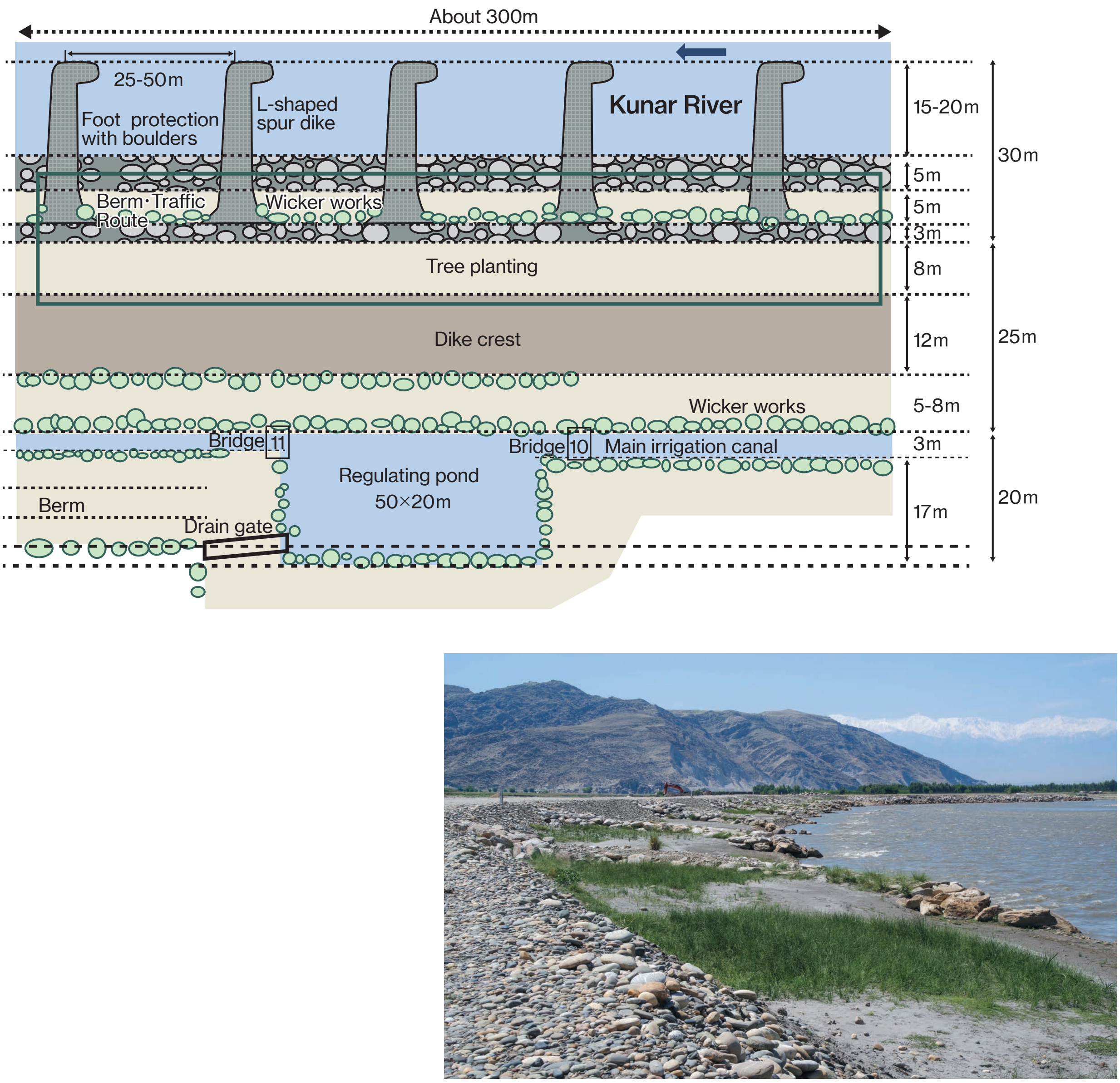


Figure 5.15 L-Shaped Spur Dikes [1)]

5.3.3 | Design Policy and Specifications for Stone Spur Dikes

Spur dike type (material components, structural type, and installation direction) of semi-overflow nontransparent stone spur dike in the existing PMS irrigation project shall be the standard design in the PMS method irrigation project. And among the specifications of the stone spur dikes, the material components, structural type, installation direction, and profile and cross section gradients are also standardized by adopting the design values of the stone spur dikes in the existing PMS irrigation project, with no changes made. On the other hand, the spur dike length, installation interval, crown width, crown height, and embedment depth are set according to the conditions of each region, including the river width and gradient in the survey area, while referring to the actual specifications of existing PMS irrigation facilities.

Spur dike length and installation interval are determined by river width and water level conditions. The width and height of the spur dike crown depend on the flow velocity and the design flood water level during the flow of the design flood discharge. The embedment depth of the spur dike foundation depends on the unit width discharge of the river calculated based on the design flood discharge and river width.

The type and design policy of specifications of the stone spur dikes in the PMS method irrigation project and the specifications design are summarized in Table 5.7. Figure 5.16–Figure 5.18 show examples of the plane view, cross section view, and front view of the stone spur dikes.

Table 5.7 Design Policy and Specifications for Stone Spur Dikes [2)]

Item	Design policy	Spur dike specifications in the PMS method irrigation project	
		Specifications that can be applied as standard designs	Specifications to be designed according to site conditions
Components of material	Use a boulder size that can ensure stability against tractive force during the flow of design flood discharge	–	Stone spur dike: Formed with boulders with a grain size of 0.5 m–1.5 m
Structural type	The plan shall adopt semi-overflow, nontransparent stone spur dikes based on the need to prevent riverbank erosion and ensure the resistance of the spur dike itself against the water flow	Semi-overflow, nontransparent stone spur dikes	–
Direction of installation	Upward spur dikes shall be adopted in order to protect the dike (riverbank) through sediment deposition and stabilize the main channel through scouring of the end of the spur dike	Upward spur dikes: Installed at 5–15° in the cross-sectional direction of the river channel	–
Length and installation interval	The spur dike length shall be about 10% or less of the river width (Flood flow width during the flood season) after the dike design. Adjust the spur dike installation interval, applying a guideline of two to four times the length of the spur dike and ten to thirty times the height.	–	The following specifications are applied in the existing PMS irrigation project in Kunar River. Spur dikes of 15–20 m in length are installed at 50–100 m intervals Spur dikes of 5–10 m in length are installed at 25–50 m intervals
Crown width	Ensure these figures or greater based on the depth during the design flood water level. Flood depth within 5 m: 2.0 m Flood depth within 5–10 m: 4.0 m Flood depth 10 m or more: 6.0 m *However, the average flow rate at high water is 2 m/s or less.	–	In the existing PMS irrigation project, 3 m is common
Crown height	A height shall be about 20 to 30cm above the average flood level shall be a guide.	–	In the existing PMS irrigation project, 3–4 m is common
Cross-sectional gradient	The slope of the spur dike cross section in the longitudinal direction of the river shall be the same gradient as the slope gradient of the dike	Stone masonry slope: 1:1.5	–
Gradient in length direction	In order to reduce the force of water on the dike (river bank), the downward gradient shall be 1/20–1/100 in the river cross section direction	Downward gradient toward the center of the river	–
Embedment depth of the spur dike foundation	Ensure an embedment depth of at least 1 m from the average riverbed elevation	–	Consider with a basis of ensuring an embedment depth of at least 1 m

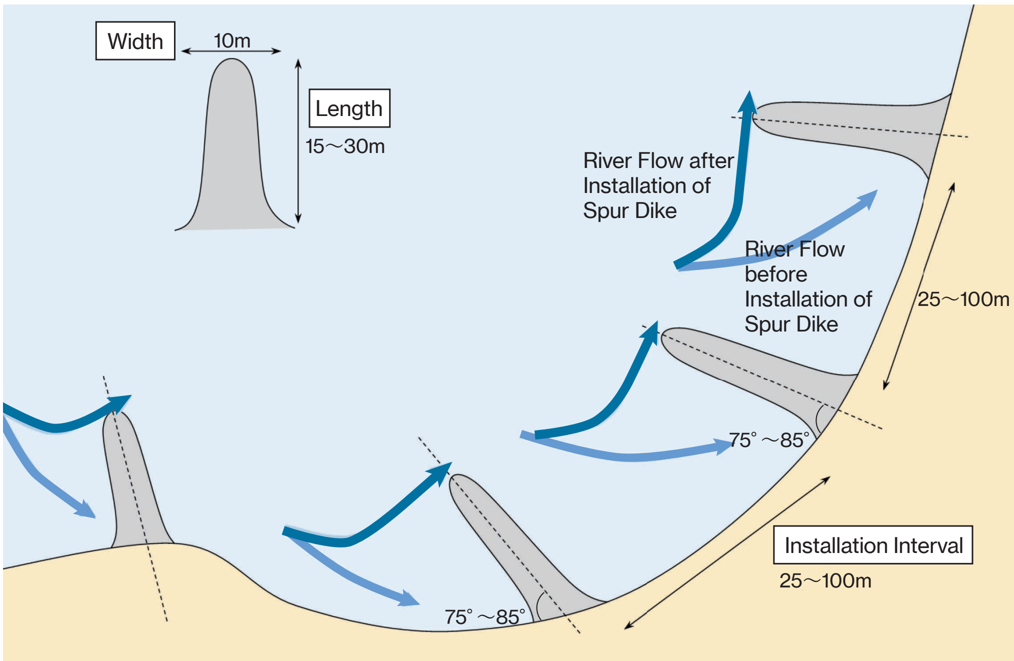


Figure 5.16 Example of a Stone Spur Dike Plane View [3)]

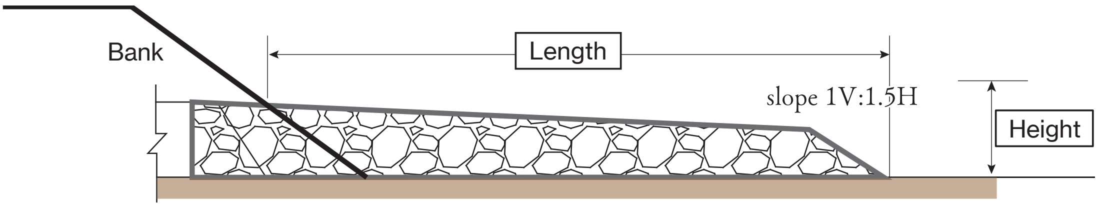


Figure 5.17 Example of a Stone Spur Dike Cross Section [1)]

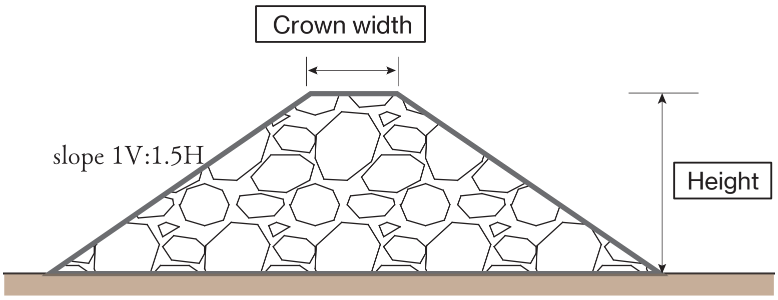


Figure 5.18 Example of a Stone Spur Dike Front View [1)]

5.3.4 | Structural Design of Stone Spur Dikes

(1) Structural Stability Study of Stone Spur Dikes

The stability of the boulders that consist the stone spur dike against flood water is the same as that of the revetment design of the dike. See *5.2.4 (2) Examining the Stability of Boulder Revetments on Dikes.*

(2) Assumed scouring depth around the stone spur dike

Depending on the stratum and river bed material that form the foundation of the stone spur dike, the foundation directly under the installed boulders may be significantly scoured. It is necessary to ensure a depth of at least 1 m from the current deepest riverbed elevation for the stone spur dike embedment. However, if deeper scouring occurs, it is necessary to build a deeper foundation in anticipation of future scouring to some extent and reduce the frequency of maintenance in the form of the resupply of boulders.

Therefore, referring to the following consideration, it is necessary to ensure that the embedding depth of the foot protection works with boulders is larger than the expected scouring depth.
The scouring depth around the spur dike can be calculated applying the following graph based on the relationship between the installation angle θ of the spur dike indicated in Figure 5.19 and the scouring depth. The scouring depth increases as the upward inclined angle: θ and the unit width discharge: q increase.

