# C3. FACILITY PLAN

## C3.1 Basis of Facility Plan

### C3.1.1 River Channels

**Channel Flow Calculation:** Surface profiles of the flood flows shall be calculated basically by uniform flow formula because of relatively steeper channel slope in the Study Area. Non-uniform flow calculations are applied to the reaches where back-water and drawdown water profiles are dominated and to the final checks of flow profiles. Manning's roughness coefficients for the flow calculations are assumed as follows:

n = 0.025 for completely lined channel
n = 0.030 for ordinary low-water channel
n = 0.060 for high-water channel

**Standard River Section:** Standard river sections are designed for each river stretch which need improvement. The standard section shall be modified, if necessary, section by section depending on the situation. Course of the Bone-Bolango-Tapodu (BBT) River is stable as a whole and the channel forms single section surrounded by house buildings and the dike located close to the riverbank. Considering such conditions of the existing river, low-water channel shall be designed so as to carry the design discharge as single section channel.

**Dike and High-water Channel:** Dike shall be provided to prevent floodwater from spilling over the land. High-water channel between the low-water channel and dike is to be provided primarily not for the floodwater conveyance but for the safety of dike against bank erosions and slope failures. The dike alignment shall be smooth allowing free flood flows.

**Width of High-water Channel:** In case bank protection is not provided, width of high-water channel shall be taken enough to the bank erosion at least during a flood season. Considering the data on bank erosion rate in Japan, the following width was proposed as the minimum width required (Figure C3.1.1):

1) In case of bank without protection works:

$$Bhw \geq m \times h\max$$

where

Bhw : Width of high-water channel

Hmax : Maximum water depth of the river section

m : Erosion rate assumed to be 5 for the river reaches in Segment 2-1 with depth (hm) grain-size (d) ratio: hm/d>500, which corresponds to the lower Bolango River.

The high-water channel is recommended to be covered with vegetation such as reed to resist erosion.

2) In case of bank with protection works:

$$Bhw \geq (n_0 - n) \times h_b > 3\text{m}$$

where

$n_0$ : Critical slope for bank failure, assumed as $n_0 = 3$

n : Slope of bank protection works expressed 1 (vertical) on n (horizontal)

$h_b$ : Bank height at the foot of the protection works

**Length of Sure-Footing:** Most of the failures of bank protection works are caused by scouring at the toe of the revetment work. Sure-footing works are important for the durability of the revetment. The length of the sure-footing shall be determined referring to the following (Figure C3.1.1).

$$Bsf = B_0 + h_s/\sin\theta = B_0 + 1.6h$$

where

Bsf : Length of sure-footing

h : Water depth

$h_s$ : Scouring depth, assumed as $h_s = 0.8h$

$\theta$ : Assumed as $\theta = 30$

$B_0$ : Minimum fixed length, advisable $B_0 \geq 2$m

**Dike:** Earth dike and concrete floodwall would be the major types of dike to prevent floodwater from spilling over the land. Earth dike shall be adopted in principle because of its durability and easiness to repair and strengthening even during the flood. Concrete floodwall shall be applied where the earth dike cannot be constructed owing to land and other unavoidable reasons. Standard earth dike section and free board necessary for the safety of dike are shown in the Figure C3.1.1.

### C3.1.2 River Structures

#### (1) Design Standards and References

**Material Standard:** Applied Standards are as follows:

- SNI (Standar Nasional Indonesia)
- SII (Standar Industri Indonesia)
- JIS (Japan Industrial Standard)
- ASTEM (American Society for Testing and Material)
- AASHOT (American Association of State Highway and Transportation)

**Design Standard:** Applied Standards are as follows:

- PBI (Peraturan Beton Bertulang Indonesia 1971 N.L-2)
- Peraturan Muatan untuk Jembatan Jalan Raya No.12/1970 (Indonesian Loading Specification for Highway Bridge)
- Technical Standards for River and Sabo issued by The Ministry of Construction, Japan
- Design and Planning Criteria for Land Improvement Works issued by The Ministry of Agriculture Forestry and Fishery, Japan
- Specifications for Road Bridge issued by The Association of Road Construction, Japan

**Measurement Unit:** Metric system is exclusively employed.

#### (2) Loading Conditions

**Dead Load:** The unit weights of materials for calculating the dead load are as follows:

| | | |
|---|---|---|
| - Reinforcement concrete (for bridge) | 2.50 | $t/m^3$ |
| - Reinforcement concrete (for structure) | 2.40 | $t/m^3$ |
| - Plain concrete | 2.30 | $t/m^3$ |
| - Water | 1.00 | $t/m^3$ |
| - Embankment material (dry) | 1.80 | $t/m^3$ |

| | | | |
|---|---|---|---|
| - | Embankment material (submerged) | 1.00 | $t/m^3$ |
| - | Asphalt pavement | 2.30 | $t/m^3$ |
| - | Soil (clay) | 1.70 | $t/m^3$ |
| - | Soil (sand) | 1.80 | $t/m^3$ |
| - | Rubber dam (by 2.0m height) | 0.40 | $t/m^1$ |

**Unit Load:** The uniform load is estimated as follows:

| | | | |
|---|---|---|---|
| - | On the ground (vehicle) | 1.00 | $t/m^3$ |
| - | On the bridge / structure | 0.50 | $t/m^3$ |

**Water Pressure:** The water pressure is calculated applying following formula:

$$Pw = \frac{1}{2} \times Wo \times H^2$$

where

| | | |
|---|---|---|
| $Pw$ | : | Water pressure (t/m) |
| $Wo$ | : | Unit weight of water ($t/m^3$) |
| $H$ | : | Water depth (m) |

**Earth Pressure:** The earth pressure is calculated by the following formula:

$$Pe = \frac{1}{2} Ka \times \gamma \times H^2$$

where

| | | |
|---|---|---|
| $Pe$ | : | Earth pressure (t/m) |
| $Ka$ | : | Coefficient of earth pressure |
| $\gamma$ | : | Unit weight of earth material ($t/m^3$) |
| $H$ | : | Height from the ground surface (m) |

The coefficient of active earth pressure under normal and seismic conditions is calculated applying Coulomb's formula.

**Wind Load:** The wind load is assumed at 100 $kg/m^2$ by the pressure.

**Machine Load:** The gate and machine load shall be decided depending on actual loads.

1) Tamalate Flood Way:
   - Inspection bridge: 225.0 t (normal), 140.0 t (seismic)

2) Tapodu River Improvement with Tapodu Gate :
   - Crossing Bridge (25.0m): 165.0 t (normal), 100.0 t (seismic)
   - Crossing Bridge (20.0m): 130.0 t (normal), 85.0 t (seismic)
   - Gate leaf: 9.0 t
   - Hoist Machine: 5.0 t
   - Lifting Load: 15.0 t

**(3) Allowable Stress**

According to the Indonesian Concrete Code, the following allowable stress shall be applied in the structural analysis.

| | Class-C (structural) | Class-E (massive) |
|---|---|---|
| 1) Concrete: | | |
| - Design strength | 210 $kg/cm^2$ | 180 $kg/cm^2$ |
| - Bending comprehensive stress | 70 $kg/cm^2$ | 60 $kg/cm^2$ |
| - Shearing stress | 3.6 $kg/cm^2$ | 3.6 $kg/cm^2$ |
| - Tensile stress | 0 $kg/cm^2$ | 0 $kg/cm^2$ |
| - Bond stress | 14 $kg/cm^2$ | 14 $kg/cm^2$ |

2) Reinforcement bar:
   - Tensile stress 1,400 $kg/cm^2$ (normal), 2,100 $kg/cm^2$ (seismic)
3) Increase of allowable stress:
   - In case of flood 0 %
   - Incase of seismic/construction 50 %

**(4) Stability Analysis**

The stability of structure shall be analyzed for the following items:

1) **Overturning:** For the safety against overturning, the condition shall be examined so as to satisfy the following:

   $e < B/6$ (Normal condition)

   $e < B/3$ (Seismic condition)

$$e = \frac{B}{2} - \frac{M}{V}$$

where

$B$ : Width of the footing in direction of overturning (m)

M :

V :

2) **Sliding:** For the safety against sliding, the condition shall be examined so that the following formula should be satisfied.

$$Fs = \frac{C \times A + V \times \tan\phi}{H} > 1.50$$

where

$Fs$ : Safety factor

$C$ : Adhesion between footing and foundation, which is equivalent to cohesion of foundation material ($t/m^3$)

$A$ : Effective area at the bottom of footing ($m^2$)

$V$ : Vertical component of resultant force at the bottom of footing (t)

$\phi$ : Angle of internal friction of foundation material

$H$ : Horizontal component of resultant force at bottom of footing (t)

3) **Bearing Capacity:** The bearing capacity as a reaction of foundation shall be calculated by the following formula:

$$Q_{\max} = \frac{V}{B}\left(1 + \frac{6e}{B}\right) e \le \frac{B}{6} \qquad \text{or} \qquad Q_{\max} = \frac{2V}{3\left(B/2 - e\right)} e \ge \frac{B}{6}$$

$$Q_{\min} = \frac{V}{B}\left(1 - \frac{6e}{B}\right)$$

## (5) Pile Design

1) **Allowable Bearing Capacity of Pile against Axial Driving Force:**

$$Ra = \frac{1}{n}\left(qd \times Ap + \sum u \times li \times fi\right)$$

where

| | | |
|---|---|---|
| $Ra$ | : | bearing capacity |
| $n$ | : | safety factor |
| $qd$ | : | $15 \times N \times Ap$ |
| $Ap$ | : | area of end pile |
| $li$ | : | thickness of layer |
| $fi$ | : | skin friction power |
| $u$ | : | periphery of the pile |

2) **Allowable Axial Pull-out Capacity of Pile:**

$$Pa = \frac{1}{n} \times \left( \sum u \times li \times fi \right)$$

where

| | | |
|---|---|---|
| n | : | 6 for normal and 3 for seismic conditions |

## C3.2 Design of Bone-Bolango River

### C3.2.1 Particular Site Conditions and Principles for Design

Names of rivers and bridges across the rivers are specified as shown in Figure C3.2.1 for the conveniences of descriptions. River improvement of the Bone-Bolango River is discussed dividing the river into the following stretches as shown in the Figure:

1) Lower Bone River
2) Bolango River Stretch-I
3) Bolango River Stretch-$II_L$
4) Bolango River Stretch-$II_R$
5) Bolango River Stretch-III

#### (1) Lower Bone River

1) River Condition: Length of stretch is about 1.1 km from river mouth to the confluence of the left and right Bolango rivers. The river is affected by tides. The river is sandwiched by granite hills with narrow flat plain. Riverbed is filled up with deep sediment with abrupt drop at its lowest end.

2) Existing Facilities: River port and fueling base are located on both banks of the river mouth. Bank protection works are provided to protect the road adjacent to the road.

3) Channel Excavation: No excavation/dredging is proposed, since the riverbed is formed with thick sediment deposit and the artificially excavated channel would be easily filled up soon.

4) Dike: Formation levels of roads on both sides of the river are high as a whole. Even though the riverine lands are flooded, the river water would not spread over and soon return to the river influenced by the tidal movement. Therefore, dikes are not planned in this stretch.

5) Bank Protection: Bank protection shall be provided at the eroded banks. Protection against corrosion due to seawater should be considered.

**(2) Bolango River Stretch-I**

1) River Condition: Stretch length is about 1.1 km from the confluence of the Bone River to the confluence of the left and right Bolango Rivers. Tidal movement affects the river flows judging from the lowest riverbed elevation. Densely built-up areas are located on the left bank in the upper portion of this stretch. River bank elevation is absolutely low, and the riverine areas are flooded by the floods from the Bolango and Bone rivers and storm water gathered from relatively high surrounding areas.

