5.1.2 Urban Drainage

The objective area of urban drainage is the run-off basin which drains to the Bantyiketu river in the reaches from the Finfine bridge up to the Filwiha bridge corresponding to the confluence of the Kechene and Kurtume rivers. The area is shown in Figure 5.9. Based on the field reconnaissance, the outline network of the existing drainage system in the objective area is estimated from the locations of street inlets along the main streets found in the field, and is shown in Figure 5.10.

The following are the description on the present conditions of the existing drainage in the objective area.

(1) Northern Basin

The northern basin of the objective area is the area in the north of Saba Square on the Churchil Avenue. The area is a strip in the direction of north to south. The northern boundary of the area is around the Saint-Georges Cathedral in front of the Municipality of Addis Ababa.

The rainfall in this area is collected into an underground drainage pipe through street inlets with curb opening along the avenue and drained to the Kurtume river before joining the Bantyiketu river. The street inlets along the Churchil Avenue are limited in numbers and their sizes are not sufficient. The inlets are clogged with various garbage and soil at places. As a result, greater part of the run-off in the area flows on the Churchil Avenue and is collected into the low-lying area around the Addis Ababa Stadium and Abiot Square. And due to the insufficient conditions of the drainage facilities to the Bantyiketu river from the area, the collected water becomes stagnant in the area and blocks the traffic in the center of Addis Ababa often in rainy seasons.

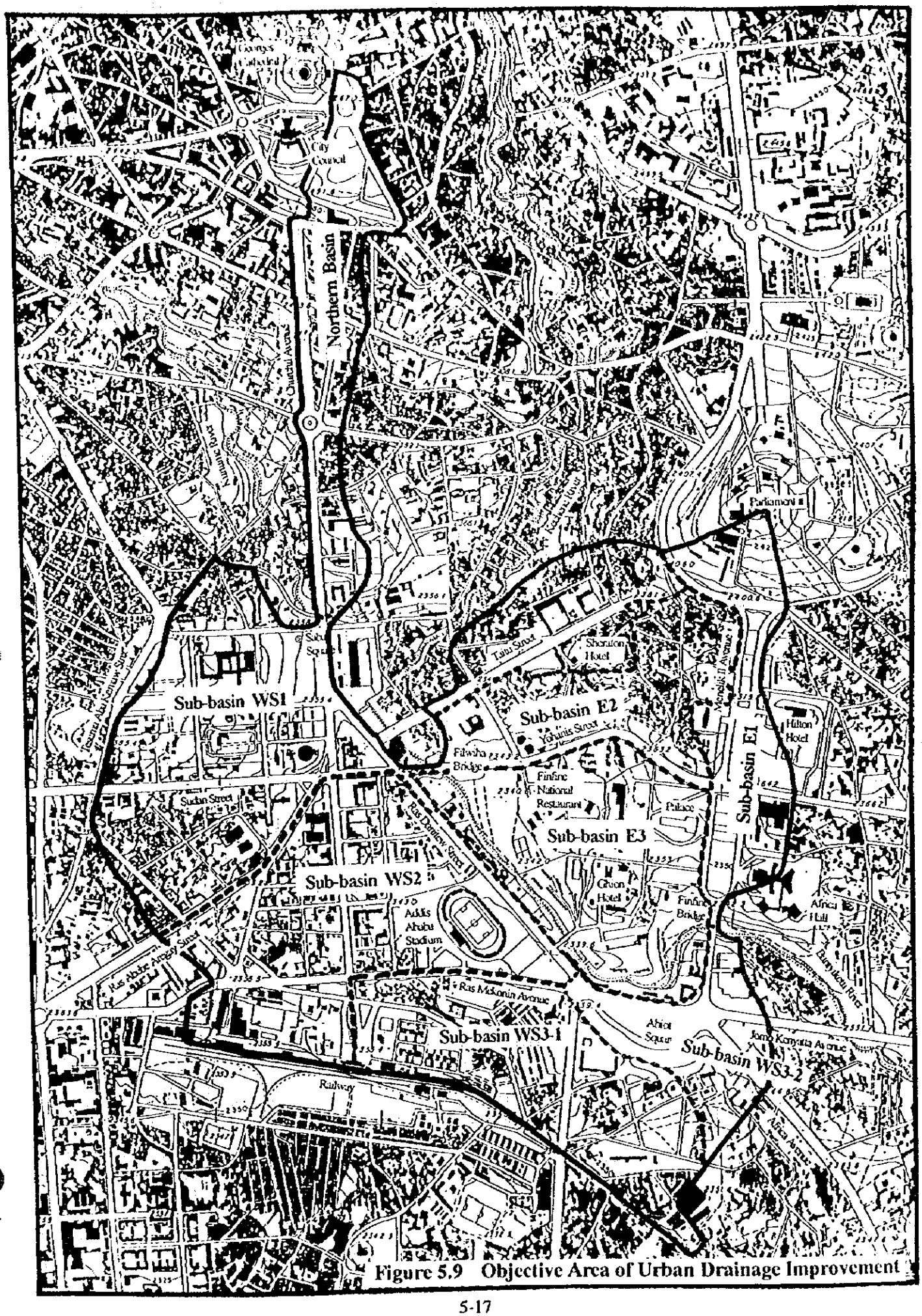


Figure 5.9 Objective Area of Urban Drainage Improvement

Figure 5.10 Outline of Existing Urban Drainage System

(2) Eastern Basin

The eastern basin is the area on the left side of the Bantyiketu river in the objective reaches. The area is further divided into three sub-basins: sub-basin-E1, sub-basin-E2 and sub-basin-E3 from their drainage characteristics.