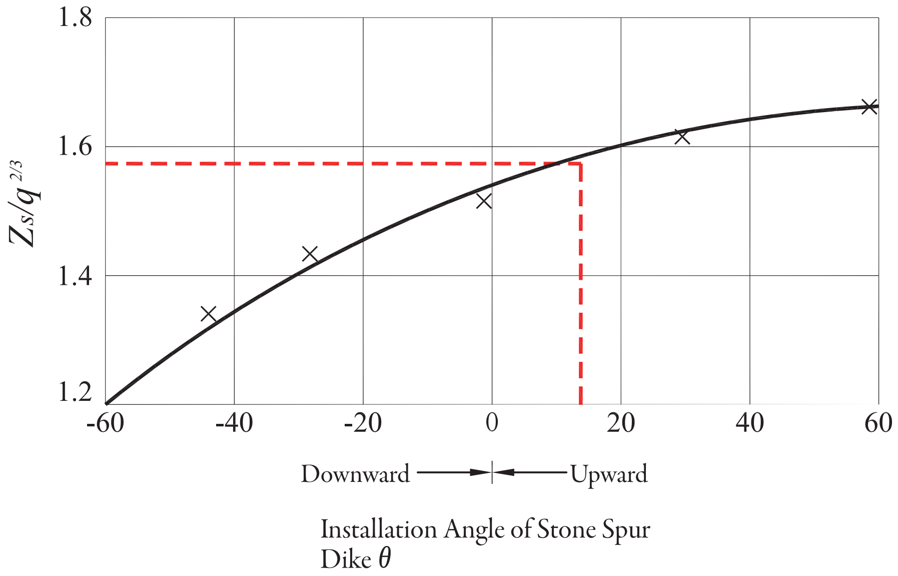


Figure 5.19 Relation Between Spur Dike Direction, Unit Width Discharge, and Scouring Depth [2), see 7)]

The following is an example of the calculation of the assumed scouring depth at the spur dike near the Miran weir in the existing PMS irrigation project. As the spur dike is installed at an angle of 5–15° in the upstream direction, according to Figure 5.19, Zs/q2/3=1.57. As a result, it is assumed that a scouring of about 3.5 m will be applied around the spur dike in the following calculation. It will be necessary to resupply the stones on a regular basis, so stones are stockpiled in some places.

Unit width discharge: $q = Q \div B = 2{,}050 \div 600 = 3.42\,m^3/s$

$Zs = 1.57 \times q^{2/3} = 1.57 \times 3.42^{2/3} = 3.53m$

where, Q: Flood flow rate (m^3/s), q: Unit width discharge (m^3/s), B: River channel width
As shown in Figure 5.20, maintenance and the resupply of stone are carried out after construction via continuous observation.

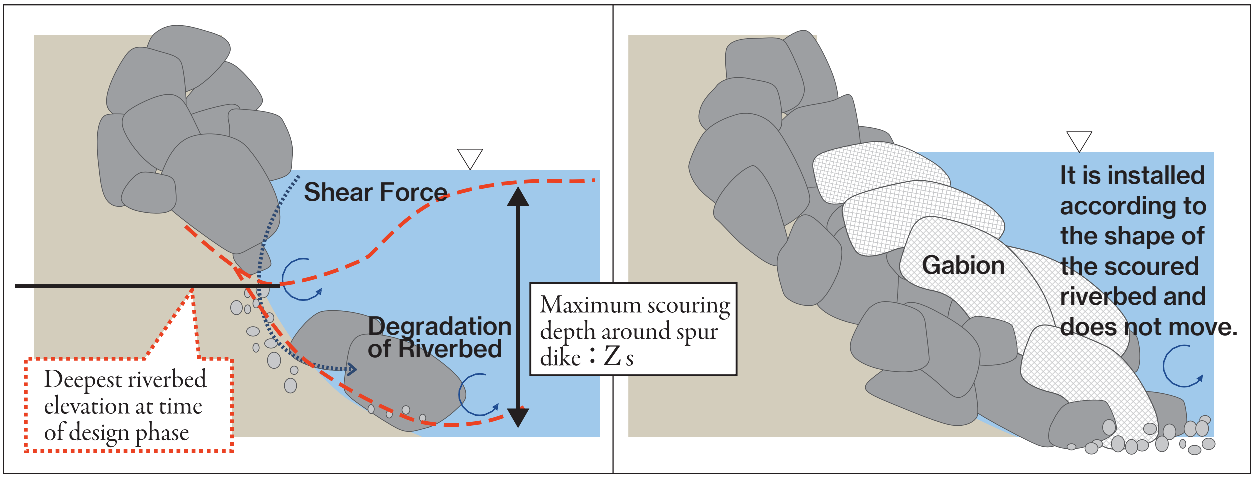


Figure 5.20 Resupply of Boulders by Continuous Observation and Application of Gabions [1), 3)]

CHAPTER

6

HOW SHOULD PMS METHOD IRRIGATION FACILITIES BE CONSTRUCTED?

What should be considered in construction supervision and construction works of PMS method irrigation facilities?

The construction of PMS method irrigation facilities requires boulders and cobblestones for construction of oblique weir, stone spur dike and annealing wires. Meanwhile, other materials for gabion works applies for the revetment of main irrigation canals, as well as cement, reinforcing bars and other general construction materials. Dump trucks, backhoes and other heavy machines are also needed and should be prepared accordingly.

Construction works also require manpower and for PMS method irrigation projects, the cooperation of beneficiary farmers is particularly crucial. Cooperation on the part of elderly council or local chiefs is also required to obtain understanding. The PMS method irrigation project involves in constructing irrigation facilities of a certain quality while ensuring the security and safety of local residents. It is also a project to develop the capacity of local residents via construction works to enhance their technical capacity and nurture candidates tasked with maintaining and managing irrigation facilities in the future.

By conducting above, the project needs to ensure the quality of PMS method irrigation facilities, manage the work progress and revise design drawings as needed to prepare shop drawings. Proper budget management is also important.

The following pages give commentary on the above contents: The following pages give commentary on the above contents:

6.1 Preparation of Construction Supervision and Construction Works

6.1.1 | Establishing Project Implementation and Execution Systems

(1) Project Implementation System

To implement and disseminate the PMS method irrigation project in Afghanistan, it is expected that the Afghanistan government will become the project implementation entities/persons funded by donors or using their official funds. Figure 6.1 shows a PMS method irrigation project implementation system for this case.

This system assigns "an advisory team for the PMS method irrigation project" to guide the basic concept/planning, design, construction supervision and operate and manage the project to government officials, consulting firms and construction companies, unlike a general implementation system. The advisory team will initially consist mainly of PMS engineers. However, it is necessary to gradually increase the number of engineers who can supervise the PMS method irrigation projects through the capacity development to the government engineers and local engineers who will carry out PMS method irrigation projects.

The project implementation entities/persons, together with the advisory team, formulates the basic concept of the PMS method irrigation project in collaboration with local residents and formulates the project plan. Then contract with a consultant to formulate a more detailed basic concept in collaboration with local residents, and carry out detailed project planning, facility design, contracts with contractors and construction supervision. In addition, the project implementation entities/persons will contract with a construction company and hire neighboring residents to carry out the construction work. During the construction work, it develops the capacity of residents who engage in labor (skilled or otherwise) while helping a water users' association (WUA) or irrigation association (IA) operate, manage and maintain irrigation facilities for a certain period after the construction works are complete.

While the progress management and technical confirmation are conducted by consultants and contractors during the construction works, the project implementation entities/persons and advisory team jointly consult as needed. Upon discussing with the project implementation entities/persons, the advisory team provides guidance directly to consultants and contractors.

Figure 6.1 shows an example of a project implementation system assuming a bidding method separating design and construction work. Other bidding/contracting methods between the project implementation entities/persons and consultants and contractors can also be considered, such as a blanket order of design and construction work and comprehensive evaluation method. These methods may accelerate construction and reduce costs, but result in the burden of responsibility between design and construction work becoming unclear when natural and social conditions change. It is therefore necessary to examine their pros and cons to decide on an appropriate method.

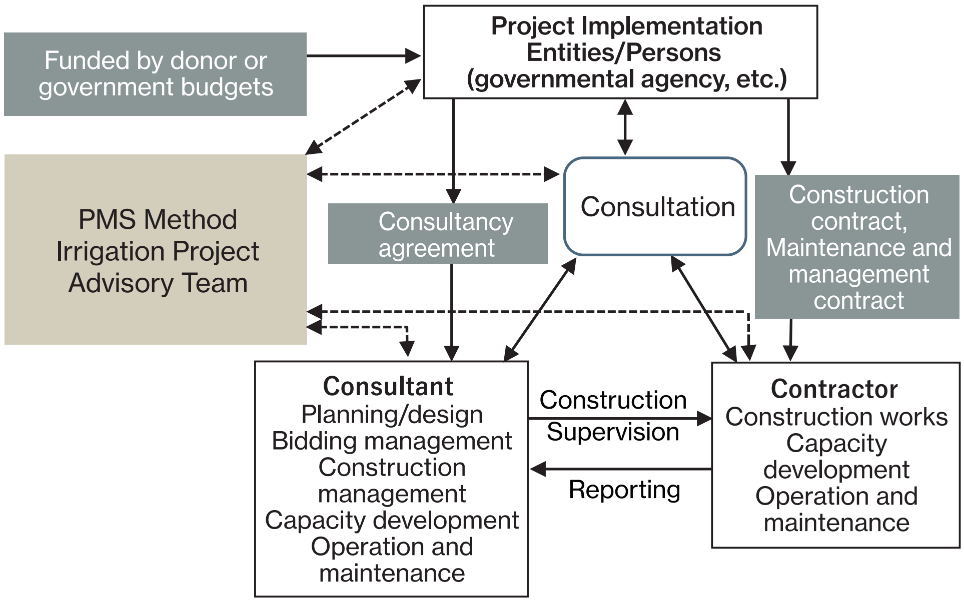


Figure 6.1 Example of Establishing a Future Project Implementation System (when a government agency is the project implementation entities/persons)[2)]

(2) Construction Executing System

While a construction executing system is generally decided by contractors and consultants, the PMS method irrigation project needs to use local surplus materials frequently for the works, develop the capacity of labors (local farmers) and help them operate, manage and maintain facilities once construction works are complete. Accordingly, a standard executing system for existing PMS irrigation projects led by the General Manager (as served by Dr. Tests Nakamura) is referenced in Figure 6.2.

In implementing a project, the general manager addresses issues, manages progress and oversees smooth project implementation as well as developing capacity and educating those in charge of the project and workmen on safety. The technical manager and persons overseeing procurement, construction supervision and accounting are allocated in the headquarters under the general manager while clerical staff are allocated in the site office. Site chiefs are assigned to manage each site while a headman and foreman are assigned by construction work to guide and instruct the workers. Mason and gabion workmen etc. are allocated as skilled labor, plus personnel operating, handling and repairing heavy machines and vehicles. Security guards are also hired where needed.

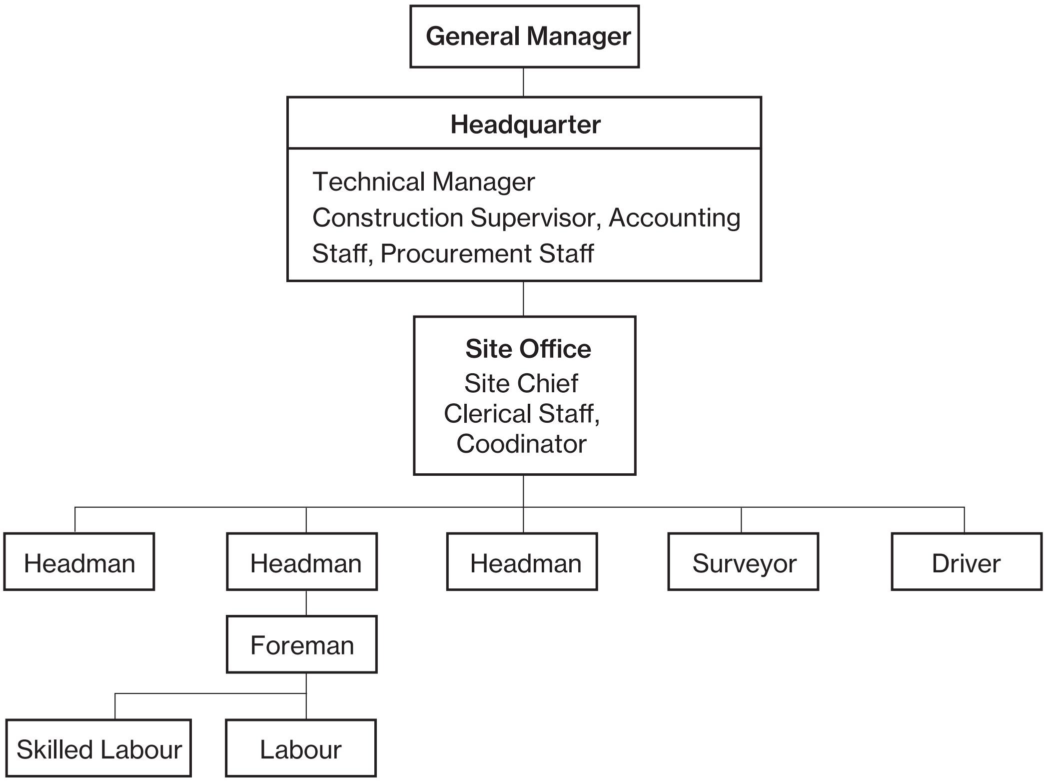


Figure 6.2 Standard Executing System in PMS Method Irrigation Project [2)]

The role of each personnel as shown in Figure 6.2 is as follows:

- The General Manager: who oversees the whole project and addresses various project implementation issues.
- The Technical Manager: who provides procurement instructions, budget processing and technical supervision to ensure the project progresses smoothly. The technical manager cooperates with each person concerned and site chief as needed to monitor construction progress as much as possible.
- Site Chief: a person responsible for construction work on site and its progress, control safety and improving the work environment.
- Clerical Staff: who handle accounting, administrative work, and other office work at the site office.
- Coordinator: who handles procurement, external relations, and other work at the site office.
- Headman: a person responsible for each construction project and its progress, control safety and improving the work environment under the instruction of the site chief,
- Driver/Mechanic: who operates, drives, and maintains heavy machines and vehicles. Hired regularly during the construction period.
- Foreman: collaborating with the headman, the foreman instructs those engaged in field labor and directly manages the construction work.
- Skilled Labor: with specific expertise such as mason, gabion works and reinforcement. Skilled laborers instruct those engaged in general labor.