2) Existing Facilities: Concrete floodwall is installed on the left bank near the lower end of this stretch. Bank protection works made of gabion (Bronjong) are provided on the left bank near the upper end of this stretch. A concrete road bridge (Tenda Br.) crosses the Bolango River.

3) Channel Excavation: Since the existing river banks are absolutely low, no channel excavation is proposed.

4) Dike: In this stretch, diking system is the only measure to prevent river water from spilling over. The dike shall be provided on both banks.

5) Bank Protection: Bank protection shall be provided at the eroded banks. Protection against corrosion due to seawater should be considered.

### (3) Bolango River Stretch-$II_L$

1) River Condition: Stretch length is about 2.1 km from the confluence of the right Bolango (Siendeng) River to the divergence of the said river. River channel in this stretch is surrounded by densely built-up areas of the Gorontalo City. In the reaches downstream from Siendeng bridge (2nd road bridge from the lower stretch end), flooding conditions are similar to those of the Stretch-I with of the low elevation riverbank and channel affected by the Bone floods and tidal movements. At about one third of distance from the upper end, there exists a large channel bent of right angle.

2) Existing Facilities: In the downstream reaches of the large channel bend, bank protection works (Bronjong) are the main facilities provided mostly on the left banks. In the upstream of the bend, left bank was protected by concrete floodwall and the right bank by concrete wall and earth dike. There are four road bridges (Siendeng-1, Siendeng, Biawu-1 and Biawu-2 bridges) and 2 footpath bridges.

3) Channel Excavation: No major channel works are planned, since the Right Bolango (Siendeng) River shall be improved as major floodway of the Bolango.

4) Dike: Concrete floodwall shall be provided for the whole stretch and partly existing dikes shall be strengthened.

5) Bank Protection: No major channel works are planned.

### (4) Bolango River Stretch-$II_R$

1) River Conditions: Stretch length is about 1.7 km from the confluence of the left Bolango River to the divergence of the said river. The river called as the Siendeng River or the Right Bolango River takes route at the skirt of the hilly land on the right bank. In the reaches downstream from Siendeng-2 bridge (lower bridge of this stretch), flooding conditions are similar to those of the Stretch-I with riverbank of low elevation and channel affected by the Bone floods and tidal movements. In the upper portion of this stretch, large channel meandering exists.

2) Existing Facilities: Bank protection works (Bronjong) are provided at the major eroded section on both bank for the whole stretch. Dikes (earth dikes and concrete flood walls) were also installed intermittently in the upper portion of this stretch. These works were constructed along the narrow existing channel. There are two road bridges (Siendeng-2 and Donggala bridges) across the river.

3) Channel Excavation: The Stretch-$II_R$ shall be improved as main floodway of the Lower Bolango River. Whole stretch of channel shall be excavated by widening and deepening.

4) Dike: Earth embankment shall be installed where the ground elevation is not high enough. Concrete floodwalls are also designed partly where the enough lands to earth dike are not available.

5) Bank Protection: In order to minimize the land to be acquired, bank protection is provided for the whole stretch on both banks.

**(5) Bolango River Stretch-III**

1) River Conditions: Stretch length is about 2.8 km from the divergence of the left and right Bolango rivers to the confluence of the Tapodu River. Existing river course seems to be stable as a whole surrounded by natural levees on both banks.

2) Existing Facilities: Continuous earth dikes are installed along almost all stretch. Concrete floodwalls and bank protection are also installed locally. There are two road bridges (Tenilo and Potanga bridges) across the Bolango River.

3) Channel Excavation: Channel shall be excavated only in the reaches where existing flow capacity below design high water level is not enough to the design discharge.

4) Dike: Existing dike shall be strengthened and incomplete works due to existing buildings and structures shall be completed.

5) Bank Protection: Bank protection is provided for the reaches subject to the channel excavation.

### C3.2.2 Design of River Channel

#### (1) Hydraulic Design Values

**Design Discharge:** Figure C3.2.2 shows the design discharge distribution based on 20-year flood. Discharge distributions for other return periods are also shown in the Figure. The design discharge is compared with the existing bank-full channel capacity in Figure C3.2.3. If the freeboard is taken into account, the effective channel capacities are less than those shown in the Figure.

**Design High Water Level (DHWL):** DHWL was set to be +6.10 m,MSL at the confluence of the Tapodu River and the slope of the DHWL was set to be 1/1200 as shown in Figure C3.2.4, considering the elevations of riverbanks and existing dike crown along the river. The DHWL at each river stretch is summarized below.

| River | DHWL (m,MSL) | Slope |
|---|---|---|
| Lower Bone R. | +1.17 to +2.62 | 1/780 |
| Lower Bolango R. | | |
| Stretch-I | +2.62 | Level |
| Stretch-$II_R$ | +2.62 to +3.80 | Level, 1/1200 |
| Stretch-$II_L$ | +2.62 to +3.80 | Level, 1/1760 |
| Stretch-III | +3.80 to +6.10 | 1/1200 |

#### (2) Site of Channel Improvement Works

In order to convey the design discharge smoothly and safely below the DHWL, channel works shown in Figure C3.2.5 are required. Except for the dike and bank protection works, the following major channel works were proposed:

1) Cut-off channel at Tenda

2) Channel excavation of the Right Bolango River including normalization of meandering sections and channel realignments at the divergence of the Left Bolango River.

3) Channel excavation in Stretch-III of the Lower Bolango River downstream reaches from Tenilo Bridge.

Principal features of these channel works are described in the following sub-sections.

**(3) Cut-off Channel at Tenda**

At about 150 m downstream of the confluence of the Left and Right Bolango rivers, the Lower Bolango River is forced to bend almost at right angle (Figure C3.2.6). Due to the bend, floodwater level is raised by about 40 cm according to the preliminary estimate for the 20-year flood. This raises the water levels of the both rivers around the confluence. At about 250 m upstream of the confluence, the Left Bolango River also bends its course almost at right angle. At the bend, floodwater often overtops the left bank and runs toward the Bolango River causing damages in the area. Coping with the above problems, a cut-off channel (COC) was proposed as shown in the Figure C3.2.6. Judging from the change in riverbed profile, drop structure or riverbed consolidation work was not planned at the lower end of the COC. The COC is expected to have following functions:

1) To promote drainage of the Left Bolango River, shifting the confluence toward downstream. According to the flow calculations water level is lowered, due to the COC, by 21 cm at maximum in the Left Bolango River and by 17 cm in the Right Bolango River under the design flood condition.
2) To make Tenda area free from flooding, changing the river course of lower portion of the Left Bolango River.
3) To alleviate water-level rising at the sharp bend downstream of the existing confluence, reducing the river discharge.

**(4) Channel Excavation of Right Bolango River**

**Right Bolango River as Main Flood Channel:** At the present conditions the Left Bolango River which passes through city center of Gorontalo serves as the main stream of the Lower Bolango River. The Right Bolango River shall be improved as a main flood channel of the Lower Bolango River, since the floodwater should be led apart from the city center and the acquisition of lands for the river improvement is relatively easier. The design discharge of the Right Bolango River is 125 $m^3/s$, while the Left Bolango River shall be subjected to minor improvement with existing channel capacity of 75 $m^3/s$.

**Standard Channel Sections:** In the lower reaches of Siendeng-2 bridges, river is affected by tide and probably by saline water, concrete revetment with slope two (vertical) on one (horizontal) was proposed. The riverbed width is 20.2 m with water depth of 3.2 m and freeboard 0.60 m corresponding to design discharge. In the upstream of the bridge, bank protection with gabion (Bronjong) was proposed with the slope one on one. The riverbed width of the standard section is 18.7 m in these reaches with the same water depth and freeboard. These standard sections are shown in the said Figure C3.2.5.

**Normalization of Right Bolango River:** The channel works of the Right Bolango River include (1) normalization of meandering sections and (2) re-alignment of channels at the divergence of the Left Bolango River as well. The Right Bolango River meanders severely in its upper reaches. The meandering shall be normalized for smooth and safe passage of floodwater flows. Outline of the channel normalization is shown in Figure C3.2.7. According to the flow calculation, water level is lowered by 19 cm at maximum due to the normalization of meandering sections under the design flood condition.

**Realignment of Channels at Divergence:** The channel of the Lower Bolango River in Stretch-III is connected straightly to the Left Bolango River at the divergence of the Right Bolango River. River channel should be realigned so as to guide the floodwater into the Right Bolango River as shown in the Figure C3.2.7. At the divergence of the Left Bolango River, a consolidation work of river section was planned to control the diverging flow within design discharge (75 $m^3/s$) for 20-year flood.

**(5) Channel Excavation in Stretch -III**

In order to increase the channel capacity in the Stretch-III of the Lower Bolango River, channel excavation was proposed for the reaches from the divergence of the Left Bolango to Tenilo Bridge.

Standard channel section in Stretch-III is shown in the Figure C3.2.5. The riverbed width is 28 m with bank slope of one on two. The design water depth is 3.2 m and the freeboard 0.8 m. In the reaches subject to the excavation, the riverbed width was taken at 23 m as an incremental flow area to the existing channel section so that the total flow area exceed that of standard section.

At the upper end of Stretch-III (upstream of Potanga Bridge), a consolidation work of river section was planned to control the discharge downstream of the Lower Bolango River being kept below the design discharge (200 $m^3/s$) for 20-year flood.

**(6) Drainage Sluice**

Two drainage sluices were planned for the tributaries crossing the dike, one crossing the left dike of the Left Bolango River and another crossing the right dike of the Right Bolango River.

### C3.2.3 Design of Appurtenant Facilities

Bridges are the major appurtenant facilities. There are eight (8) road bridges and two (2) footpath bridges crossing the Lower Bolango River. Out of these, two (2) road bridges and one (1) footpath bridge need re-construction, two (2) bridges need heightening. The remaining four (4) road bridges and one (1) footpath bridge would not require the works in relation with the channel improvement works. One new bridge across the Tenda COC also needs to be constructed. Name of the bridges requiring works are summarized below:

| River/Bridge | Required works |
|---|---|
| Stretch-I / Tenda Br. | Heightening |
| Stretch-$II_L$ / New Br. | New bridge for Tenda COC (4 m x 24m) |
| Stretch-$II_L$ / Footpath Br. | Re-construction (4m x 25m) |
| Stretch-$II_R$ / Siendeng-2 Br. | Re-construction (4m x 32 m) |
| Stretch-$II_R$ / Donggala Br. | Re-construction (4m x 32 m) |
| Stretch-III / Tenilo Br. | Heightening |

## C3.3 Design of Tapodu River with Tapodu Gate

### C3.3.1 Particular Site Conditions and Principles for Design

**Component Works:** Tapodu River Improvement Project includes construction of (1) Tapodu River, (2) Tapodu Gate and (3) lake/river dikes as component works. The main functions of the Tapodu River are to lead floodwater of the Bolango River to the lake and to drain stored water to the Bolango as early as possible preparing for the forthcoming floods. Tapodu Gate installed across the Tapodu River primarily serves for maintaining lake water level above 4.00 m,MSL for fishery. The lake/river dikes aims to protect the surrounding villages from the lake water. General layout of the Tapodu River Improvement with Tapodu Gate is shown in Figure C3.3.1.

**Topography:** The proposed site is a part of the low-lying area located at the outlet of the lake. Ground elevation is around +4 to +5 m,MSL. The area is presently suffering from long lasting inundation due to floodwater from tributaries of the Lake Limboto and that from the Bolango River as well.

**Geology:** Tapodu gate is proposed to be installed across the Tapodu River at the outlet of Lake Limboto. No base rock was confirmed according to the drilling works. However, recent deposits of sandy gravel are distributed in the river section. Sandy gravel layers of more than 30 in N-value appear to have sufficient strength for foundation of the structures. The area seems to be once a part of the course of the Bolango River judging from the existence of gravel layers.