Table 6.1 shows the actual number of personnel assigned and construction costs borne in existing irrigation projects implemented by PMS: the Rehabilitation of Irrigation Systems in Koti, Taran, Kachara and Bela Villages, Sheiwa District (Marwarid II Project), the Rehabilitation of the Irrigation System in Miran, Behsud (Miran Project) and Rehabilitation of the Irrigation System in Kashkot, Sheiwa District (Kashkot Project) to which one to two site chiefs and six to eight headmen were allocated according to the construction scope. Construction costs are calculated by summing up the cost of 1) construction equipment and materials, 2) rent fees for heavy machines and other vehicles, 3) wages for staff directly involved in construction work, 4) wages for technical manager, procurement staff, accounting staff, drivers and other staff, 5) office equipment costs, 6) alliances and supplies and others.

Table 6.1 The Number of Personnel Allocated and Construction Costs in Existing PMS Irrigation Projects [1)]

Project Title	Marwarid II Project	Miran Project	Kashkot Project
Period	October 2016 ~ September 2018	October 2014 ~ September 2016	October 2012 ~ September 2014
Number of Months	24	24	24
Project Cost (USD)	3,343,945	3,371,980	3,110,116
Total Number of Work Days	76,500	63,300	98,000
Number of Workers (Max: Person/day)	137	140	194
Labours at working site	60	60	120
Skilled labours at working site	60	60	40
Skilled labours at jakago workshop			20
Labours of water control at watergate	9	6	2
Special skilled labours at working site (mason)	8	8	6
Supervisors	6	6	6

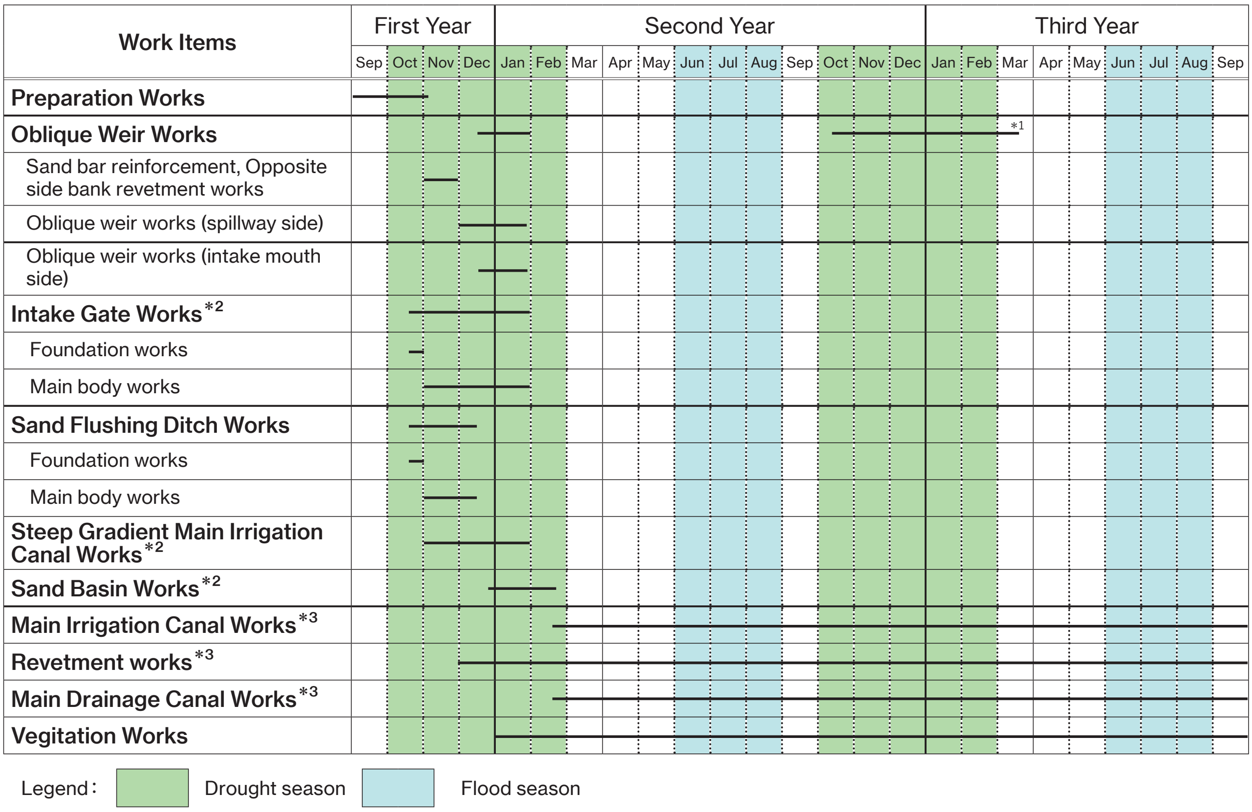
6.1.2 | Planning of the Construction Schedule

The construction contents of PMS method irrigation facilities consist of preparation works, oblique weir works, intake gate works, sand flushing ditch works, steep gradient main irrigation canal works, sand basin works, main irrigation canal works, revetment works, main drainage canal works, vegetation works and others. Although the construction period in the PMS method irrigation project varies according to the project scale, the construction of intake weir in one project is expected to be completed in around two years. Regarding the construction works that are expected to take longer period, the works shall be divided and allocated to multiple construction teams, and the work completion shall be aimed at within two years as much as possible. Points to be noted when planning the construction schedule are as follows and a general construction schedule of PMS method irrigation project is shown in Figure 6.3:

- For construction work in a river channel and tributary (wadi), where the water level and flow rate between flood season and drought season vary considerably, the work shall be divided in types which are more or less affected by water flow respectively. The worst affected types of work shall then have their execution scheduled for drought season, allowing construction work to be completed before a flood season.
- An intake weir is a structure crossing the river and constructed during a drought season. Over 60% of all the construction work was executed during the drought season of the first year of construction period, with the remainder completed during the drought season of the following year.
- Since construction of the intake gate, sand flushing ditch and sedimentation pool involves concrete placing works, dry construction is applied by establishing a temporary coffer dike. The intake gate, sand flushing ditch and sedimentation pool are completed during a drought season of the first project year.
- Inland facilities, such as the main irrigation canal, sand basin and drainage canal, can be constructed year-round.
- In the case of construction of small-scale intake weir and intake gate irrigation projects, the construction work shall be completed within one year as much as possible in order to start the operation early. For facilities involving relatively large-scale construction work taking multiple years, temporary drainage (intake) will be conducted so that the supply of irrigation water will not be interrupted even during the construction period.

- Prior to the construction work, it is important to confirm whether the project can secure all boulders, cobblestones, gabion wire, reinforcement bar, cement and other construction materials, dump trucks, backhoes and other heavy machinery, and field labors, workers and other human resources during the construction period.
- Discussions shall continue with elderly associations, beneficiary farmers and other stakeholders concerning security measures during the construction period and adequate measures shall be taken.
- Adequate safety measures shall be taken and occupational accidents during the construction period shall be considered.
- A ground-breaking ceremony shall be held when the works get underway and a completion ceremony on completion of construction. With the participation of the provincial governor and irrigation department staffs in these ceremonies, revealing the event schedule will enhance the morale of workers toward the works as well as boosting expectations for sense of community unity and ownership.

In the Marwarid II Project, 137 labors , 50 staffs and 20 heavy machines were working daily to complete the intake weir construction during a drought season of the first year. Moreover, the project inputs also include a total of 3,000 to 4,000 vehicles used to transport stones for constructing the boulder oblique weir with 1.35m height and covering a boulder area of 10,500 ㎡, and 1,000 to 1,500 dump trucks for constructing 1 km of revetment and stone spur dike.



*1 The weir must be observed and will be completed after the second year of rehabilitation after the flood season.
*2 In the case the water supply for irrigation is urgent, water can be transmitted as soon as the intake gate, steep gradient main irrigation canal, and lower part of the sand basin are completed.
*3 The construction period of the main irrigation canal, revetment, and main drainage canal varies greatly depending on the scale of construction work.

Figure 6.3 Example of Work Execution Process for PMS Method Irrigation Project [2)]

6.1.3 | Procurement and Preparation of Construction Materials and Equipment

The following construction materials and equipment are mainly needed for PMS method irrigation project. By calculating required quality, shape, and amount for construction materials as well as the types and number of vehicles for construction equipment, construction materials and equipment are procured and prepared as follows:

- Large stones (boulders and cobblestones) and sediments and soils for dike embankment: these materials are basically procured locally. Investigation of the areas around the construction site shall be conducted to understand the amount of existing stone materials and check their transportation route.
- In the case of procuring boulders, the required transportation volume within the construction period shall be predicted, the "daily transportation volume" of the dump truck is determined, and the loading capacity is monitored at the site. Also, it is necessary to keep a stockpile of boulders near the construction site to prepare for emergencies. Here, in areas where there are no large boulders, some considerations such as using cobble stones as a filling material for pilings of gabions shall be required.
- Annealing wires applied for gabion: works mainly imported from neighbouring countries so far. In existing PMS irrigation projects, proper quality annealing wires were purchased from Lahore in Pakistan.
- General construction materials: e.g. cement, mortar, sands, reinforcing bars, crushed stones, frames, and bags are available from major neighbouring cities. In existing PMS irrigation projects, those materials were mainly procured from Jalalabad. General construction materials are distributed and available in those cities where reinforced concrete is used to construct buildings and bridges.
- Construction equipment: heavy machines (backhoes, bulldozers, rollers, dump trucks, etc.) and concrete mixing vehicles are needed.

6.1.4 | Quality Management, Design Change and As-built Drawings

The following basic policies are applied for quality management during the work execution:

- It is recommended to use good quality construction materials and equipment.
- Compaction involves spreading and levelling embankment materials around 30 cm-thick to construct embankments.
- If the foundation of the embankment is soft, it should be replaced with proper quality sandy soil mainly composed of locally surplus materials.
- For the foundation of concrete structures such as intake gate, sand flushing ditch and sedimentation pool after confirming the boulder layer of the foundation ground, the gravel layer is thickly concreted (0.5 m or more) up to the boulder layer. A robust reinforced concrete bottom slab with a thickness of 40 cm or more is constructed on it. If there is soft ground, it should be removed and replaced with proper quality sandy soil.
- The design concrete (bending pressure) strength and the standard slump shall be secured.
- Concrete is placed at a temperature of between 4 and 38℃, avoiding work at high and low temperatures as much as possible.
- The concrete curing period shall be at least three weeks. When the strength of a one-week aged concrete test piece exceeds the design strength, the concrete form can be removed.
- It is recommended to use the design standard products for reinforcement works. Reinforcing bars are visually inspected before use.
- **It is necessary to carefully check whether the embedded parts, etc. that disappears after construction is constructed as designed.** These include structural foundations, wings of intake weirs penetrating sandbar (natural ground) and backfilling portions of revetment.

Before commencing the construction, a shop drawing is prepared based on the design drawing and in line with actual site conditions. If the number of works changes at the execution stage due to site conditions changing from the design stage, a shop drawing is prepared by adapting the design to the site condition. An as-built drawing is also prepared as a drawing reflecting all changes having occurred in the process of construction works. The as-built drawing shows the completed form of the construction works and will become a key reference during the future renovation of facilities.

Text Block 6-1: Construction of Main Irrigation Canal

- Collapse of the canal bed due to insufficient confirmation of the foundation ground. There was no foundation. It is a site where there were as many as 60 people. The human eye is easily fooled by its appearance.

Photo: Collapse of Main Irrigation Canal Bed [1)]

6.1.5 | Cost Management

Costs shall be managed as follows to ensure construction works are completed on budget:

- Formulation of a budget plan: the target cost against the project budget shall be planned before commencing works.
- Monitoring and comparing budget and actual costs: it is important to monitor the costs incurred against the budget and compare the two sets of figures. If the cost exceeds the budget, it is recommended to consider improvements at the construction site. This may include reducing standby time by reviewing work procedures, levelling the works and balancing out workloads, personnel and construction materials that could reduce the costs of labor and renting construction materials for a certain volume of works.
- Confirming the appropriateness of the procurement cost and rental fees for construction materials: it is better to understand the proper external purchase cost for construction materials and fees for renting heavy construction machinery. If their costs exceed the budget, they shall be managed by considering other suppliers or other measures.

6.1.6 | Safety Measures for Construction Works

Major occupational accidents having occurred during the construction work include: 1) personal injury or death related to construction machine operation, 2) personal injury during material processing, 3) injury due to materials and equipment having fallen or caused crushing injuries, 4) fall accident from scaffolding, slopes or elsewhere. Careful attention shall be paid to such occupational accidents to ensure safety measures. Major safety control/measures are shown as follows:

- A safety manager is assigned who monitors, supervises and raises awareness of accident prevention and safety control.
- The safety manager shall closely communicate with the site chief and headmen to promote accident prevention while improving the emergency response system for accident occurrences.
- Daily safety shall be managed and confirmed during the construction period.
- Safety management education shall be provided regularly to staff and laborers.
- Accidents are more likely during rainfall or at low temperatures. Very close attention shall be paid to works in the river, particularly during flood season, given that the river water level rises and on-site scaffolding conditions worsen. Workmen also have to be careful of heatstroke.

Although a staff member died due to a heart attack during construction work on existing PMS irrigation projects, no casualties have been observed during this work since safety control was thoroughly conducted. Conversely, however, many injuries were observed for the canal works. Accordingly, safety management education and other measures must be taken. Since accidents involving falls and e.g. leakage have occurred in siphons and elsewhere after completing construction, there is also a need to install a protection net and take other measures.

6.1.7 | Ensuring Security

Considering the current security situation in Afghanistan, security measures during the construction period are important. Since the PMS method irrigation project involves cooperation with the community and local residents, military, police and private security troops are not introduced as security measures in the project, as a general rule. Alternatively, security during the construction work is secured by obtaining the understanding of the community as a whole and via cooperation with the community and local residents. To this end, the following collaboration with local society and local government is underway:

- As well as explaining the purpose and contents of the irrigation project to elderly associations, chieftains and residents in irrigation beneficiary areas and surrounding regions and obtaining their understanding, it is recommended to reaffirm that to be viable, the PMS method irrigation project must be implemented collaborating with local society.
- It is better to obtain their understanding and approval that local residents be paid to participate in construction work as workmen or laborers, acquire civil engineering skills from technical education and take over maintenance and management of irrigation facilities once the project is complete.
- Accordingly, their approval for irrigation beneficiary areas and surrounding communities to cooperate in maintaining security during the project period is obtained.
- At the same time, it is recommended to request the cooperation of local government in ensuring security during the construction work as well as obtaining their understanding regarding the purpose and contents of the PMS method irrigation project.
- A ground-breaking ceremony shall be held when the works get underway and a completion ceremony on completion of construction. With the participation of the provincial governor and irrigation department staffs in these ceremonies, revealing the event schedule will enhance the morale of workers toward the works as well as boosting expectations for sense of community unity and ownership
- Moreover, for those who may suffer disadvantages by the construction works, the purpose and contents of the project shall be carefully explained in advance, consensus building shall be made, and sufficient compensation shall be provided.

6.1.8 | Capacity Development of Local Farmers and Those Involved in Construction Works

The participation of local residents in the construction work involves key implications in the PMS method irrigation project. These local residents are expected to earn a living from the works during the construction period, acquire relevant skills and become core members maintaining and managing irrigation facilities once the project is complete.

There are two types of capacity development during the construction period as follows:

- On-The-Job Training by getting directly involved in works: targeting field laborers, workmen/skilled laborers and engineers, training participants learn field work practically on site. Transferring skills from one person to another is also promoted.
- Regular education/training at a training facility: targeting workmen/skilled laborers and engineers in principle, further training on field engineering and functions and education on planning and design engineering for engineers are provided.

It is also expected that a PMS method irrigation project will help spawn a sense of solidarity among people with various backgrounds by working together for a common purpose. Borrowing the Dr. Tetsu Nakamura's phrase, Text Block 6-2 shows how "**building a community sense of solidarity**" is one of the key outcomes of the PMS method irrigation project.

Text Block 6-2: Working People (Words of Dr. Tetsu Nakamura)

- One of the factors underpinning work is the morale and patience of hundreds of laborers and drivers.
- Workers shall be technically regarded as workmen so that they are not seen as "amateur groups" as was previously the case.
- The collective group under the work has become a unit of ability, playing a key role in the region that transcends blood and regional bonds.
- While division of labor is necessary, the same workman handles everything: reinforcing bar processing, form preparation, assembly works, gabion production and concrete placement.
- When a machine fails, use a shovel.
  When a shovel is broken, use hands.
  When a vehicle stops, you can walk. This is the PMS style.

Photos: Dr. Nakamura Put Importance on the Field Workers [1)]

6.1.9 | Planning and Executing Temporary Works

In executing the construction work, it is necessary to secure construction vehicle roads and drying construction yards in the river. Major temporary works are described as follows. Photos 6.1 to 6.4 show the above local scenery.

- Temporary road: a road for construction vehicles, which shall be minimum 4.0 m width or width of 8.0 m or more for oncoming roads. The dike crown is usually used as a temporary road.
- Temporary bridge: a temporary bridge is installed if traversing over the rivers and canals to approach the construction yard. Often when crossing canals, concrete pipes are set up and sand bags and an embankment are installed so that vehicles can traverse over the area. The sand flushing ditch installed next to the intake gate will play a role of a temporary bridge by passing woods during weir construction and rehabilitation.
- Temporary coffer dike: the construction yard shall be surrounded by a temporary coffer dike (cutoff wall) and a dry environment ensured by pumping up the water to construct an intake weir, sand flushing ditch, sedimentation pool and other concrete structures.
- Temporary waterway: when coffering canals, a temporary waterway is installed so that the supply of water will not be interrupted. It shall be ensured that the flow section of the temporary waterway is basically equivalent to the cross-sectional area of existing canals.

Photo 6.1 Example of a dike using as temporary road (Miran project) [1)]

Photo 6.2 Example of a temporary bridge (Kama weir Ⅱ) [1)]

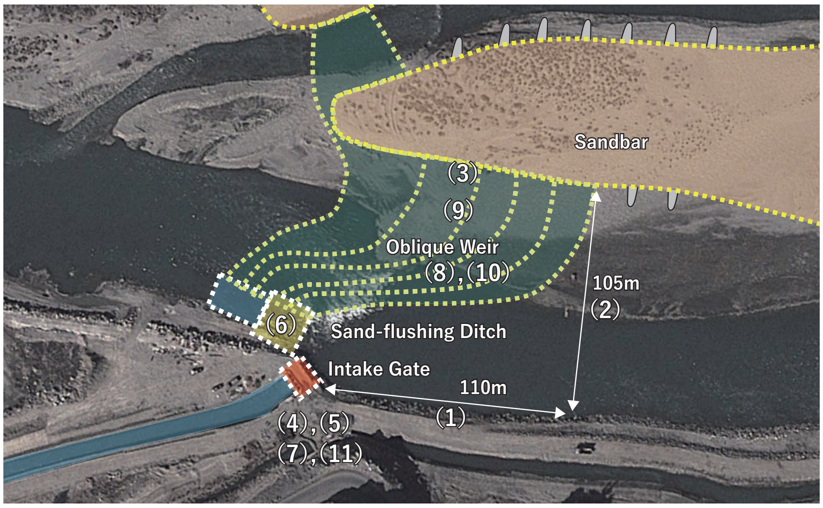
Photo 6.3 Coffer Dike(Cutoff Wall, KamaⅠ) [1)]

Photo 6.4 Temporary Irrigation waterway (Miran) [1)]

6.2 Construction Supervision of Intake Weirs and Gates

6.2.1 | Construction Procedures of Intake Weir/Gate

The construction of intake weirs and intake gates involves preparation works, temporary works, main body civil works, earthworks, foundation works, revetment works and equipment works.
Figure 6.4 shows the whole location image of intake weirs and intake gates while photos of existing PMS irrigation projects and Figure 6.5 shows their construction procedures.



Note: Numbers in parentheses correspond to those of each construction process as shown in the photos in Figure 6.5.

Figure 6.4 The Whole Site Image of Intake Weir and Intake Gate (Kama Weir Ⅱ Project) [1]

(1) Preparation works: determine the longitudinal location of the intake weir/gate. (Kama Weir I)

(2) Preparation works: determine the horizontal location of the intake weir/gate. (Kama Weir I)

(3) Opposite bank reinforcement/revetment works: the intake weir wing on the opposite bank (attachment part to sandbar) is reinforced in advance. (Kama Weir I)

(4) Temporary works: construct a round temporary coffer dike surrounding the proposed intake weir, sand flushing ditch and sedimentation pool. (Marwarid Weir II)

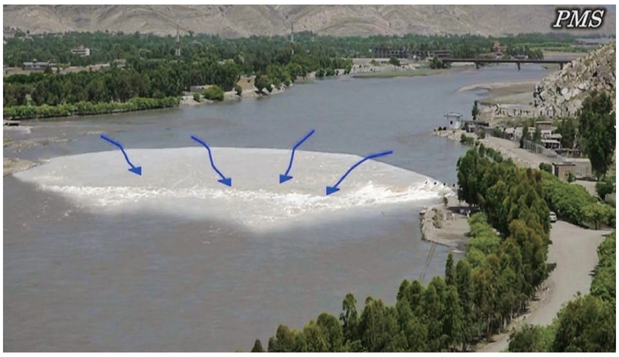
(5) Construction of intake gate, sand flushing ditch and sedimentation pool: carry out foundation works, main civil works, equipment works, revetment works and apron works. (Marwarid Weir II)

(6) Install temporary bridge on sand flushing ditch: for traffic of heavy machines used to construct the main body of intake weir. (Marwarid Weir II)

(7) Removing temporary works: after constructing intake gate and sand flushing ditch, remove temporary coffer dike and conduct water into the coffered area. (Kama Weir I)

(8) Main civil works of intake weir: establish the intake weir body by piling up boulders from both side banks. (Kama Weir I)

(9) Install a spillway when the water level is low during drought season.(Kama Weir Ⅱ)



(10) Completion of boulder oblique weir: water can be stably drawn by increasing the water level at the intake weir. (Kama Weir I)

(11) Checking the performance of equipment works: check the performance of the double flush boards and lift-up equipment of intake gate and sand flushing ditch. (Kashkot Weir)

(12) Construction is completed. (Kama WeirⅡ)

Figure 6.5 Construction Procedures of Intake Weir and Intake Gate [1)]

6.2.2 | Construction Supervision of Intake Weir

In supervising the boulder oblique weir construction, the following shall be noted. Here, the construction location for each process is shown in Figure 6.6 and the explanation used by image photos showing the intake weir construction in an existing PMS irrigation project.

Note: Numbers in parentheses correspond to those of each construction process below.

Figure 6.6 Construction Process Location for Boulder Oblique Weir [2)]

(1) Locating the Oblique Weir with Boulders

Photo 6.5 Locating the Oblique Weir with Boulders (Marwarid WeirⅡ) [1)] ：October 16, 2018

- The weir body length is shorter on the intake gate side and the longitudinal gradient is steep due to a sand flushing ditch installation.
- A gentle gradient of the weir body on the opposite bank side of the intake gate and spillway is installed to avoid significant inflow of water to the intake gate during flooding.
- The weir attachment part to the sandbar / river bank on the opposite bank of the intake gate should have a gentle slope as much as possible, and boulders should be spread to prevent scouring.
- Since constructing an intake weir involves transporting boulders in bulk, stone transporting routes are secured on the top of the weir.