**Long Lasting High Water:** The lake area is huge ranging from 28 $km^2$ at +4.00 m,MSL to 50 $km^2$ at +5.00 m,MSL. Because of the wide lake area, if the lake water is once raised high, it takes long period to draw down for a few months. This matter should be kept in mind for the facility design.

### C3.3.2 Design of River Channel

**Design Discharge:** The design discharge was decided to be 550 $m^3/s$ in reverse flow (from the Bolango River to Lake Limboto).

**River Route:** Route of the proposed Tapodu River was selected as shown in the Figure C3.3.1. The route were decided considering the existing channel route and the open space so as to minimize the land acquisition and house compensation.

**Longitudinal Profile:** Riverbed was designed to be level at +2.00 m,MSL considering the bed elevations of the lake and the Bolango River, and flow directions of both regular and reverse flows. Total improvement length is about 2,830 m, out of which river stretch confined by the dikes is 1,850 m long. DHWL of the lake is +5.50 m,MSL and elevation of the lake dike crown is +6.50 m,MSL taking 1-m freeboard, while DHWL of the Bolango River is +6.10 m,MSL with dike elevation of +6.90 taking freeboard corresponding to the design discharge. The longitudinal profile of the Tapodu River is shown in Figure C3.3.2.

**Standard Design Section:** Required width of the Tapodu River was determined according to the flood storage calculations. The design riverbed was decided to be 70 m with bank slope of one (vertical) on two (horizontal). Bank protection works are not provided for the river channel except for the river bends. In stead, high-water channels of 15 m wide were provided on both banks between the earth dike and the low-water channel considering the safety of dike against erosion. It is also proposed that the high-water channels should be covered with vegetation to resist the erosion. In the downstream of Tapodu Gate, high water channels were not provided since the riverbanks were protected.

**Hydraulic Model Test:** In order to design the appropriate channel shape to ensure the discharge diversion and to investigate the sediment movement at the confluence of the Bolango and Tapodu rivers, hydraulic model test should be carried out at the detailed design stage.

**Further Study on Sedimentation:** Sedimentation is anticipated on the riverbed of the Tapodu and its confluence with the Bolango River. Further studies on the method of maintenance and the use of the sediment materials should be made at the detailed design stage. The improvement of the Tapodu River may increase the turbid water inflow to Lake Limboto from the Bolango River. Influence of the turbid water should also be studied at the following stage.

### C3.3.3 Design of Tapodu Gate

#### (1) General Conditions

Flood discharge of the Bolango River is planed to be led to Lake Limboto to control discharge in the Lower Bolango River. On the other side, water level of Lake Limboto will also be controlled within the range from +4.00 m,MSL at the lowest and +5.50 m,MSL at the highest. Basically the gate pass the 550 $m^3/s$ of flood discharge from the Bolango River. Design high water level of the Bolango River is set at +6.10 m,MSL at the confluence of the outlet channel of the lake (the Tapodu River) with design riverbed +2.00. During the flood of the Bolango River, flow direction of the Tapodu River is from the Bolango to the lake to store the floodwater, while the flow direction during ordinary time is opposite to drain the stored water. Therefore, the Tapodu River and Tapodu Gate must be designed considering the flows under both directions.

**(2) Design Conditions of Gate**

The hydraulic conditions around the proposed Tapodu Gate are summarized below.

| | |
|---|---|
| 1) Lake water level | |
| Design high water level: | +5.50 m,MSL |
| Minimum water level to be maintained: | +4.00 m,MSL |
| 2) Tapodu River | |
| Design discharge: | 550 $m^3/s$ |
| Design high water level: | +5.50 m,MSL |
| Riverbed elevation: | +2.00 m,MSL |
| Design dike crown: | +6.50 m,MSL |
| Low-water channel width (bottom): | 80 m |
| River width (dike to dike): | 110 m |
| 3) Bolango River | |
| Design high water level: | + 6.1 m,MSL |
| Design dike crown: | + 6.9 m,MSL |
| 4) Tapodu Gate | |
| Design discharge: | 550 $m^3/s$ |
| Design high water level (lake-side): | +5.50 m,MSL |
| Design high water level (Bolango-side): | +6.10 m,MSL |
| Bed elevation: | +2.00 m,MSL |

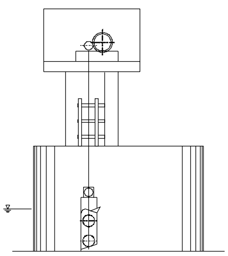
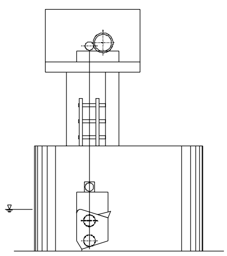
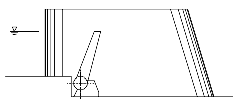
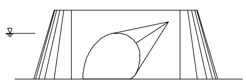
Tapodu Gate shall be operated under the following conditions:

1) Gate shall be closed to keep the lake water above +4.00 m,MSL.
2) The gate shall be fully opened to lead floodwater of the Bolango River to the lake or, on the contrary to drain the stored as early as possible so as to keep the lake water level below 5.50 m,MSL.

In addition to the above, the gates are preferably to be operated by the power other than those of commercial power taking account of the dependability and cost of power supply.

### (3) Selection of Gate Type

**Type of Control Gates:** As a type of control gate lake Tapodu Gate, fixed wheel gate, flap gate and rubber gate is generally considered to be applicable. In case of fixed wheel gate, the gate is further categorized into two types, namely girder and shell types, according to the ratio of height and span. Where the ratio of height and span is less than 1/10, the shell type is generally adopted. Since the Tapodu Gate has a height of 2 meters, the shell type should be selected for the span of 10 meters or more. In case of the span less than 10 meters, the girder type can be adopted also. The principal profile of each type is shown below.

| | | | |
|---|---|---|---|
|  |  |  |  |
| Girder type fixed wheel gate | Shell type fixed wheel gate | Flap gate | Rubber gate |

**Selection of Gate Type:** Where sedimentation heavily occurs like the Tapodu River, the flap gate is not suitable to adopt because the gate will not lie down flatly due to sedimentation. Thus, the fixed wheel gate and rubber gate was considered as the applicable type of gate. Taking account of the requirements for the Tapodu Gate, the functional characteristics are compared between the fixed wheel gate and rubber gate in Table C3.3.1.

Through the comparative study on functional characteristics and economical efficiency, the rubber gate was judged suitable for Tapodu Gate, having advantages over the fixed wheel gate mainly on the following aspects:

1) Light Weight: Bearing capacity of gate site is low with thick and soft sediment layers. The rubber gate is light in weight and requires lighter civil structure on such soft foundation. The construction work is easier and short in period.

2) Simple Operation and Maintenance: The rubber gate is capable to open (deflate) without power. Accordingly, the operation on flooding is reliable. Operation system consisting of blower with engine and piping has a simple structure to maintain. No electric power supply is required for control and protection system. Running cost of diesel engine, as the prime mover is economical compared with the diesel engine generator.

3) Enough Durability: Lifetime is enough long provided that the maintenance is suitably made for the rubber body where it is damaged.

From the design requirements of both regular and reverse flows, double clumping type of rubber gate is selected.

**(4) Design of Gate**

**Weir**

The weir functions as a settling layer for rubber gate anchoragement. Considering the required space for movement of rubber gate deflated during regular and reverse flow directions, a 19.0 m wide concrete slab was designed as main slab.

Geological investigation executed around the structure site showed that the soil layer was dominated by poor soil. Even below 40.0 m in depth, the foundation material was gravelly clay. The Standard Penetration Test shows that the N-value ranges from 6 to 12 until the depth of 22.0 m. Considering the above, lighter foundation was recommended by "hollow concrete pile" of diameter 45 cm piled at the intervals of 2.25 m x 2.25 m. Length of pile was assumed at 25.0 m based on the load data and geological conditions.

Structural analysis showed that the dead load of weir was the main load to be born by the piles. Thinner slab but enough thickness required for setting accessories of rubber gate (pipes, cables etc.) should be studied at the detailed design stage. The effective slab width of 19.0 m was determined also considering the soil bearing capacity.

The stability analysis was carried out for the following load cases:

| Load Case | Upstream | Downstream |
|---|---|---|
| Case 1 : Normal condition | Reservoir level | Normal level |
| Case 2 : Flood condition | Flood level | Normal level |
| Case 3 : Seismic condition | Reservoir level | Normal level |
| Case 4 : Construction condition | No water | No water |

The combination of load for each case was determined as follows:

| Item | Case 1<br>Normal | Case 2<br>Flood | Case 3<br>Seismic | Case 4<br>Construction |
|---|---|---|---|---|
| Dead load | O | O | O | O |
| Uniform load | O | O | O | - |
| Water pressure | O | O | O | - |
| Up-lift | O | O | O | - |
| Hydrostatic pressure | O | O | O | - |
| Earth pressure | - | O | O | - |
| Seismic | - | O | - | - |
| Dynamic Hydro presses. | - | O | - | - |
| Wind load | O | O | O | - |
| Machine load | O | O | O | - |
| Lifting load | O | O | - | - |
| Construction equipment | - | - | O | - |

**Apron**

Aprons were designed for both sides (upstream and downstream) of the weir. The apron shall have functions (1) to prevent piping and (2) to dissipate flow energy by forming hydraulic jump as stilling basin. Hydraulic checking was made under the following extreme conditions:

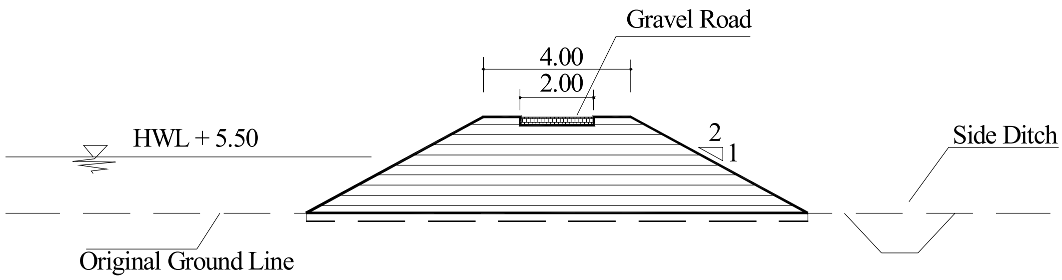
- Combination of design high water level of Bolango River (+ 6.10 m,MSL) and lowest water level of Lake Limboto (+4.00 m,MSL), and
- Combination of design high water level of Lake Limboto +5.50 and +2.50 on downstream portion.

According to the seepage analyses by “weight creep ratio method” of Lane, the apron length more than 18.0 m is safe enough to prevent piping. Setting of steel sheet pile of 3-m length at least is recommended for prevention of up-lift and structural stability.

Although the analysis of hydraulic jump mentioned above shows that the apron length is enough to reduce the velocity with the part of apron, placing of rip-rap layer is recommended for at least 30 m on Lake Limboto side and 20 m for Bolango River side to secure safety against scouring and degradation. Rip-rap shall be constructed using cobble stones with diameter ranging from 500 mm to 300 mm (minimum unit weight of 2.60 t/$m^3$) and set at the thickness of 0.80 m. General layout of the Tapodu Gate are shown in Figure C3.3.3.

### (5) Lake Dikes and Sluices

**Tapodu and Lake Dikes:** Dikes along the Tapodu River is required to protect the settlement and farmlands from the Bolango floodwater led by the improved Tapodu River. The lake dikes connected with the Tapodu dikes were also proposed for the effective use of the excess excavated material of the Tapodu River. North and south dikes were proposed. Length of the north dike is 3,150 m and the south dike is 2,130 m. The dikes were designed with crown elevation at +6.50 m,MSL taking 1-m freeboard. The dike crown is paved with gravel bedding (2.0 m width and 0.20 m thickness) as inspection and rural road. The standard dike section is shown below.