(2) Construction of the Oblique Weir with Boulders

Photo 6.6 Stones with Height Mark for Piling up Boulders (Kama Weir Ⅰ) [1] : October 29, 2018

- Following the drawings, the elevation of each section is measured precisely.
- The foreman marks the design height and driver loads and piles up boulders following the marks.
- Stone materials used for apron works of the weir are piled up stepwise with intervals of around 15 cm between levels.
- To withstand the flow pressure, stone materials are piled up ensuring that the long side of boulders are placed in the flow direction.

(3) Laying Stones for Filling Spaces

Photo 6.7 Laying out Filling Stones (Kama Weir Ⅰ) [1] : October 31, 2018

- Cobblestones and gravels (filling stones) are filled by hand between boulders to establish a weir.

(4) Installation of a Temporary Road on the Top of the Intake Weir

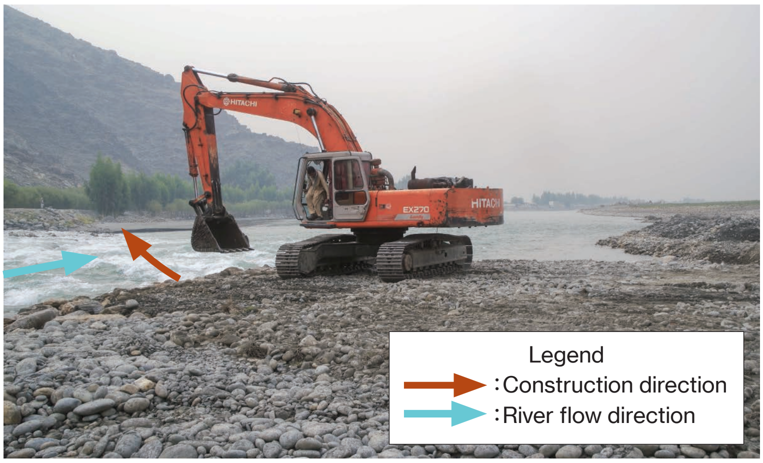


Photo 6.8 Construction of Temporary Road on the Top of Weir (Kama Weir Ⅰ) [1] : October 31, 2018

- Relatively fine gravel is laid on the top of boulders filled by filling stones to facilitate the transport of heavy machineries.
- While constructing temporary roads, a weir is constructed to the next section in order.

(5) Main Civil Works of the Oblique Weir with Boulders

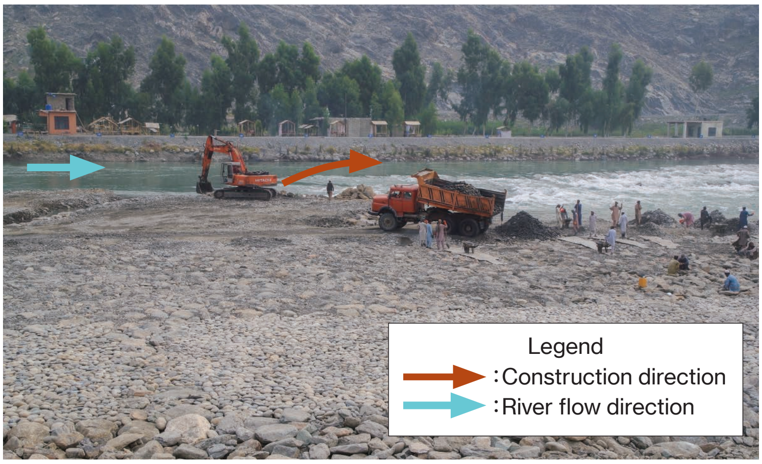


Photo 6.9 Pile-up Works of Boulders toward the River Center (Kama Weir I) 1) :October 31, 2018

- Boulder pile-up works for weirs are gradually extended from both side banks to the center of the river.
- Detailed pile-up works are carried out manually.

(6) pillway Construction

Photo 6.10 The State of Water Flow in Spillway (Kama Weir I) 1) :December 24, 2018

- Both side spillway walls are built robustly by setting up extra-large boulders to prevent them from collapsing due to river water flow.
- To adjust the intake water level of the intake weir by narrowing the cross section of the spillway, a cross-section of spillway is arranged by filling cobblestones between boulders. Refer to "4.2.5.(1) Cross-sectional Design of the Boulder Oblique Weir".
- In the event of a flood, running water is released from spillway to reduce the pressure on the weir body.

(7) Arrangement of Wicker Works for Protecting the Sand Bar

Photo 6.11 Gabion Works and Fascine Revetment (Wicker) Works for Sand Bar Protection (Miran) 1) :October 22, 2015

- An image of gabion works and fascine revetment (wicker) works constructed to protect the sand bar. U-shaped lines are prepared around the gabion works constructed at right angles to the river and wickers are installed.

(8) Wicker Works for the Protection of Sandbars

Photo 6.12 Fixing of Wickers (Miran) [1]
：October 22, 2015

- Thick-stem wickers are tied firmly and fixed to gabion works and twigs are laid over them like weaving. 0.6 to 1.0 m of the wicker root is buried in the gravel layer.
- The height of the wicker branches shall be kept higher than the expected flood depth.

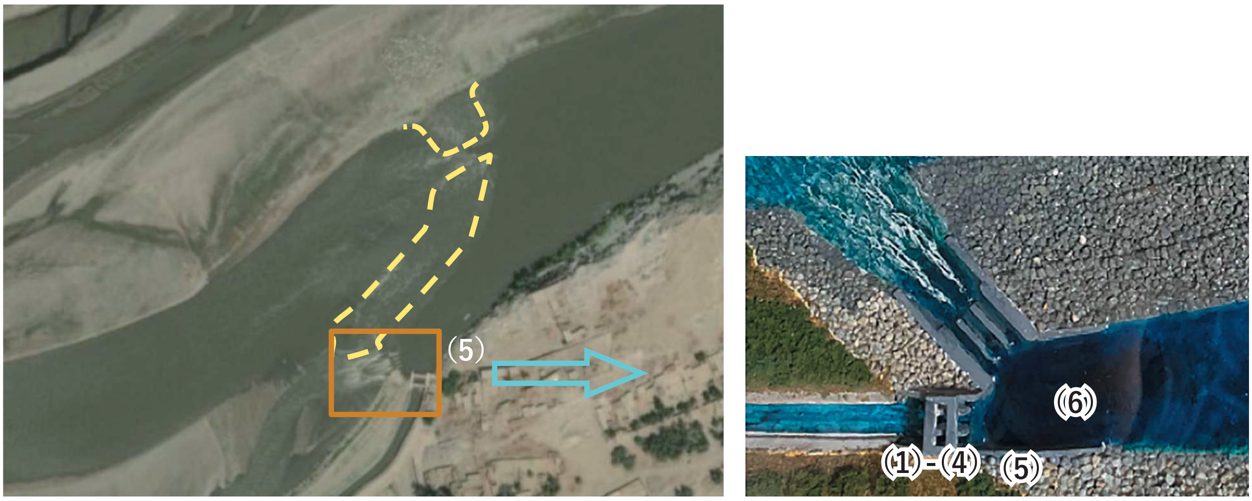
(9) Completion of the Intake Weir for the Protection of Sandbars

Photo 6.13 Completed Intake Weir (Kama Weir Ⅰ) [1]
：December 1, 2018

- By overflowing water after the completion of the intake weir, fine gravels for the temporary road on the surface of the weir will be washed away, and the stone pavements of boulders will appear.
- A longer moderate slope weir body embedded to the riverbank or sandbank on the opposite side of the intake gate will prevent scouring of joints.
- The boulder oblique weir forms a wide and shallow flow. By constructing a spillway with a moderate gradient towards the center of the river flow, the river flow becomes stable.

6.2.3 | Construction Supervision of Intake Gate

In supervising intake gate construction, the following shall be noted. Here, the construction location for each process is shown in Figure 6.7 and the explanation used by photos image showing the construction of double flush board method intake gate in the existing PMS irrigation project.



Note: Numbers in parentheses correspond to those of each construction process below.

Figure 6.7 Construction Process Location for Intake Gate [2)]

(1) Spread Foundation

Photo 6.14 Construction of Spread Foundation 0.5m or more Thickness (Miran Intake Gate) [1)] : November 24, 2014

- The foundation of the lower bottom slab of the intake gate will be a spread foundation in which cement is poured into the cobblestone and gravel layer (usually 0.5 m or more) by digging up to the boulder layer.
- The cement is agitated with a backhoe so that it is evenly mixed with the cobblestone and gravel layer, and the layer is flattened.
- A coffer dike is implemented before concrete structure constuction. Due to seepage water from the river, a dry construction method is applied using a drainage pump.

(2) Bottom Slab of the Foundation Concrete

Photo 6.15 Form Works by Bricks (Marwarid Ⅱ Intake Gate) [1] ：November 8, 2016

- It should be bordered with bricks as a concrete form works on a spread foundation with cement poured into the cobblestone and gravel layer.
- A reinforced concrete slab with a thickness of 40 cm or more is casted.
- The reinforced concrete bottom slab shall have a continuous structure to the intake gate superstructure.

(3) Gate Pier Reinforcement

Photo 6.16 Gate Pier Reinforcement and Dry Construction Method by Temporary Coffer Dike Applied to Intake Gate Construction (Kashkot Intake Gate) [1] ：November 4, 2012

- Reinforced bars and gate ditch for piling up flush boards used for the gate pier are vertically installed.

(4) Gate Ditch Structure in which Flush Boards are Inserted

Photo 6.17 Structural Reinforcement of Gate Piers and Installation of Gate Ditch (Kashkot Intake Gate) [1] ：November 15, 2012

- The gate ditch in which flush boards are inserted is strengthened using a welding processed steel plate 6 mm thickness connected to the reinforcing bar of the bottom slab foundation.

(5) Concrete Revetment at the Upstream Attaching Part of the Intake Gate

Photo 6.18 Reinforcement of Concrete Revetment (Kashkot Intake Gate) [1)]:November 7, 2012

- The immediately upstream side of intake gate where rapid flow pressure is applied shall be a large round concrete revetment and reinforced concrete is used for the wall.
- Since intense erosion occurs, particularly in the lower part, a robust revetment structure should be applied.
- The connecting part of the intake gate and upstream revetment shall be firmly constructed.

(6) Sedimentation Pool Part Between the Intake Gate and Sand Flushing Ditch

Photo 6.19 Construction of Intake Gate, Sand Flushing Ditch and Sedimentation Pool (Kama Weir Ⅰ Intake Gate) [1)]:January 22, 2019

- The intake gate and sand flushing ditch are connected via the reinforced concrete revetment as an integrated structure.
- The revetment shape between the intake gate and sand flushing ditch shall be smooth and curved against the water flow.
- A sedimentation pool is installed upstream of the sand flushing ditch with a reinforced concrete lining to prevent the foundations of the gate pier and sand flushing ditch from being eroded.
- Sedimentation pool are encouraged to drain by making a gradient on the sand flushing ditch side.

6.2.4 | Construction Supervision of the Sand Flushing Ditch

In supervising the sand flushing ditch construction, the following shall be noted. Here, the construction location for each process is shown in Figure 6.8 and the explanation used by photos image showing the construction of sand flushing ditch in the existing PMS irrigation project.

Note: Numbers in parentheses correspond to those of each construction process below.

Figure 6.8 Construction Process Location for Sand Flushing Ditch [2)]

(1) Spread Foundation

Photo 6.20 Construction of Spread Foundation 0.5 m or more Thickness (MarwaridⅡ Sand Flushing Ditch) [1)]
：October 17, 2016

- The foundation of the lower bottom slab of the intake gate will be a spread foundation in which cement is poured into the cobblestone and gravel layer (usually 0.5 m or more) by digging up to the boulder layer.
- The cement is agitated with a backhoe so that it is evenly mixed with the cobblestone and gravel layer, and the layer is flattened.

(2) Reinforcement of the Bottom Slab and Gate Piers

Photo 6.21 Reinforcement of the Bottom Slab and Gate Piers (Kama Weir Ⅰ Sand Flushing Ditch) [1] : December 25, 2018

- In placing concrete, multiple concrete mixing machines shall be arranged and fully operated by a labor-intensive method.