**Intake Sluice:** Considering existing water use, local drainage, and conservation of existing natural river environment (for such as eel), the right and left Tapodu channels will be kept run. For this purpose, an intake shall be installed at the each head of the existing channel across the dike. Two (2) slide gates with 2.00 m width x 1.50 m height were proposed to control the water discharge during normal condition. The sluices were joined with concrete culvert that functions as bridge over the sluice.

Section and profile of the intake sluice are shown in Figure C3.3.4.

**Drainage Sluice:** The existing Tapodu channels are led to the downstream of Tapodu Gate and drained into the new Tapodu River. At the outlet of each channel, drainage sluice was proposed to drain excess interior water and to check floodwater of the Bolango River. The sluice with opening size of 2.00 m width and 1.50 m height has steel gate. Bed elevation was proposed at +3.00 m,MSL, 1.0 m higher than bed elevation of the drainage channel. In the detail design stage, local drainage capacity should be confirmed considering the run-off from the hillsides. Retarding capacity also should be analyzed to prevent inundation in the areas surrounded by the dikes. Profile of the drainage sluice is shown in Figure C3.3.5.

### C3.3.4 Design of Appurtenant Facilities

Two (2) bridges (4.0 m width x 88.0 m length) need to be constructed across the Tapodu River around Kuba and Tapodu villages (Figure C3.3.6). Another bridge (7.0 m width x 80.0 m length) was also proposed for the existing main road in the stretch between Tapodu Gate and the Bolango River.

The result of the geological investigation executed at the proposed site shows that the dominant sub-surface layers are composed of poor soil showing gravelly clay mixed with organic matters and coastal sediment even at the depth of 15.0 m. The Standard Penetration Test shows that N-value ranges from 6 to 13 till the depth of about 20.0 m.

Considering the poor soil conditions of the foundation light-weight bridge should be chosen for bridge structures. Steel beam by span between 20 m to 25 m was proposed for super-structures. Reinforced concrete piers and abutments support the sub structure. To distribute the loads, hollow concrete pile with a size of 20-m depth and 40 cm diameter was proposed for pile foundation. To prevent the settlement, soil-mechanics investigation and study should be executed at the detailed design stage for all proposed bridges.

Sub-structure of the bridge should be safe against scouring. Ripraps of 20.0 m in length were designed for the bridge section to prevent local scouring and riverbed degradation. The riprap should be placed more than 0.80 m in thickness using cobblestone with diameter from 500 mm to 300 mm. To prevent loss of fine material due to suction, gravel layer should be placed underneath the cobble riprap. The bridge should cross the Tapodu River at right angle and be connected to the existing roads.

## C3.4 Design of Tamalate Floodway

### C3.4.1 Particular Site Conditions and Principles for Design

**Component Work:** Tamalate Floodway Project includes construction of (1) floodway, (2) diversion weir and (3) sluice gate as component works. The floodway is the main facility to convey floodwater of the Tamalate River to the Bone River. At the head of the floodway a diversion weir is installed to consolidate the bed or crest elevation at the divergence. The existing Tamalate River is closed for floodwater at the diverging point, but a sluice gate is installed to supply water during ordinary time for the water use in the downstream reaches and maintenance of the river environment. General location map of Tamalate Floodway is shown in Figure C3.4.1.

**Topography and Geology:** The proposed floodway traverses fertile paddy fields and natural levee of the Bone River, of which ground elevation ranges from +8.1 to +9.7 m,MSL. The materials to be excavated would be alluvial deposit composed of silt, sand and gravel. Recent deposits of sand and gravel are distributed around the inlet of Tamalate Floodway. No bedrock was confirmed through drilling works. However, outcrops of tuff breccia are observed around 200 m west of the proposed weir site.

### C3.4.2 Design of Floodway

**Basic Design Value:** Design discharge of the floodway is 120 $m^3/s$ based on 20-year flood, taking whole runoff of the Tamalate River at the diverging point (Figure C3.4.2). Floodway route was planned where the Tamalate River get closer to the Bone River and open lands for the floodway are available using the topographic maps prepared based on the aerial photos, so that the floodway length and house compensation could be minimized.

**Longitudinal Profile:** The Total floodway length subject to the works is about 2.7 km. Design riverbed was designed to be at +6.50 m,MSL at the head of the floodway and connected to the riverbed of the Bone River with design bed slope of 1/1,000 which is almost the same slope as the upper Tamalate River connected to the floodway (Figure C3.4.3). DHWL is +9.70 m,MSL at the head of the floodway (the Tamalate River) and +6.98 m,MSL at the lower end of the floodway (the Bone River)

**Standard Floodway Section:** Riverbed width was designed to be 14 m with bank slope of one (vertical) on two (horizontal). The water level below DHWL is 3.20 m. Bank protection works are designed for the whole floodway. The standard floodway section is shown in the Figure C3.4.1.

**Influence to Bone River:** With regard to the design discharge distribution inflow from the Tamalate Floodway does not influence the peak runoff of the Bone River, since the runoff of the Tamalate fast and the discharge is by far small comparing to that of the Bone River.

However, the inflow of the Tamalate Floodway may influence the Bone River before its improvement. In order to clarify the influence of the Tamalate Floodway, a preliminary study was made, assuming that the inflow of the Floodway ($Q_F$=120 $m^3/s$) happen to meet with 2-year flood discharge of the Bone River ($Q_{B2}$=290 $m^3/s$) as follows:

1) Without floodway inflow: $Q_B = Q_{B2} = 290$ $m^3/s$
2) With floodway inflow: $Q_B = Q_{B2} + Q_F = 410$ $m^3/s$

According to the flow calculations, water level of the Bone River get higher by 41 cm at maximum comparing the cases with and without floodway inflow as shown in Figure C3.4.4. However the river water level with floodway inflow still below the surrounding settlement areas. The inflow of the Tamalate Floodway will not cause substantial damages and no structural countermeasure is considered for the Bone River.

**Further Studies:** In relation with the construction of the Tamalate Floodway, following studies would be required further in the following stages:

1) Facility plan and compensation of the existing bridges and irrigation facilities affected by new floodway.
2) Study and investigation on ground water draw down, due to floodway excavation
3) Study on frequency of floodway flows and preparation of warning system to secure the safety of the resident people.
4) Hydraulic model test to examine the shape of diversion facility and sediment movement at the diverging point.

### C3.4.3 Design of Diversion Facilities

#### (1) Tamalate Diversion Weir

Layout plan and profiles of the diversion facilities for the Tamalate Floodway are shown in Figures C3.4.5. The diversion weir was designed with the crest elevation at +6.50 m,MSL, the width of 14.0 m and the side slope of one on two, so that the weir could pass the design discharge of 120 $m^3$/sec. The freeboard of 0.60 m was taken above the DHWL. Transition slope is required to connect original riverbed (+6.00 m,MSL) to floodway crest (+6.50 m,MSL).

The left dike of the floodway was designed as new rural road paved with gravel bedding up to the downstream bridge. This will enable for the villager to cross the floodway.

According to the result of geological investigation around the proposed site, foundation is good. Wet rubble masonry was use for the construction of Tamalate diversion weir.

#### (2) Sluice Gate

In order to supply water to the lower Tamalate River during ordinary time, a 2-m wide of sluice gate is proposed to install across the existing Tamalate River. The sluice gate is combined with concrete culvert that serves as a bridge to connect to the existing footpath.

### C3.4.4 Design of Appurtenant Facilities

#### (1) Bridges

Four (4) bridges of 4.0 m width x 28 m length were planned across the Tamalate floodway and one (1) bridge of 7.0 m width x 28 m length for the provincial road. A typical road bridge is shown in Figure C3.4.6.

#### (2) Waterway

Four (4) aqueducts were planned to keep the serves for irrigation water supply to the areas separated by the Tamalate floodway. The width of the aqueduct varies from 0.80

m (mainly for tertiary canals) to 2.0 m (Alale secondary canal).

Flume section was proposed for all the aqueducts with one or two piers to support the superstructures. Reinforced concrete is used for the main aqueducts. Wet rubble masonry and riprap works are also included. Detail investigation for the irrigation system and studies on alternative measures to cope with farmlands to be separated by the floodway should be made at the detail design stage. A typical waterway bridge is shown in Figure C3.4.7.

## C3.5 Design of Sediment Trap Works

### (1) Sedimentation Problems of Lake Limboto

Sedimentation volume of Lake Limboto was estimated within the range of 1 to 2 MCM annually, according to the comparison of sounding survey results of the lake conducted in 1996 by CIDA Team and 2001 by the JICA Study Team. This amount is quite large. Supposing the land reclamation using the sediment materials, an area of 1 to 2 $km^2$ of land could be reclaimed annually with one-meter thickness.

It is quite sure that the sediment comes from its own basin transported by river flows. However, the sources of sediment scatter over basin, namely in the watershed areas as original sources and in the plain areas secondary sources. According to the analysis using satellite images taken in around 1990 and 2000, any specific sites of severe sediment yield were not identified.

### (2) Measures to Cope With Lake Sedimentation

The following measures could be conceived in general to cope with the sedimentation problems:

**<u>Measures to Reduce Sediment in Lake</u>**

1) Dredging and excavation: The dredged material could be used for land reclamation in the low-lying area around the lake. Some portion of the lake sediment might be able to use as construction materials. However, the effect would be limited since the dredging volume would be small comparing to the inflow sediment.

2) Flushing by water flow: Flushing of sediment by the proposed Tapodu River can be expected to some extent, though the effects are limited to the area near the outlet.

**<u>Measures to Reduce Sediment from Plain Area</u>**

1) Prevention of side erosion: Riverbank erosion of the river channels is one of the important sources of sediment transported to the lake. River training and bank protection works are effective to stabilize the river course and to reduce the bank erosion.
2) Reduction of sediment flowing into river channels: Vegetation cover and grass-belts planted along the riverbanks are expected to prevent the sediment flowing into the channel. These also resist against the side erosion. The various measures traditionally taken to cope with sheet erosion are also effective to this purpose.
3) Sediment retention scheme: This scheme aims to lead floodwater intentionally to the low-lying areas adjacent to the river to retain sediment. The floodwater may bring about fertile soil and naturally reclaim the land; instead, the sediment to the lake is expected to reduce.

**<u>Measures to Reduce Sediment from Watershed</u>**

Following measures were discussed in the sub-section presenting "Watershed Management":

1) Construction of erosion control facilities
2) Afforestation and land-use control
3) Dissemination activities

Although descriptions on these measures are not repeated here, the watershed management is an important and inevitable measures to cope with the sedimentation issues of the lake.

### (3) Sediment Trap Works in Lake Limboto

As was discussed in the above paragraphs, various measures to cope with the sediment issues are conceivable, but no definitive solution is found. In order to initiate the measures to the lake problem, sediment trap works were proposed as follows:

1) Sediment trap works in Lake Limboto aims to trap the sediment transported by the Biyonga, Alo-Pohu and other rivers flowing into the specified sedimentation area, for the purpose of sediment research in the lake and project development for use of the trapped sediment.

2) Sediment trap works consist of mainly two works, sediment trap works and realignment of the Biyonga River and the Alo-Pohu River at their lowest ends. General layout of the sediment trap works is shown in Figure C3.5.1.

3) The sediment trap is a bamboo-net fence installed in the Lake with crest elevation at +4.00 m,MSL. The sediment trap is placed from the Biyonga river mouth to the Alo-Pohu river mouth confining northwestern part of the lake. The confined area is the specified area for sedimentation.

4) The Biyonga and the Alo-Pohu rivers are realigned so as to lead the sediment inside the confined area. Other two rivers, the Meluopo and Marisa rivers also empty into the area.

5) Research Works: By measuring the sedimentation conditions and testing the sediment materials, (1) sedimentation volume and (2) the physical characteristics and geo-technical features of the sediment will be studied, seeking for the possible usage of the sediment materials.

6) Land reclamation project by use of lake sediment will be exercised as a test work, probably starting from reclamation in the near-by low-lying lands. Test-work by the third sector agency to be established by the private corporations and government agency can also be considered. The area to be reclaimed should be selected so as not to reduce the flood storage capacity of Lake Limboto.

7) Further Study: Compensation issues may arise for the agriculture and fishery in and around the sediment trap area. Further study is necessary on this matter in the following stage. It is also recommended that in carrying out the research work and test work, the scale of the work should be gradually

increased observing the conditions of the sedimentation and the lake water movements.

### C3.6 Quantities of Works

Quantities of works estimated based on the results of facility design are shown in the Table C3.6.1. Breakdown of the quantities for the Bone-Bolango-Tapodu River Improvement are also shown in Table C3.6.2.

### C3.7 Land Acquisition and Compensation

General procedures for land acquisition are shown in Table C3.7.1 for reference. Land acquisition and compensation required for the project implementation cover following objects in general:

1) Land Acquisition: (1) Agriculture land, (2) residential land and (3) bush land. The land type (1) and (2) were assumed that owners have certificates and the compensation should be considered. The land type (3) was assumed that the land belongs to government property or no certificate owned by peoples.

2) Compensation for Building and Structures: (1) Private property owned by local people/ individual such as houses, fence etc; and (2) government property such as bridges, river structures, public roads and public offices.

3) Compensation for Plant: Coconut tree, paddy, and other neighboring plantations.

In this Study, houses to be removed (urban and rural) and lands to be acquired (resident and agriculture) were estimated, using the topographic maps prepared based on the aerial photos taken in the year 2001. The quantities of these houses and lands are summarized below by component sub-projects.

| Sub-project | Houses (nos) | | Lands ('000 $m^2$) | |
|---|---|---|---|---|
| | Urban | Rural | Resident | Agriculture |
| 1) BBT-R.I. | 28 | 50 | 59 | 545 |
| ① Lower Bolango R.I. | - | - | - | - |
| ② Bolango R.I.: Stretch-I | - | - | - | - |
| ③ Tenda COC | 11 | - | 5.5 | - |
| ④ Bolango R.I.: Stretch-$II_R$ | 12 | - | 13 | 10 |
| ⑤ Bolango R.I.: Stretch-$II_L$ | - | - | - | - |
| ⑥ Bolango R.I.: Stretch-III | 5 | - | 5.5 | 5 |
| ⑦ Tapodu R.I./Gate | - | 50 | 35 | 530 |
| 2) Tamalate Floodway | - | 40 | 27 | 197 |
| 3) Sediment Trap Works | - | 10 | 1 | 70 |
| Total | 28 | 100 | 87 | 812 |

R.I: River improvement

Sub-projects which include important resettlement problems are Tenda COC, Bolango R.I/Stretch- $II_L$, Tapodu R.I/Gate and Tamalate Floodway. As to the Tenda COC and Bolango R.I/Stretch- $II_L$, resettlement sites could be found at the abandoned channel areas. Regarding the Tapodu R.I/Gate, the land reclaimed with the excess excavated soil in the area protected by dike would be available for resettlement. For the Tamalate Floodway, resettlement sites were not yet specified, it is preferable to look for the sites coupled with excess soil disposal sites.

The land acquisition and compensation issue often become the cause of social problems and delay or suspension of the project implementation. Careful consideration should be given on these mattes and proper procedures should be taken with enough time to communicate with relevant organizations and individuals.

## Table C3.3.1 COMPARISON OF TYPES FOR TAPODU GATE

| | Fixed Wheel Gate | Rubber Gate |
|---|---|---|
| Hydraulic characteristic | The gate is adopted for both flow conditions of regular and reverse.<br>The gate discharges in both way of overflow and underflow.<br>Except the crack open discharge, the gate can control the flow in full range of gate opening. | The gate is adopted for both flow conditions of regular and reverse.<br>The gate discharges in the way of overflow without discharge control.<br>The gate cannot control discharge.<br>In case of regular flow, inhibition of flow is less. In case of reverse flow, some inhibition may occur. |
| Operation | Generally electric motor hoist is used. Without powered drive, the gate cannot be opened.<br>Electric power supply is essential.<br>In case of long span gate, control system is complicated. | The gate can be opened, namely deflated without powered drive, by hand.<br>The speed of deflation is depending on the condition of flow velocity.<br>The gate closure, namely inflation, will take around 30 minutes to one hour. |
| Maintenance | The protection coating of gate leaf is repaired at an interval of several years.<br>The electric parts and controls are required to inspect and maintain frequently. | The protection against corrosion is unnecessary.<br>For the operation system is simple, inspection is required for a few points. |
| Safety | Since the gate is the steel structure, it is strong as a structure against impact shock of flowing trashes.<br>In case of power failure or malfunction of hoist, the gate cannot be controlled. | The gate can be deflated (opened) without power. During flooding, operation of opening is reliable.<br>As the gate body is made from the rubber, it is weak against the flowing material, such as woods, gravel, etc. |
| Durability | Although the structural parts are durable enough for thirty years and more, lifetime of mechanical and electrical parts is shorter. | The strength of rubber as the material will be kept for thirty years, but abrasion and damage of rubber body is inevitable. |

## Table C3.6.1 QUANTITIES OF WORKS FOR PRIORITY PROJECTS

| No. | WORK ITEM | UNIT | BBT River Improvement | Tamalate Floodway | Sediment Trap in L. Limboto | Total |
|---|---|---|---|---|---|---|
| 1 | CHANNEL WORKS | | | | | |
| 1.1 | Earth Works | | | | | |
| | Excavation | cu.m | 623,000 | 210,000 | 49,000 | 882,000 |
| | Embankment | cu.m | 161,000 | 29,000 | 0 | 190,000 |
| | Sodding | sq.m | 95,000 | 9,000 | 0 | 104,000 |
| 1.2 | Stone Works | | | | | |
| | Bank Protection (Type-1) | m | 1,900 | 0 | 0 | 1,900 |
| | Wet Rubble Masonry | cu.m | 14,000 | 7,600 | 0 | 21,600 |
| | Riprap | cu.m | | | | |
| | Gravel Bedding | cu.m | 2,000 | 2,000 | 0 | 4,000 |
| | Gabion Mattress | cu.m | 0 | 2,500 | 0 | 2,500 |
| 1.3 | Concrete Works | | | | | |
| | Bank Protection (Type-2) | m | 2,000 | 0 | 0 | 2,000 |
| | Concrete Dike (Type-3) | sq.m | 1,800 | 0 | 0 | 1,800 |
| | Concrete | cu.m | 4,700 | 0 | 0 | 4,700 |
| | Reinforcement Bar | ton | 100 | 0 | 0 | 100 |
| 1.4 | Sluice, Drainage Sluice Works | | | | | |
| | U/s. Sluice. | L.S | 2 | 0 | 0 | 2 |
| | Drainage sluice str. (2gates x 2m x 1.5m) | L.S | 4 | 0 | 0 | 4 |
| | Sluice Gate (2m x 1m) | Pc. | 0 | 1 | 0 | 1 |
| | Drainage sluice str. (1m x 1m) | L.S | 0 | 4 | 0 | 4 |
| 2 | WEIR WORKS | | | | | |
| 2.1 | Earth Works | | | | | |
| | Excavation | cu.m | 51,000 | 4,000 | 0 | 55,000 |
| | Embankment | cu.m | 6,000 | 4,000 | 0 | 10,000 |
| 2.2 | Stone Works | | | | | |
| | Wet Rubble Masonry | cu.m | 0 | 1,700 | 0 | 1,700 |
| | Riprap | cu.m | 4,500 | 20 | 0 | 4,520 |
| | Gabion Mattress | cu.m | 0 | 100 | 0 | 100 |
| 2.3 | Concrete Works | | | | | |
| | Concrete | cu.m | 8,000 | 100 | 0 | 8,100 |
| | Reinforcement Bar | ton | 540 | 10 | 0 | 550 |
| 2.4 | Pile Works | | | | | |
| | PC Concrete Pipe Pile ( $\phi$ =450) | m | 7,000 | 0 | 0 | 7,000 |
| | Steel Sheet Pile | sq.m | 1,100 | 0 | 0 | 1,100 |
| 2.5 | Rubber Gate | | | | | |
| | Rubber Gate Sets | L.S | 1 | 0 | 0 | 1 |
| 3 | SEDIMENT TRAP WORKS | | | | | |
| 3.1 | Sediment Trap Works | | | | | |
| | Bamboo mess Type 1 (h=1.0 m) | m | 0 | 0 | 1,300 | 1,300 |
| | Bamboo mess Type 2 (h=2.0 m) | m | 0 | 0 | 1,300 | 1,300 |
| 4 | APPURTENANT WORKS | | | | | |
| 4.1 | Bridge Works | | | | | |
| | Br. Type-1(W=4.00m) | m | 343 | 110 | 0 | 453 |
| | Br. Type-1(W=7.00m) | m | 100 | 30 | 0 | 130 |
| | Heightening of Bridge | L.S | 2 | 0 | 0 | 2 |
| 4.2 | Waterway | L.S | 0 | 1 | 0 | 1 |

## Table C3.6.2 BROKEN-DOWN WORK QUANTITIES FOR BBT RIVER IMPROVEMENT(1/2)

| No. | WORK ITEM | UNIT | ①Lower Bone River | ②Bolango R. Stretch-I | ③Tenda COC | ④Bolango R. Stretch-$II_R$ |
|---|---|---|---|---|---|---|
| 1 | CHANNEL WORKS | | | | | |
| 1.1 | Earth Works | | | | | |
| | Excavation | cu.m | 0 | 0 | 6,000 | 61,000 |
| | Embankment | cu.m | 0 | 0 | 3,000 | 1,000 |
| | Sodding | sq.m | 0 | 0 | 0 | 0 |
| 1.2 | Stone Works | | | | | |
| | Bank Protection (Type-1) | m | 600 | 0 | 0 | 1,300 |
| | Wet Rubble Masonry | cu.m | 0 | 0 | 0 | 0 |
| | Riprap | cu.m | | | | |
| | Gravel Bedding | cu.m | 0 | 0 | 0 | 0 |
| | Gabion Mattress | cu.m | 0 | 0 | 0 | 0 |
| 1.3 | Concrete Works | | | | | |
| | Bank Protection (Type-2) | m | 0 | 0 | 300 | 1,700 |
| | Concrete Dike (Type-3) | sq.m | 0 | 1,000 | 0 | 800 |
| | Concrete | cu.m | 0 | 0 | 0 | 1,300 |
| | Reinforcement Bar | ton | 0 | 0 | 0 | 0 |
| 1.4 | Sluice, Drainage Sluice Works | | | | | |
| | U/s. Sluice. | L.S | 0 | 0 | 0 | 0 |
| | Drainage sluice str. (2gates x 2m x 1.5m) | L.S | 0 | 0 | 0 | 1 |
| | Sluice Gate (2m x 1m) | Pc. | 0 | 0 | 0 | 0 |
| | Drainage sluice str. (1m x 1m) | L.S | 0 | 0 | 0 | 0 |
| 2 | WEIR WORKS | | | | | |
| 2.1 | Earth Works | | | | | |
| | Excavation | cu.m | 0 | 0 | 0 | 0 |
| | Embankment | cu.m | 0 | 0 | 0 | 0 |
| 2.2 | Stone Works | | | | | |
| | Wet Rubble Masonry | cu.m | 0 | 0 | 0 | 0 |
| | Riprap | cu.m | 0 | 0 | 0 | 0 |
| | Gabion Mattress | cu.m | 0 | 0 | 0 | 0 |
| 2.3 | Concrete Works | | | | | |
| | Concrete | cu.m | 0 | 0 | 0 | 0 |
| | Reinforcement Bar | ton | 0 | 0 | 0 | 0 |
| 2.4 | Pile Works | | | | | |
| | PC Concrete Pipe Pile ( $\phi$ =450) | m | 0 | 0 | 0 | 0 |
| | Steel Sheet Pile | sq.m | 0 | 0 | 0 | 0 |
| 2.5 | Rubber Gate | | | | | |
| | Rubber Gate Sets | L.S | 0 | 0 | 0 | 0 |
| 3 | SEDIMENT TRAP WORKS | | | | | |
| 3.1 | Sediment Trap Works | | | | | |
| | Bamboo mess Type 1 (h=1.0 m) | m | 0 | 0 | 0 | 0 |
| | Bamboo mess Type 2 (h=2.0 m) | m | 0 | 0 | 0 | 0 |
| 4 | APPURTENANT WORKS | | | | | |
| 4.1 | Bridge Works | | | | | |
| | Br. Type-1(W=4.00m) | m | 0 | 0 | 24 | 64 |
| | Br. Type-1(W=7.00m) | m | 0 | 0 | 0 | 0 |
| | Heightening of Bridge | L.S | 0 | 1 | 0 | 0 |
| 4.2 | Waterway | L.S | 0 | 0 | 0 | 0 |