(3) Reinforcement Works in Detail

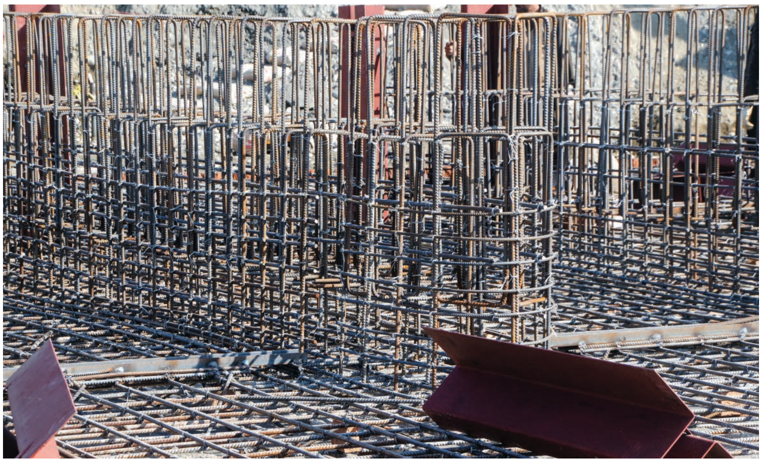


Photo 6.22 Reinforcement of Bottom Slab and Gate Piers in Detail (Kama WeirⅠ Sand Flushing Ditch)[1] : December 24, 2018

- Reinforcing bars are arranged with the bar diameter and space in accordance with the design drawing.
- Reinforcement bars are arranged by removing deposits such as mud on the surface of the reinforcement bars.
- Sufficient additional and anchored lengths of bars shall be secured.

(4) Flush Board Inserting and Removing Test

Photo 6.23 Flush Board Removing Test (Marwarid WeirⅡ Sand Flushing Ditch) [1] : January 22, 2019

- For the sand flushing ditch, detachable flush boards 2.2 m width and 20 cm height are applied.

Flush board reinforced by steel plate
March 9, 2017

(5) Apron Works and Downstream Bed Protection Works of the Sand Flushing Ditch

Photo 6.24 Apron and Downstream Bed Protection of the Sand Flushing Ditch (Kama Weir Ⅱ Sand Flushing Ditch)[1] : January 17, 2018

- In order to prevent river bed from scouring by flow velocity, bed protection works with boulders shall be provided at downstream of the sand flushing ditch. See Figure 4.30 on page 177.
- The joint of concrete apron and bed protection works will be connected without gaps.

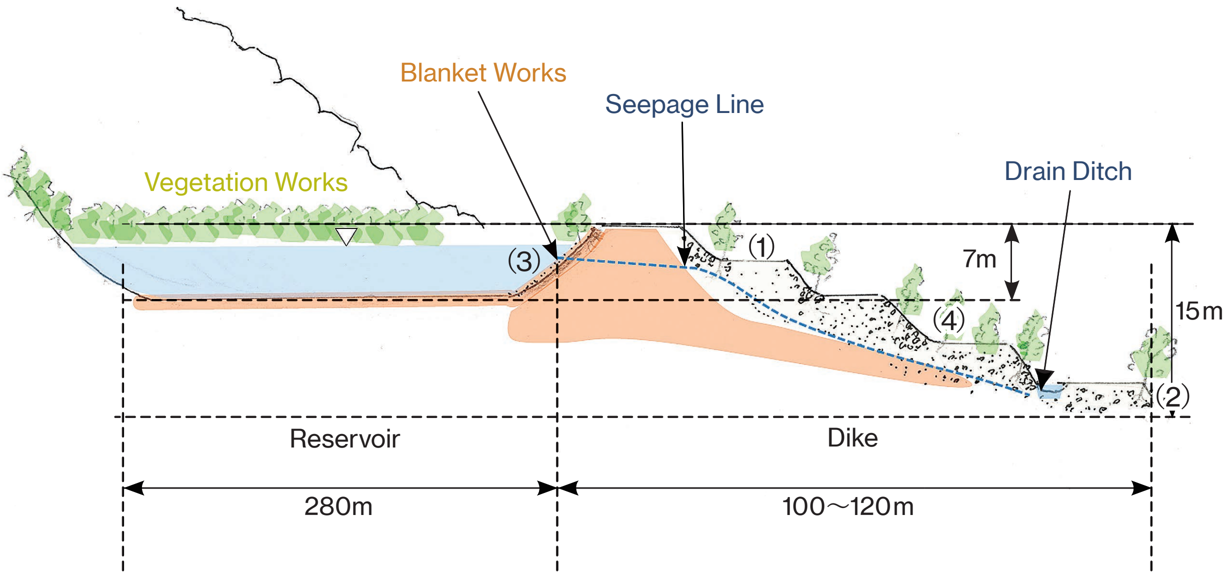
(6) Formulation of Apron Works and Downstream Bed Protection Works of the Sand Flushing Ditch

Photo 6.25 Formulation of Apron and Downstream Bed Protection of the Sand Flushing Ditch (Kama Weir Ⅱ Sand Flushing Ditch)[1] : February 12, 2019

- Bed protection in the downstream of apron is installed until the same place as the downstream end line of the apron of the intake weir.

6.3 Construction Supervision of the Reservoir

When supervising reservoir construction, the following shall be noted. Here, the construction location for each process is shown in Figure 6.9 and the explanation used by photos image showing the construction of reservoir in the existing PMS irrigation project.



Note: Numbers in parentheses correspond to those of each construction process below.

Figure 6.9 Construction Process Location for Reservoir [2), see 3)]

(1) Dike Embankment

Photo 6.26 Heavy Machines, Dump Trucks and Workers in the Dike Embankment (Marwarid Main Irrigation Canal Q2 Reservoir) [1)]

: May 6, 2009

- Construction of the dike embankment shall proceed with the following process: loading and transporting embankment materials and rolling compaction using pavement rollers.
- Each step constructed in the embankment at 30cm-intervals is finally finished as a single slope.
- Since the overall dike embankment section of reservoirs forms a wide valley which is necessary to embank considerable soil volume, construction works shall be divided into multiple sections (around three) as well as dividing excavator, roader and dump trucks into around three teams to proceed with the works.

(2) Leakage Control -1

Photo 6.27 A Wetland is Formed below the Dike Embankment Slope by Seepage Water (Lower Left) (Marwarid Main Irrigation Canal Q2 Reservoir) [1] : June 28, 2009

- The lowest step of the dike embankment is formed by gravels to retain the embankment soil at the foot of the slope and a lower the seepage line in the embankment.

(3) Leakage Control -2

Photo 6.28 Blanket Works (Marwarid Main Irrigation Canal Q2 Reservoir) [1] : July 15, 2009

- Local surplus materials are applied for the dike embankment as a rule. To ensure the embankment remains waterproof, the surface slope of the reservoir embankment (slope on the reservoir side) is blanketed with silty clay.

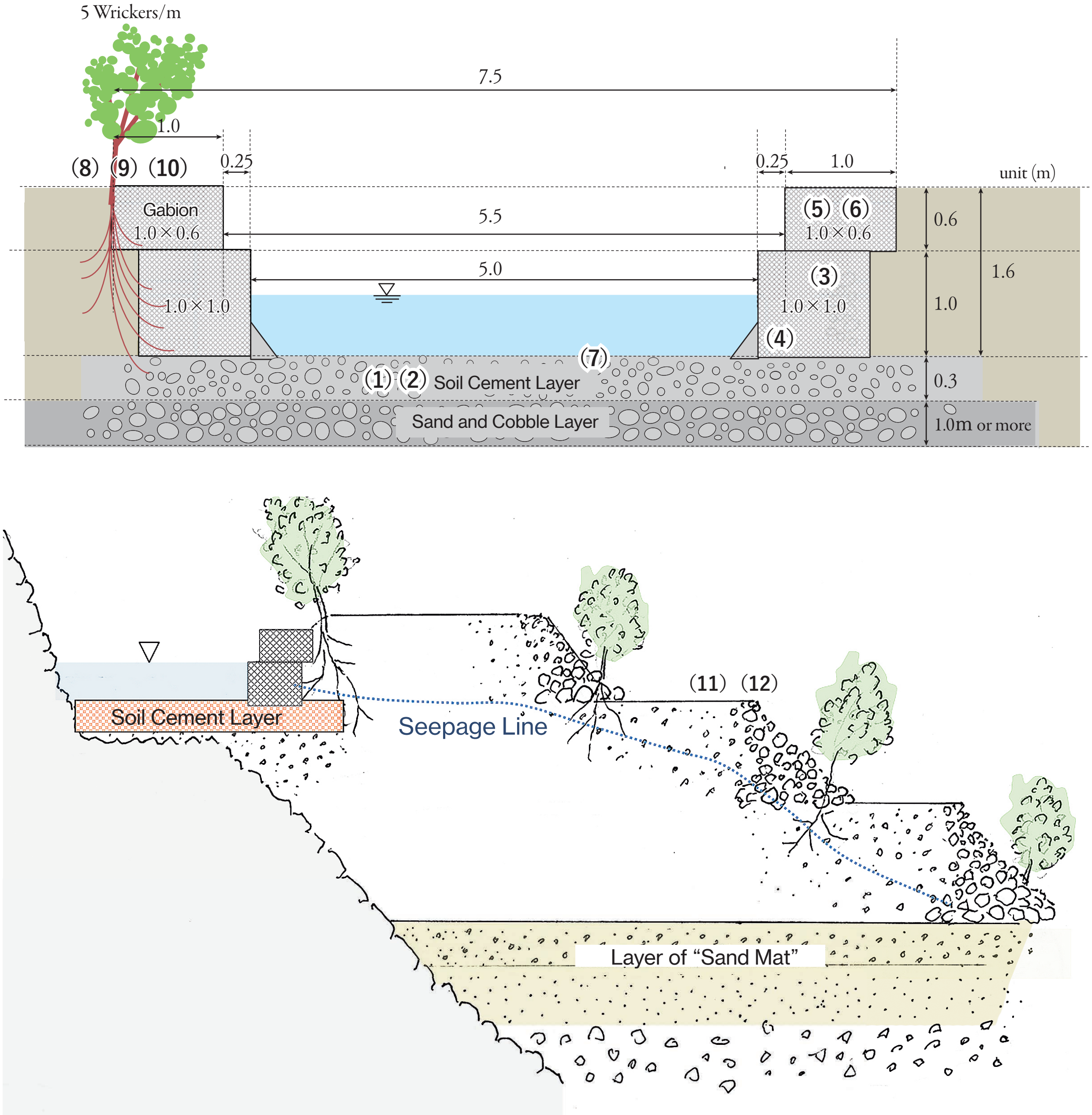
(4) Leakage Control -3

Photo 6.29 Strengthening back slope of the Reservoir Embankment by Eucalyptus (Marwarid Main Irrigation Canal Q2 Reservoir) [1] : September 19, 2011

- In the part where the back slope of the reservoir embankment is in touch with the natural ground, the embankment is strengthened by planting eucalyptus that does not rot.

6.4 Construction Supervision of the Main Irrigation Canal and Wicker Works

When supervising main irrigation canal construction and wicker works, the following shall be noted. Here, the construction location for each process is shown in Figure 6.10 and the explanation used by photos image showing the construction of main irrigation canal in the existing PMS irrigation project.



Note: Numbers in parentheses correspond to those of each construction process below.

Figure 6.10 Construction Process Location for Main Irrigation Canal 2), see 3)

(1) Under Construction of Soil Cement Lining and Other Canal Bed Works

Photo 6.30 Under Construction of Soil Cement Lining and Other Canal Bed Works (MarwaridⅡMain Irrigation Canal) [1] : April 27, 2017

- The original silt and fine sandy ground of the bed of the main irrigation canal is replaced with gravel and a soil cement lining around 30 cm thick is conducted on the surface layer.
- Immediately after that, it is sufficiently compacted

(2) Soil Cement Lining and Other Canal Bed Works

Photo 6.31 Soil Cement Lining Works on the Canal Bed (Miran Main Irrigation Canal) [1] : December 11, 2014

- Since the flow velocity increases at partial steep gradient sections, for protecting the canal bed lining, the consistent gradient of canal bed is kept by drop works, or the flow velocity is loosened by increasing roughness on the surface by making it uneven with stones and bricks.
- The canal bed gradient elevation is controlled using a survey instrument to ensure a difference in altitude of 15 cm per 100 m.

(3) Gabion Works-1

Photo 6.32 Creating and Laying Gabions (Lower Layer) (MarwaridⅡMain Irrigation Canal) [1] : December 18, 2016

- Gabions are laid on the lower bank of the main irrigation canal.
- Gabions are laid by checking the condition of the foundation (bed) surface where the gabions are installed.
- If the irrigation water supply is urgent, water supply will be started after installing the lower part of the gabions and filling soil cement in the corner of the canal bed.

(4) Filling Soil Cement in the Corner of Main Irrigation Canal Bed

Photo 6.33 Filling Soil Cement in the Canal Bed Corner of Main Irrigation Canal (Marwarid Ⅱ Main Irrigation Canal) [1] : December 24, 2016

- The corners of the main irrigation canal are filled with smoother soil cement to increase flow velocity by reducing roughness and preventing sedimentation at the canal. In addition, the permeation loss of irrigation water is suppressed.

(5) Gabion Works-2

Photo 6.34 Creating and Laying Gabions (Upper Layer) (Marwarid Ⅱ Main Irrigation Canal) [1] : April 8, 2019

- Gabions are laid on the upper bank of the main irrigation canal.
- This is done while confirming that backfill soils on the back of the gabion works are not loosened.

(6) Piling up the Canal Embankment by Gabion Works

Photo 6.35 Piling up the Canal Revetment by Gabion Works (Marwarid Ⅱ Main Irrigation Canal) [1] : July 18, 2018

- The longitudinal gradient of main irrigation canal maintains consistency as a general rule. Where part of the gradient needs to be loosened due to bedrocks and other factors, the design water depth of such section needs to increase. In this case, gabions are piled up to form the higher canal embankment.

(7) Occurrence of Piping on the Main Irrigation Canal Bed

Photo 6.36 Occurrence of Piping on the Main Irrigation Canal Bed (Marwarid Main Irrigation Canal, FG Section) [1)]: April 6, 2020

- Piping may occur on the canal bed due to seepage water from the canal, leakage from the surrounding regulating pond, water seeping when the water level of the riverside canal rises, rainwater flowing into the canal from the bank slope on the side of the canal if any, and other factors.

(8) Preparation for Wicker Works along the Main Irrigation Canal

Photo 6.37 Making Ridges prior to Wicker Works (Shigi Main Irrigation Canal) [1)]: January 29, 2015

- Compartments are formed every 1 meter in the mixed soil of silt and sand backfilled in the back of the gabion revetment in the canal by the same way as the ridges on the farmland.
- By forming a compartment, the poured water remains in the compartment.

(9) Planting wickers

Photo 6.38 Planting along the Canal (MarwaridⅡMain Irrigation Canal) [1)]: June 12, 2017

- Wickers are planted at a certain density (10 to 12 wickers per 1 m^2) in the section of ridges.
- After planting, watering is repeated earnestly to increase the percentage of rootage.
- For watering, a bucket rather than a pump is used, to increase the percentage of rootage because a pump is costly to maintain and often washes out the soil for planting.

(10) Checking the Growing Condition of the Wickers

Photo 6.39 Wicker Works in Three to Four Months after Planting (Miran Main Irrigation Canal) 1) : September 21, 2015

- By patiently watering in the summer, the willow will take root in about half a year.

(11) Planting on the Back Slope of the Canal Embankment

Photo 6.40 Planting on the Back Slope of Canal Embankment (Marwarid Main Irrigation Canal, FG Section) 1) : March 28, 2010

- On the back slope of the canal, wickers are used for planting while those more resistant to dryness are also planted in the embankment.
- The mulberry is the main tree planted, as well as olive and viyella.

(12) Leakage Control of the Main Irrigation Canal on the Embankment

Photo 6.41 Irrigation Canal and Stone Spur Dike on the revetment (Marwarid Main Irrigation Canal, FG Section) 1) : March 24, 2008

- When constructing a main irrigation canal at the top of a high embankment in wetland, the soft foundation ground 1.0 m to 1.5 m thickness is first replaced with gravel and proper quality soils (sand mat method), whereupon an embankment is constructed.
- Drain works are installed at the bottom foot of the embankment slope as leakage control.
- If there is a river near the irrigation canal and there is a risk that a diversion channel will approach, a stone spur dike will be provided to keep the river channel away.

Text Block 6-3: An Example of Changes Over the Years After Construction[1)]

a) An example of the main irrigation canal: from one and a half to three years after the construction

One and a half years after construction, wickers along the main irrigation canal (upper step) grow to 1.0 to 1.5 m in height. Mulberry trees on the second and third steps have just been transplanted with young trees. As of April 28, 2007.

Three and half years after construction, the mulberry trees grow to 2 to 2.5 m in height and are rooted. Wickers grow to around 4m. As of April 9, 2009.

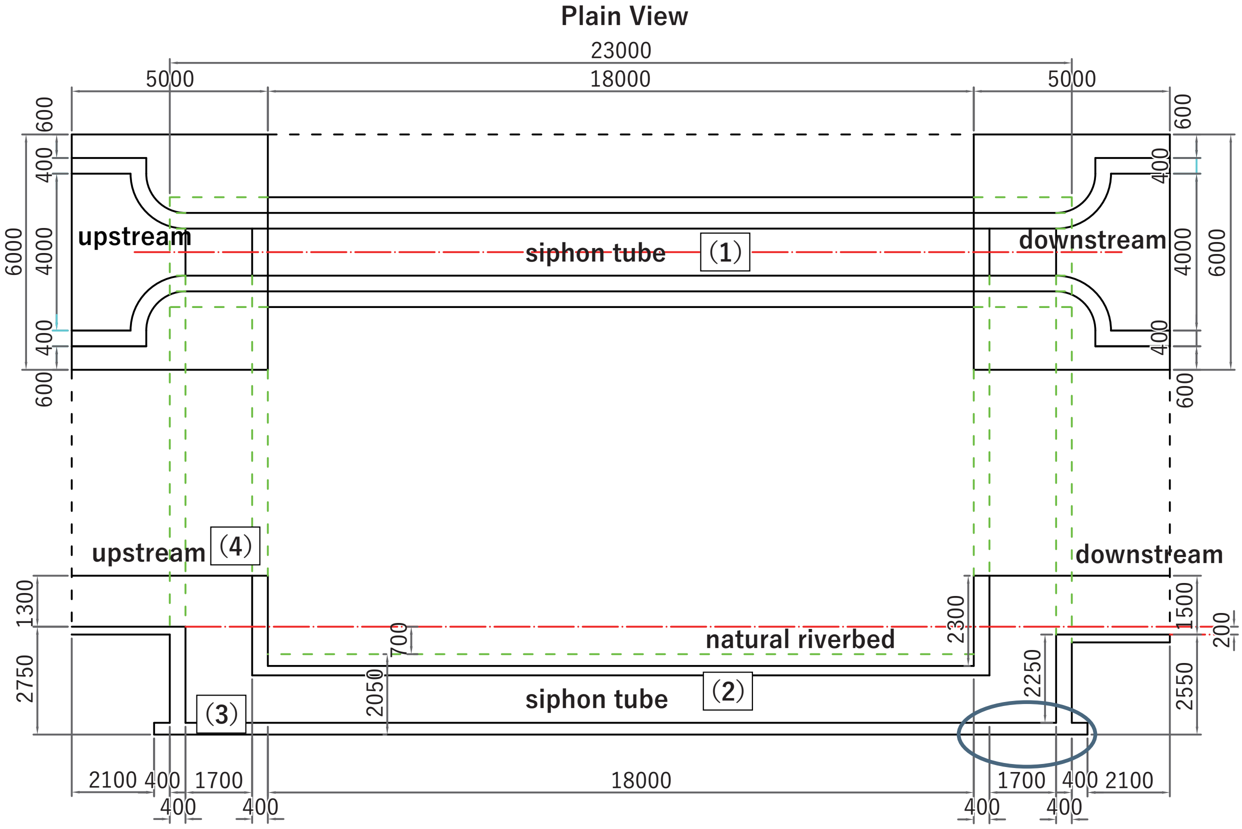
b) An example of the embankment canal section: during constuction and four years later

The canal on the embankment is under construction. Bedrock and wetlands are shown on the left and right sides, respectively. As of February 27, 2005.

The same location four years after construction.
As of May 10, 2009.

6.5 Construction Supervision of Siphon

When supervising siphon construction, the following shall be noted. Here, the design example is shown in Figure 6.11 and the explanation used by photos image showing the construction of siphon in the existing PMS irrigation project.



Note: Numbers in parentheses correspond to those of each construction process below.
⬭: Ideally, a sedimentation pool shall be provided at the bottom of the siphon shaft.

Figure 6.11 Design Example of Siphon [1]

(1) Setting the Location of the Siphon

Photo 6.42 The Status before Constructing the Siphon (Marwarid Main irrigation Canal, Gamberi Floodway) [1] : April 10, 2012

- Traces of debris flow and flash flood are surveyed to confirm the location and section of the siphon to be installed.
- Landmarking by putting stones or piles is carried out at the shaft point and on the liner of the underground pipe to label and confirm the location of structures prior to their construction.

(2) Constructing the Siphon

Photo 6.43 Construction of a Siphon
(Marwarid Canal, Gamberi Floodway)[1] ：October 24, 2012

- In readiness for flood flows during construction, surrounding areas are hardened by banks.
- In addition, the buried box length of the siphon is divided into construction sections and backfilled after the construction of each section.

(3) Siphon Shaft Construction -1

Photo 6.44 Construction of the Siphon Shaft Foundation
(Marwarid Canal, Gamberi Floodway)[1] ：April 10, 2012

- Foundation works are important when constructing shafts of a siphon to prevent subsidence.
- Prospecting is conducted to check the gravel layers and other bearing layers.
- Cement is poured into the gravel layer to form a firm spread foundation. Further, reinforced concrete slab 40 cm thickness is installed as the shaft foundation.

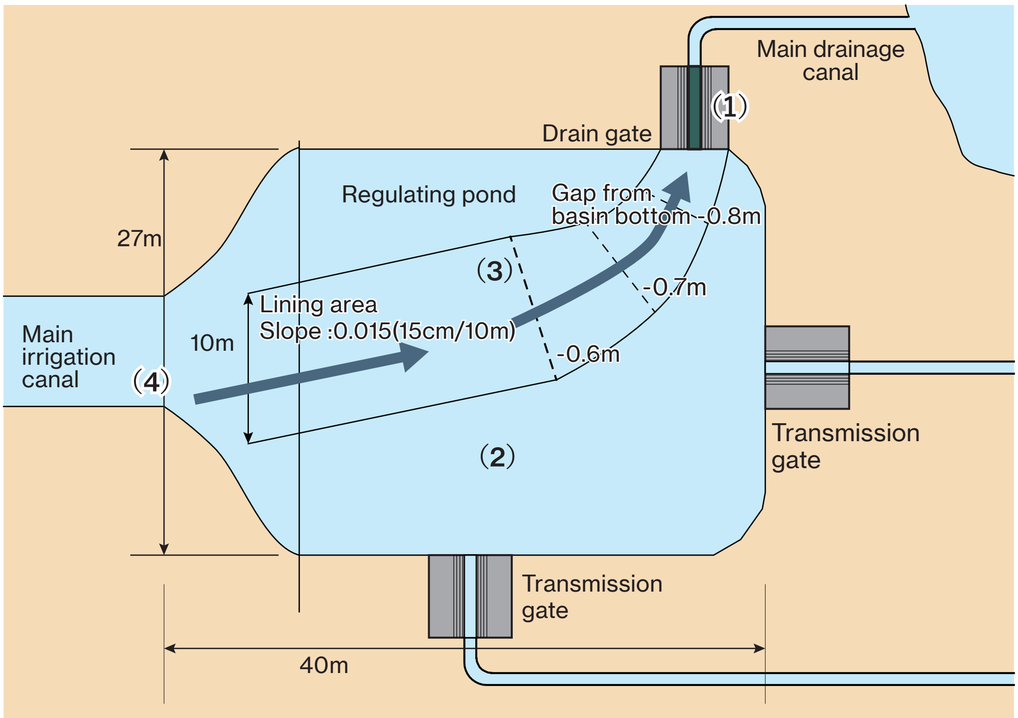
(4) Siphon Shaft Construction-2

Photo 6.45 Safety Measures for the Siphon(MarwaridⅡ Canal) [1]
：June 30, 2018

- To prevent accidents involving children falling into the siphon shaft, a protective net is installed on the top of shaft.

6.6 Construction Supervision of the Sand Basin

When supervising sand basin construction, the following shall be noted. Here, the construction location for each process is shown in Figure 6.12 and the explanation used by photos image showing the construction of sand basin in the existing PMS irrigation project.



Note: Numbers in parentheses correspond to those of each construction process below.

Figure 6.12 Construction Process Location for Sand Basin [2), see 3)]

(1) Drain Gate Construction

Photo 6.46 Height Difference at the Drain Gate (Miran) [1)]
: February 7, 2015

- The bottom level of the drain gate shall be set to 50 cm to 1 m lower than the sand basin floor and water transmission gate to enhance the sand drain function.
- The drain gate will be a slide gate, and the bottom water in the sand basin will be drained together with the earth and sand.
- The joint of the floor between sand drain channel and bottom of the drain gate are filled by plain concrete to equalize the level difference.