# Table C3.6.2 BROKEN-DOWN WORK QUANTITIES FOR BBT RIVER IMPROVEMENT(2/2)

| No. | WORK ITEM | UNIT | ⑤Bolango R. Stretch-$II_L$ | ⑥Bolango R. Stretch-III | ⑦Tapodu R. with Gate | Total |
|---|---|---|---|---|---|---|
| 1 | CHANNEL WORKS | | | | | |
| 1.1 | Earth Works | | | | | |
| | Excavation | cu.m | 0 | 20,000 | 536,000 | 623,000 |
| | Embankment | cu.m | 0 | 10,000 | 147,000 | 161,000 |
| | Sodding | sq.m | 0 | 0 | 95,000 | 95,000 |
| 1.2 | Stone Works | | | | | |
| | Bank Protection (Type-1) | m | 0 | 0 | 0 | 1,900 |
| | Wet Rubble Masonry | cu.m | 0 | 0 | 14,000 | 14,000 |
| | Riprap | cu.m | | | | |
| | Gravel Bedding | cu.m | 0 | 0 | 2,000 | 2,000 |
| | Gabion Mattress | cu.m | 0 | 0 | 0 | 0 |
| 1.3 | Concrete Works | | | | | |
| | Bank Protection (Type-2) | m | 0 | 0 | 0 | 2,000 |
| | Concrete Dike (Type-3) | sq.m | 0 | 0 | 0 | 1,800 |
| | Concrete | cu.m | 1,800 | 0 | 1,600 | 4,700 |
| | Reinforcement Bar | ton | 0 | 0 | 100 | 100 |
| 1.4 | Sluice, Drainage Sluice Works | | | | | |
| | U/s. Sluice. | L.S | 0 | 0 | 2 | 2 |
| | Drainage sluice str. (2gates x 2m x 1.5m) | L.S | 1 | 0 | 2 | 4 |
| | Sluice Gate (2m x 1m) | Pc. | 0 | 0 | 0 | 0 |
| | Drainage sluice str. (1m x 1m) | L.S | 0 | 0 | 0 | 0 |
| 2 | WEIR WORKS | | | | | |
| 2.1 | Earth Works | | | | | |
| | Excavation | cu.m | 0 | 0 | 51,000 | 51,000 |
| | Embankment | cu.m | 0 | 0 | 6,000 | 6,000 |
| 2.2 | Stone Works | | | | | |
| | Wet Rubble Masonry | cu.m | 0 | 0 | 0 | 0 |
| | Riprap | cu.m | 0 | 0 | 4,500 | 4,500 |
| | Gabion Mattress | cu.m | 0 | 0 | 0 | 0 |
| 2.3 | Concrete Works | | | | | |
| | Concrete | cu.m | 0 | 0 | 8,000 | 8,000 |
| | Reinforcement Bar | ton | 0 | 0 | 540 | 540 |
| 2.4 | Pile Works | | | | | |
| | PC Concrete Pipe Pile ( $\phi$ =450) | m | 0 | 0 | 7,000 | 7,000 |
| | Steel Sheet Pile | sq.m | 0 | 0 | 1,100 | 1,100 |
| 2.5 | Rubber Gate | | | | | |
| | Rubber Gate Sets | L.S | 0 | 0 | 1 | 1 |
| 3 | SEDIMENT TRAP WORKS | | | | | |
| 3.1 | Sediment Trap Works | | | | | |
| | Bamboo mess Type 1 (h=1.0 m) | m | 0 | 0 | 0 | 0 |
| | Bamboo mess Type 2 (h=2.0 m) | m | 0 | 0 | 0 | 0 |
| 4 | APPURTENANT WORKS | | | | | |
| 4.1 | Bridge Works | | | | | |
| | Br. Type-1(W=4.00m) | m | 25 | 0 | 230 | 343 |
| | Br. Type-1(W=7.00m) | m | 0 | 0 | 100 | 100 |
| | Heightening of Bridge | L.S | 0 | 1 | 0 | 2 |
| 4.2 | Waterway | L.S | 0 | 0 | 0 | 0 |

## Table C3.7.1 PROCEDURE FOR LAND ACQUISITION AND COMPENSATION

| No. | Steps | Main Parties Concerned |
|---|---|---|
| **1** | **Identification of the Location** | |
| | < Request for identification of land | Governor |
| | < Coordination Meeting for investigation (compared with RTRW) | Bupati/ Walikota |
| | < Approval of acquisition of requested lands | BPN |
| | < Request for land acquisition | Bappeda Agency |
| **2** | **Land Acquisition Request** | |
| | < Preparatory work | Committee |
| | < Information dissemination/sharing ("sosializasi") | Agency |
| | < Determination of area boundary | Land owners |
| | < Inventory preparation | Local residents |
| | < Publication of inventory results | |
| **3** | **Consultation** | |
| | < Negociation on the compensation | Committee |
| | < Notification of results of the consultation | Land owners |
| **4** | **Objections to the Committee's Decision** | |
| | < Submission of objections to the Governor | Committee |
| | < Examination by "Provincial" Committee | Land owners |
| | < Governor's decision | Agency |
| **5** | **Payment of Compensation (Implement Conpensation Measures)** | |
| | < Preparation of nominative list of beneficiaries | Committee |
| | < Payment /others | Land owners |
| **6** | **Pronouncementof the Release of Land Rights and Transfer of the Land** | |
| | < Pronouncement of release of land rights / transfer of use right | Committee |
| | < Proceed cancellation of land rights | Land owners |
| **7** | **Cancellation of land rights** | |
| | < Formation of Estimating Committee by national level | Estimating Committee |
| | < Cancellation of land rights | |
| | < Request for a new land right | |
| **8** | **Issue of Land Certificate** | |

***Notes :***

1). **Committee:** Land Acquisition Committee / Panitia Pengadaan Tanah (members are from various agencies including Bappeda and Kimpraswil, and heads of local governmental bodies such as Kabupaten, Kota, Kelurahan/Desa and Kecamatan)
   * Committee charges 4 % of total compensation amount (of which 1% as a consultation fee, 1% administration fee and 2 % operation fee)

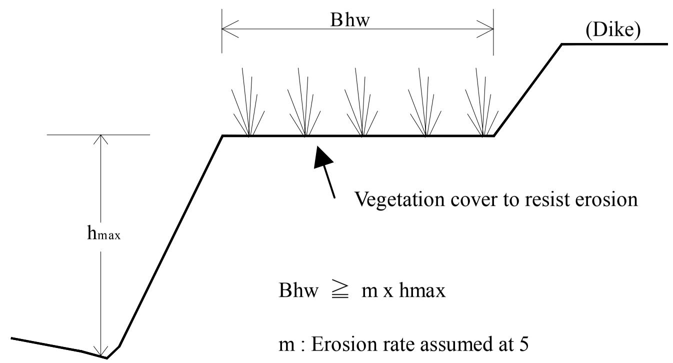
2). **BPN:** Badan Pertanahan Nasional / National Land Agency
   * Lands in Kabupaten are treated by Kabupaten BPN, those in Kota by Kotamadya and lands extending in two asministrative territories are in charge of the provincial one.

3). **Agency:** Project executing government agency
   * In case of a private investment, this can be read as a private company.

4). **RTRW:** Regional Spatial Plan

## Minimum Width of High Water Channel

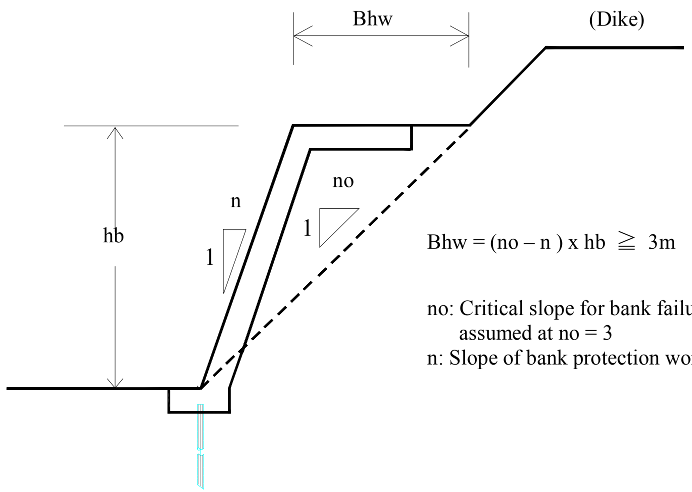
1) In Case of Bank without Protection Works :




Bhw ≧ m x hmax

m : Erosion rate assumed at 5

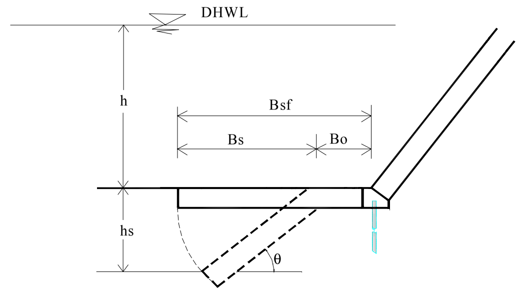
2) In Case of Bank with Protection Works :




Bhw = (no – n ) x hb ≧ 3m

no: Critical slope for bank failure
assumed at no = 3
n: Slope of bank protection works

## Length of Sure-Footing

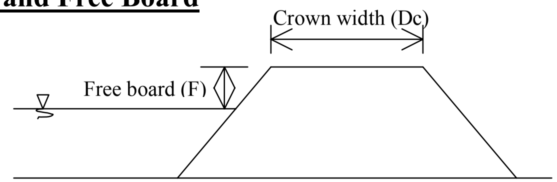



Bsf = Bo + hs/sinθ = Bo + 1.6 h

Where :

| | |
|---|---|
| Bsf | : Length of sure-footing |
| h | : water depth |
| hs | : Scouring depth, assumed at hs = 0.8 h |
| θ | : Assumed as θ = 30° |
| Bo | : Minimum fixed length, advisable Bo ≧ 2m |

## Dike Section and Free Board




Crown Width of Dike

| Q ($m^3/s$) | Dc (m) |
|---|---|
| < 500 | 3 |
| < 2000 | 4 |

Free Board

| Q ($m^3/s$) | Dc (m) |
|---|---|
| < 200 | 0.6 |
| < 500 | 0.8 |
| < 2000 | 1.0 |