(2) Construction of the Sand Basin Floor

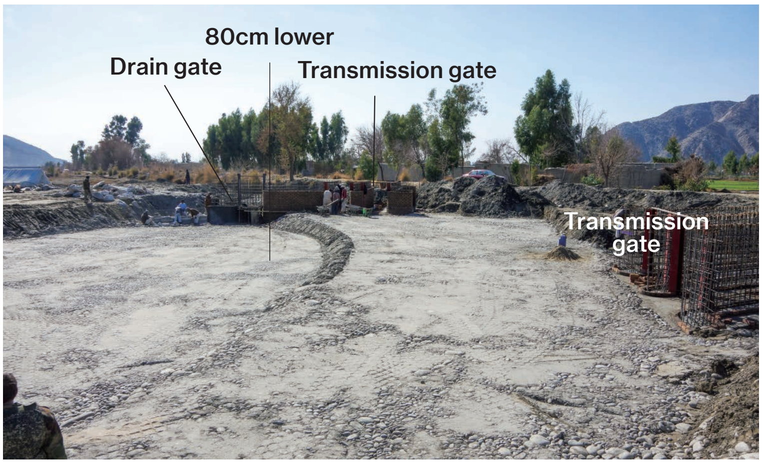


Photo 6.47 Construction of the Sand Basin Floor (Miran)[1)]
: January 29, 2015

- A transmission gate with flush board will be provided at the same level as the floor level of sand basin.
- A sand drain channel connecting to the drain gate is installed on the floor of the sand basin.
- To enhance the sand drain function, the floor of the sand drain channel slopes toward the drain gate bottom level.
- When installing the slope, the level is managed to ensure the gradient is set as designed.

(3) Lining Works of the Sand Drain Channel

Photo 6.48 Concrete Lining Works in the Sand Drain Channel (Miran)[1)] : February 7, 2015

- The sand drain channel in the sand basin is lined with concrete toward the drain gate. The roughness is reduced to enhance the sand drain function.
- When lining the concrete, it shall be laid with even thickness.

(4) Completion of the Sand Basin

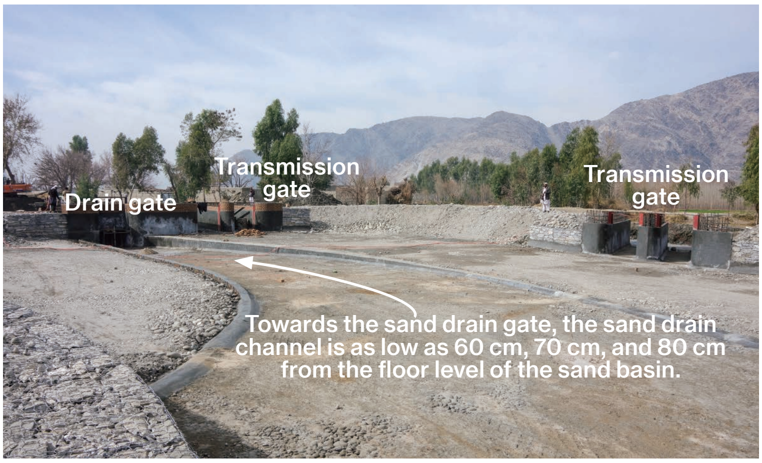
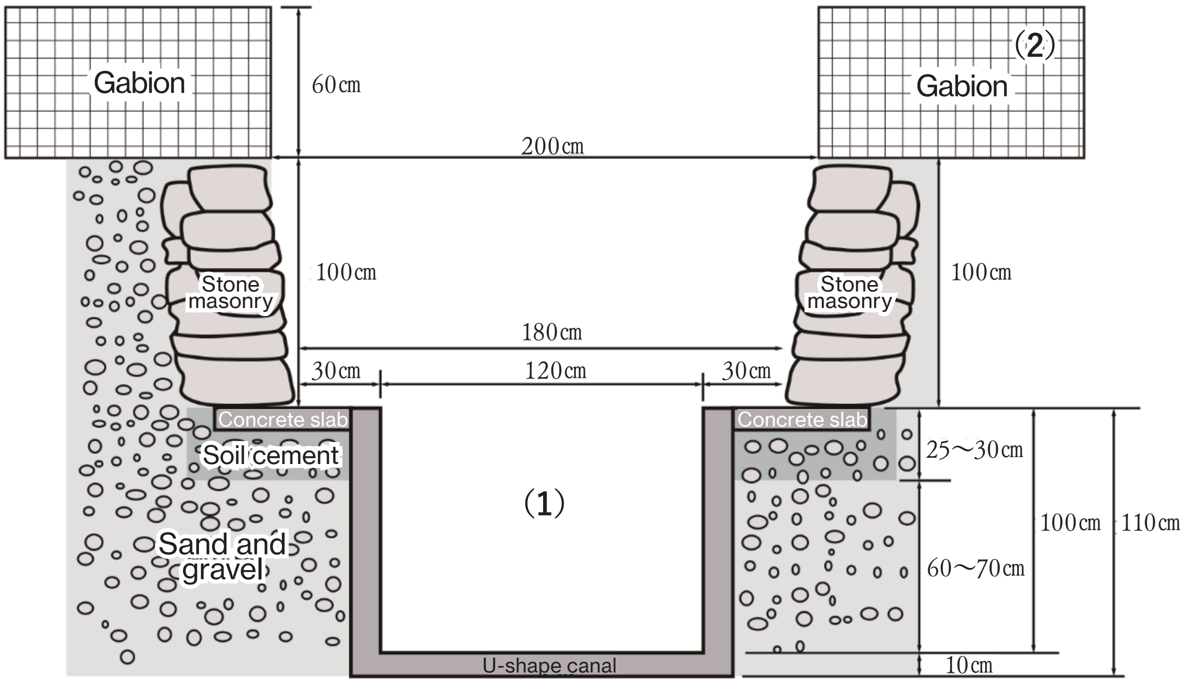


Photo 6.49 The Sand Basin Configuration (Miran)[1)]
: February 12, 2015

- If the length of the sand basin is taken too long in the flow direction, the gradient of the sand drainage channel will become gentle and it will be difficult to discharge sediment. Therefore, the shape of the sand basin shall be 40 to 50 m on the long side and 30 to 40 m on the short side

6.7 Construction Supervision of the Drainage Canal

In supervising drainage canal construction, the following shall be noted. Though the structure of the main drainage canal is veried by the site condition, here, a design example of U-shaped canal is shown in Figure 6.13 and the explanation used by photo images showing the construction of main drainage canal in the existing PMS irrigation project.



Note: Numbers in parentheses correspond to those of each construction process below.

Figure 6.13 Design Example of U-shaped Main Drainage Canal [2), see 3)]

(1) Installation of a U-shaped Canal in the Main Drainage Canal

Photo 6.50 Installation of a U-shaped Canal in the Drainage Canal (Gamberi Main Drainage Canal) [1)]：July 23, 2016

- If soft ground is observed when digging 2.0 to 2.5 m down from the current ground surface, around 0.5 m is replaced with gravel to form the foundation of a U-shaped canal.
- A U-shaped canal is lifted by a crane and installed.

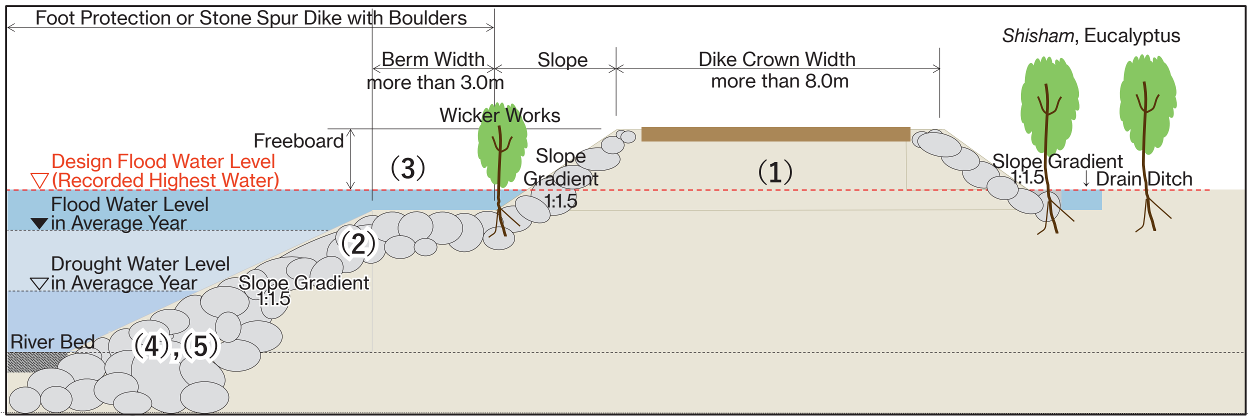
(2) Earth Retaining on the Upper Part of the Main Drainage Canal

Photo 6.51 Earth Retaining on the Upper Part of the Main Drainage Canal (Gamberi Main Drainage Canal)[1] : September 28, 2017

- A gabion is installed on the upper part of the U-shaped canal to retain earth. The backfill soil on the back of the gabion is firmly compacted to ensure the soil does not loosen.

6.8 Construction Supervision of Dike/Stone Spur Dike

In supervising dike/stone spur dike construction, the following shall be noted. Here, the construction location for each process is shown in Figure 6.14 and the explanation used by photos image showing the construction of dike/spur dike in the existing PMS irrigation project.



Note: Numbers in parentheses correspond to those of each construction process below.

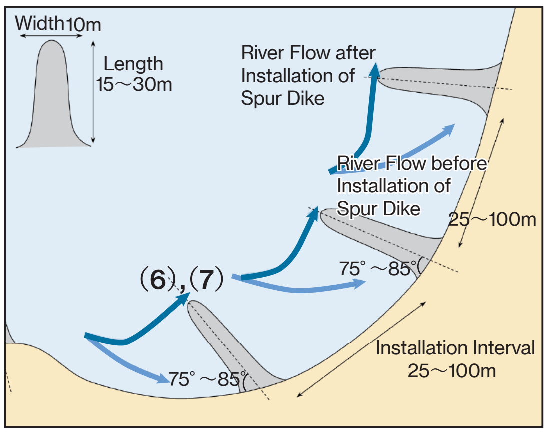


Figure 6.14 Construction Example of Dike/Stone Spur Dike [2), see 3)]

(1) Dike Body Construction

Photo 6.52 Unwinding and Rolling Compaction of the Embankment Materials (Behsud Bank Protection)[1] : October 13, 2010

- The crown is used for a construction road and a maintenance road after the construction.
- Less permeable silt is mixed with gravel for use in construction.
- Embankment materials unwound at 30 cm-thickness intervals are rolled and compacted.
- The slope on the river side is covered by boulders to withstand severe flow pressure.

(2) Riprap Works of Dike

Photo 6.53 Riprap Works on the Riverside Dike Slope (Behsud Bank Protection)[1] : June 18, 2011

- Riprap works with two small stages installed at the top and bottom and both covered in a thick layer of boulders.
- The riprap works of the bottom stage protect the foot of dike from erosion. It is connected to a stone spur dike installed at certain intervals.

(3) Dike Protection by Vegetation Works

Photo 6.54 Dike Protection by Vegetation Works (Behsud Bank Protection)[1] : October 24, 2012

- Wickers and *shisham* are planted on the riverside slope to protect the dike from the flow of water.
- Dense planting of wickers on the bottom stage protects the dike combining with foot protection works.

(4) Construction of the Stone Spur Dike Foundation

Photo 6.55 Construction of the Stone Spur Dike Foundation (Miran)[1] ：October 22, 2014

- To construct the food protection of the dike, which comprises the foundation of the stone spur dike, boulders are deposited by dump trucks.

(5) Inputting Stone Materials to Construct the Stone Spur Dike

Photo 6.56 Inputting Stone Materials to Construct the Stone Spur Dike (Hundreds of Meters from the Miran Revetment Starting Point)[1] ：February 12, 2015

- Sufficient amount of stones shall be input to construct a thick and deep foundation in the section with the most severe water flow, such as the external side of curved river.
- To construct a single stone spur dike, boulders for dozens of trucks are required.

(6) Construction of a Group of the Stone Spur Dikes

Photo 6.57 Construction of a Group of the Stone Spur Dikes (Miran)[1] ：January 24, 2015

- Stone spur dikes constructed along with a dike at certain intervals can effectively prevent the foot of the dike slope from being eroded.
- Compaction by construction machinery is performed from the top of the stone spur dike after pilling up the boulders to secure the embedded depth under the riverbed surface.
- Dump trucks come and go to the top of the spur dike multiple times during the construction, which promotes the compaction of the spur dike.

(7) Effects of the Stone Spur Dike

Photo 6.58 River Flow at Installation Section of Stone Spur Dikes at the Curved Part Where Erosion is Most Intense (Miran)[1] : April 20, 2015

- A semi-overflow and non-transparent type of the stone spur dike is effective for keeping severe river flow away from the riverbank.