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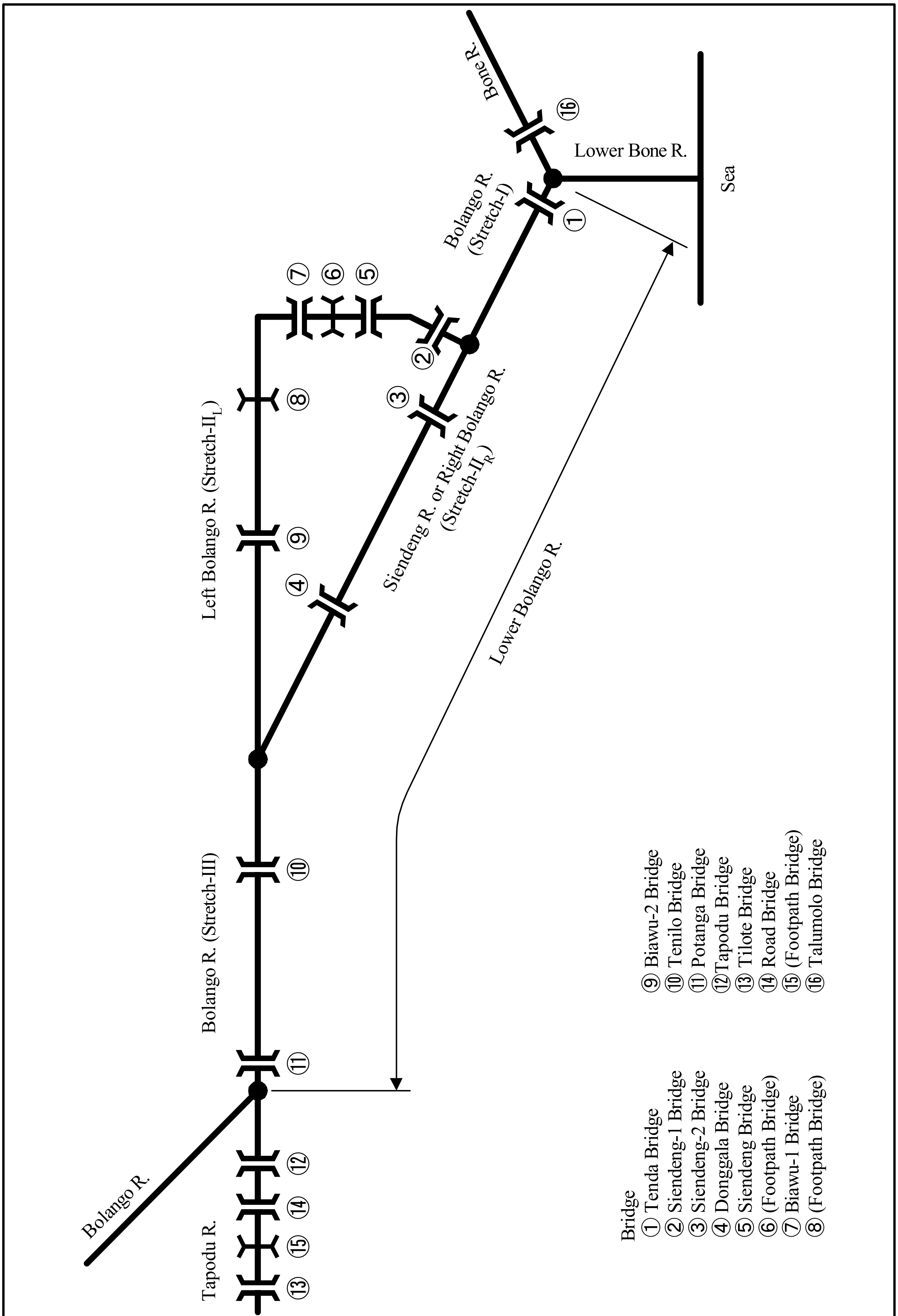
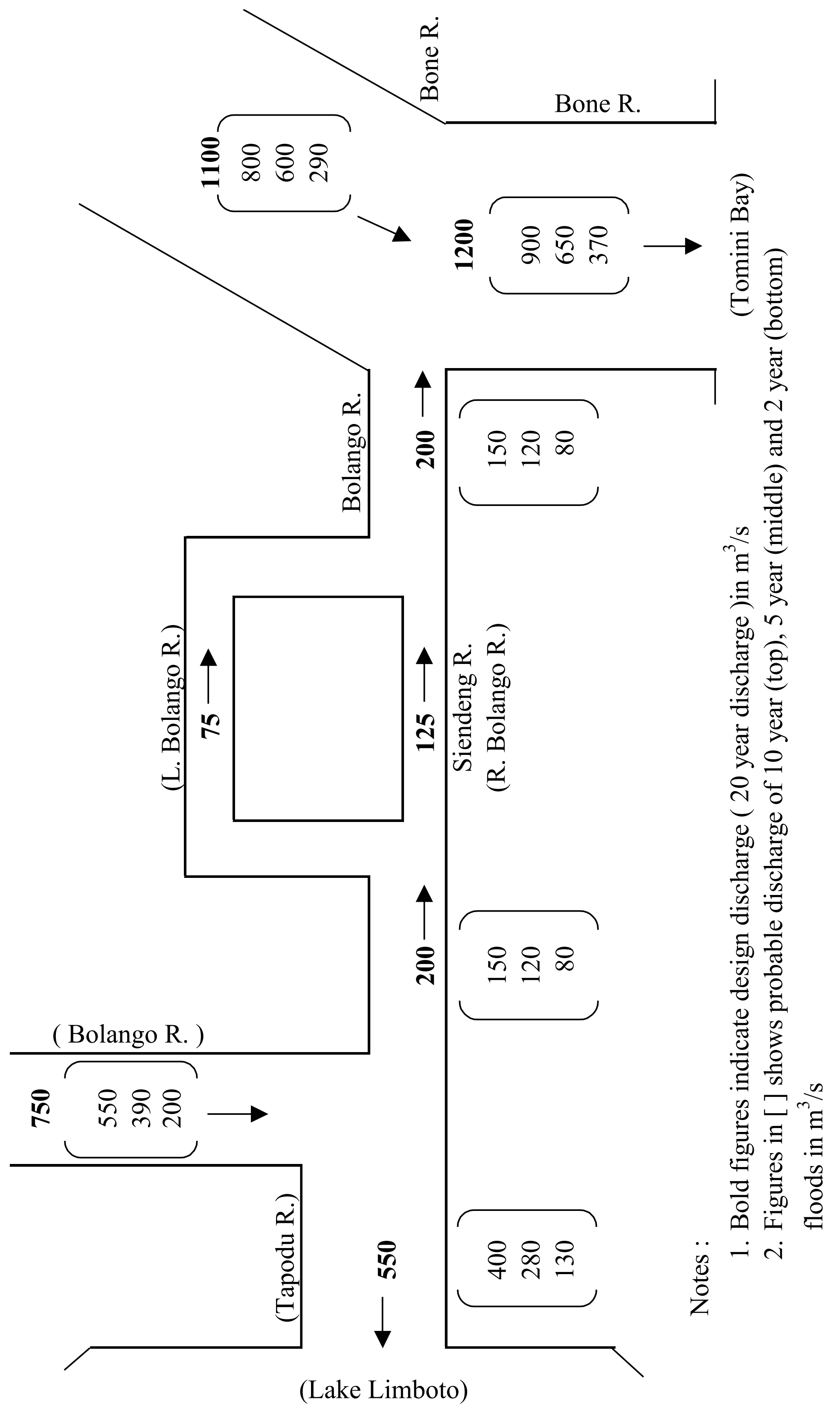
**Figure C3.1.1**

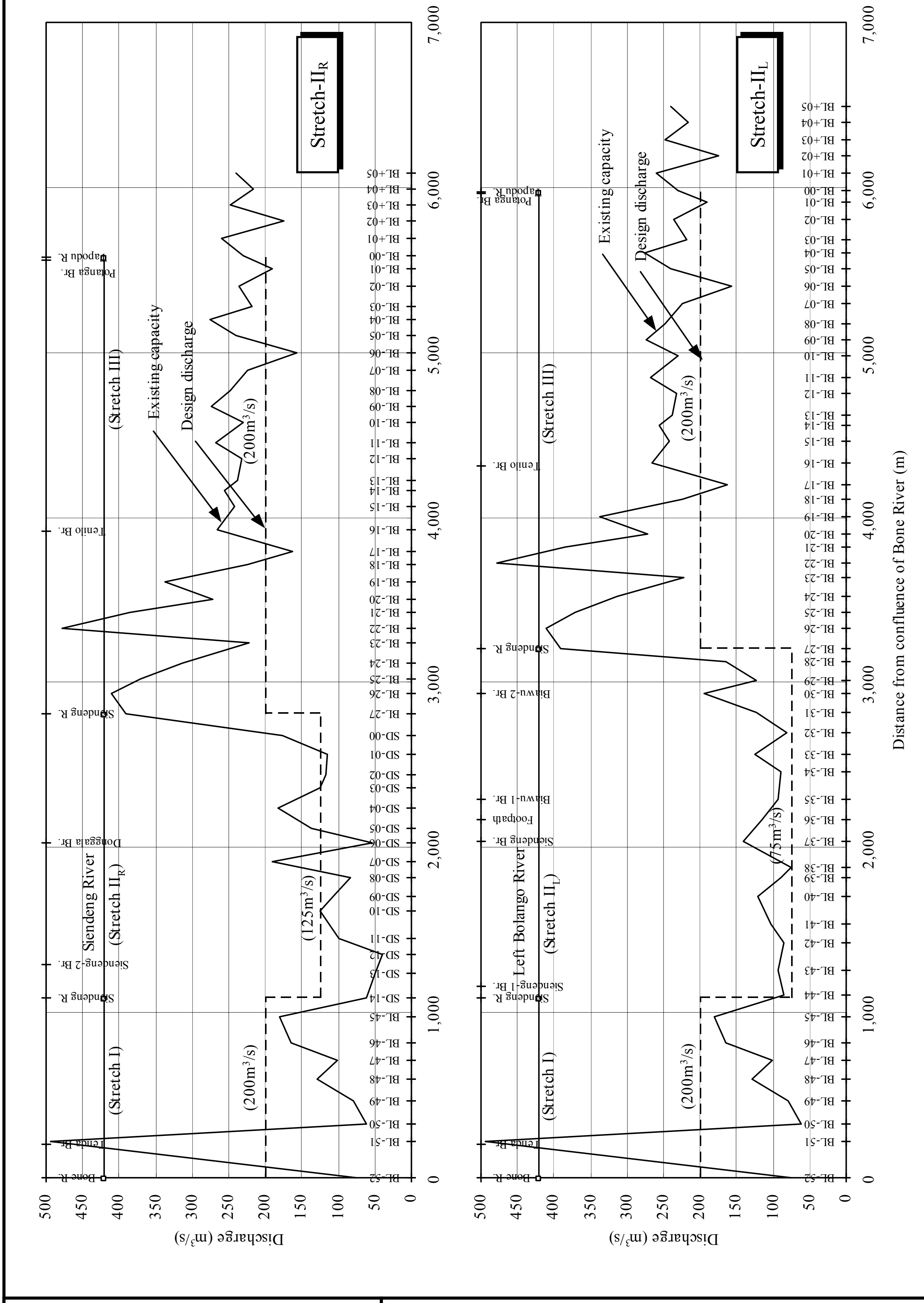
**STANDARDS FOR CHANNEL DESIGN**



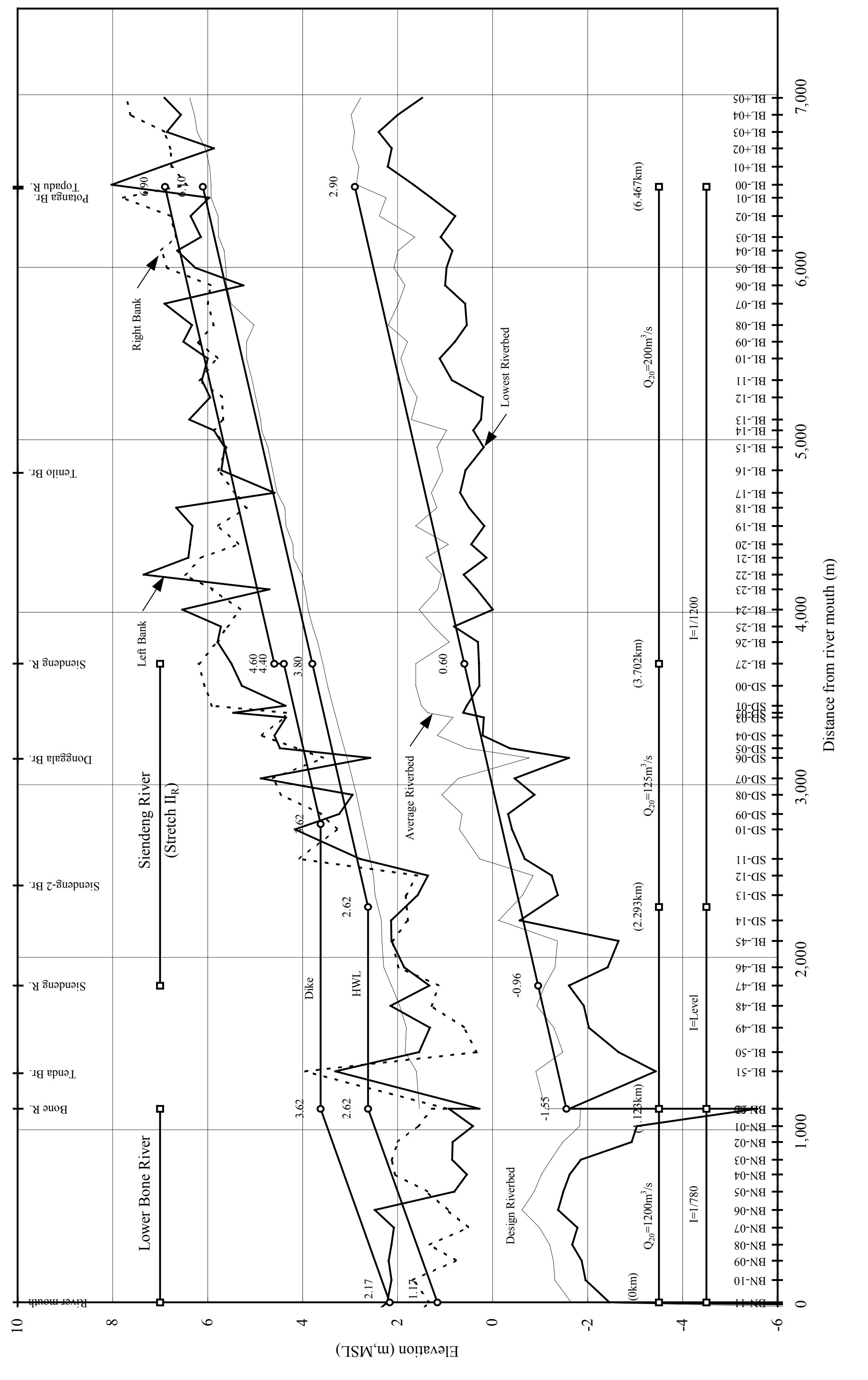

| | |
|---|---|
| ***The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia*** | **Figure C3.2.1** |
| ***Japan International Cooperation Agency*** | **NAMES OF RIVER STRETCHES AND BRIDGES** |



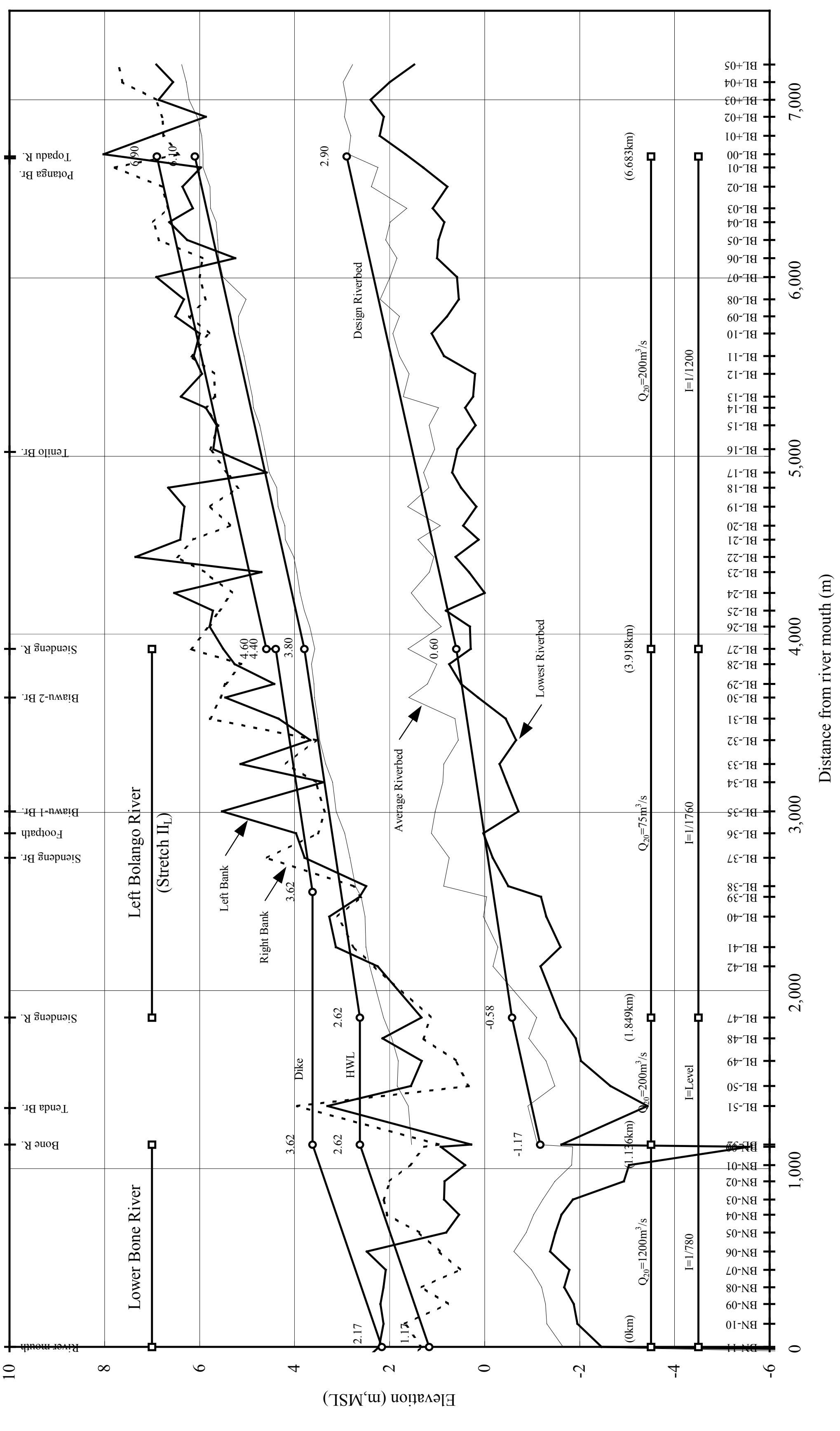

| *The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia* | **Figure C3.2.2** |
|---|---|
| *Japan International Cooperation Agency* | **DESIGN DISCHARGE DISTRIBUTION : BONE-BOLANGO-TAPODU RIVER** |




| | |
|---|---|
| ***The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia*** <br> ***Japan International Cooperation Agency*** | **Figure C3.2.3** <br> **CARRYING CAPACITY OF BOLANGO RIVER** |




| *The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia* | **Figure C3.2.4** |
|---|---|
| ***Japan International Cooperation Agency*** | **DESIGN LONGITUDINAL PROFILE OF BOLANGO RIVER (STRETCH $II_R$ : 1/2)** |

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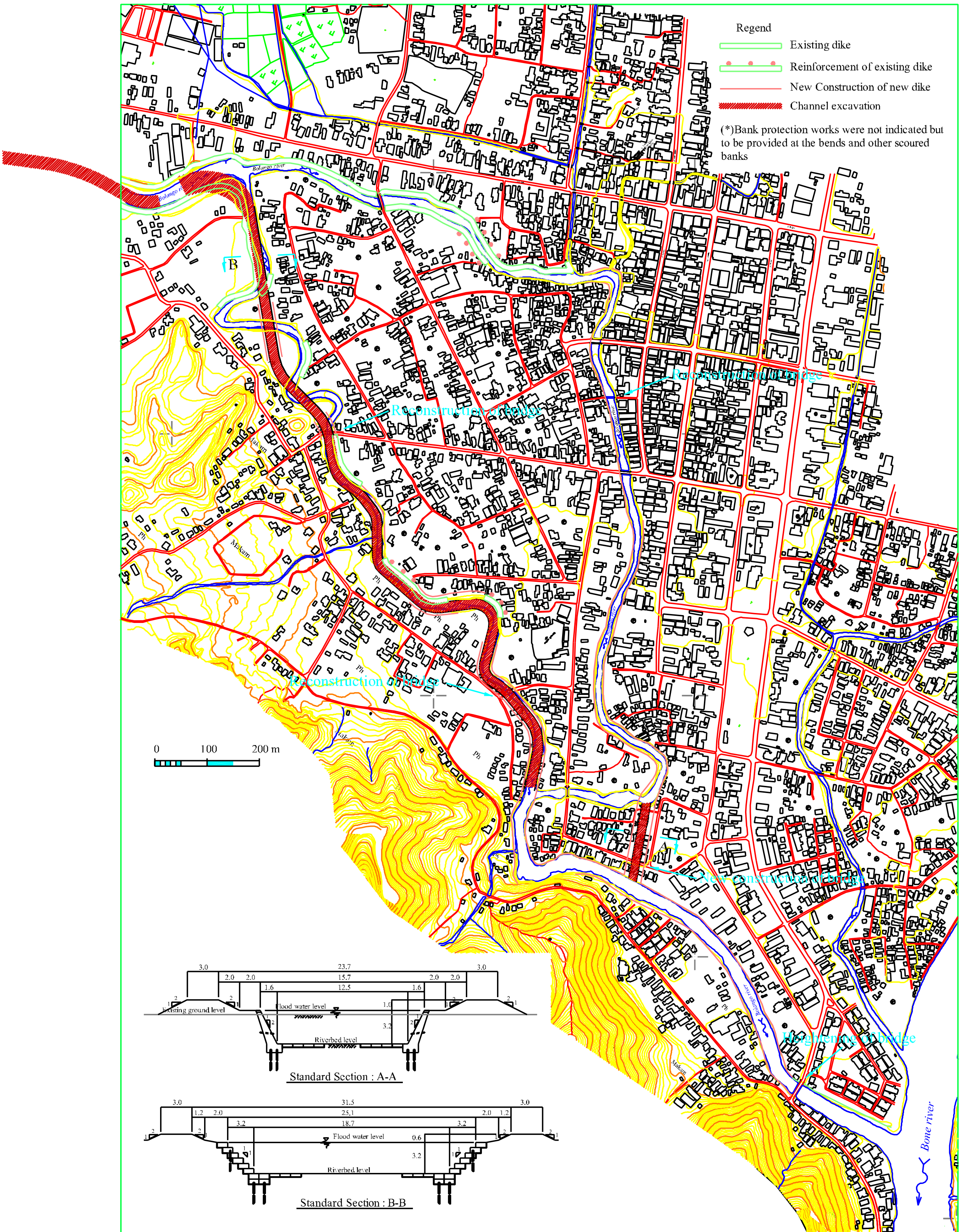
*Japan International Cooperation Agency*

**Figure C3.2.4**
**DESIGN LONGITUDINAL PROFILE OF BOLANGO RIVER (STRETCH II$_L$ : 2/2)**




| *The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia* | **Figure C3.2.5** |
|---|---|
| *Japan International Cooperation Agency* | **DESIGN PLAIN OF BOLANGO RIVER (1/2)** |