1) Sub-basin-E1

This basin is a strip along the Menelik II Avenue in the direction of north to south. The rainfall in this area is collected into an underground drainage pipe through street inlets with curb opening along the avenue and drained to the Bantyiketu river. The outlets of the drainage to the Bantyiketu river are concrete culverts of the dimension of about 0.5 m × 0.5 m under the Finfine bridge on the both sides.

Due to the same reasons in the northern basin, greater part of the run-off in the area flows on the Menelik II avenue and passes over the Finfine bridge and is collected into the low-lying area in front of the Abiot Square.

And due to the insufficient conditions of the drainage facilities to the Bantyiketu river from the area, the collected water becomes stagnant in the area and blocks the traffic in the center of Addis Ababa often in rainy seasons.

2) Sub-basin-E2

This basin is an area where the Sheraton hotel is under construction in the center of the sub-basin. The Sheraton hotel is now constructing drainage facilities consisting of road side ditch and underground pipe along the Taitu Street to drain the rainfall in the hotel complex to the Kechene river. The drainage facilities also drain the rainfall in the area on the northern side of the Taitu Street in front of the hotel. The new drainage facilities by the Sheraton hotel are to be connected with the existing drainage system in front of the hotel. Accordingly the rainfall in this sub-basin is to be drained along the Taitu Street to the Kechene river or along the Yohanis Street to the Bantyiketu river.

The rainwater in this area other than that drained to the Kechene river along the Taitu Street, is collected in front of the Finfine National Restaurant mainly along the Yohanis Street. Since the Yohani Street is ascending to the direction of the Bantyiketu river with a distance of about 100 meters, the collected rainwater is drained by underground drainage pipes through the grassland on the downstream side of the Filwiha Bridge.

Due to the reasons that street inlets with curb opening are insufficient in numbers and size, the collected water becomes stagnant near the Finfine National Restaurant.

3) Sub-basin-E3

This basin is an area surrounded by the Yohanis Street and the Menelik II Avenue. In this area, the palace of the president of the Federal Democratic Republic of Ethiopia and the Ghion Hotel are located. Since the area has natural slope to the direction of the Bantyiketu river and the ground height is rather high, this area has basically no serious drainage problem.

(3) West-southern Basin

The west-southern basin is the area on the right side of the Bantyiketu river in the objective reaches. The rainfall in this area is all collected to the low-lying area along the Bantyiketu river around the Addis Ababa Stadium and in front of the Abiot Square. Due to the above-mentioned reasons, the collected water becomes stagnant and blocks the traffic in the center of the Addis Ababa often in rainy seasons.

The area is also further divided into three sub-basins: sub-basin-WS1, sub-basin-WS2 and sub-basin-WS3 from their drainage characteristics.

1) Sub-basin-WS1

This basin is the area surrounded mainly by the Churchil Avenue, the Tesema Aba Kemaw Street, and the Ras Abebe Aregay Street. The drainage from this area converges to the crossroads of the Yohanis Street and the Ras Danitew Street. The existing drainage system seems to drain the run-off in this area through an underground drainage pipe to the Bantyiketu river just downstream of the confluence of the Kechene and Kurtume rivers. Due to the same reasons mentioned above, greater part of the run-off goes to the direction of the Abiot Square along the Ras Danitew Stree and becomes stagnant near the Addis Ababa Stadium and Abiot Square.

2) Sub-basin-WS2

This basin is the area surrounded mainly by the Ras Abebe Aregay Street, Ras Danitew Street and the Ras Mekonin Avenue. The drainage in this area converges around the Addis Ababa Stadium and is drained to the Bantyiketu river through the drainage system along the road on the northern side of the Stadium and along the Ras Danitew Street. Due to the same reasons mentioned above, the collected water becomes

stagnant around the Stadium and often disturb the traffic around there during rainy season.

3) Sub-basin-WS3

This basin is the area surrounded mainly by the railway and the Ras Mekonin Avenue. The drainage in this area converges around the Abiot Square and is drained to the Bantyiketi river through the street inlets with curb opening or grating and the culvert.

The existing drainage system from the low-lying area in front of the Abiot Square to the Bantyiketu river consists of street inlets with curb opening or grating along or in the center of the street, underground drainage pipes and underground drainage culvert to the Bantyiketu river. The street inlets around the Abiot Square are more than 50 in numbers with the dimensions of 0.2 m × 0.4 m to 1 m × 1 m. In addition, there exists the drainage ditch with grating in the Abiot Square with the width of about 0.3 meters. The outlet of the culvert to the Bantyiketu river has the dimension of about 2.7 m × 2.7 m. The outlet is located about 20 meters downstream of the bridge of the Ghion Hotel that is located behind the Ethiopian Tourism Commission about 270 meters upstream of the Finfine bridge.

The culvert itself does not seem to have any problem. However, due to the reasons that the street inlets along the street in front of the Abiot Square are insufficient in the size. Many of the inlets are clogged with garbage and soil. The collected water in front of the Abiot Square becomes stagnant in the area and blocks the traffic in the center of Addis Ababa often in rainy seasons. The locations of street Inlets around the Abiot Square are shown in Figure 5.11.

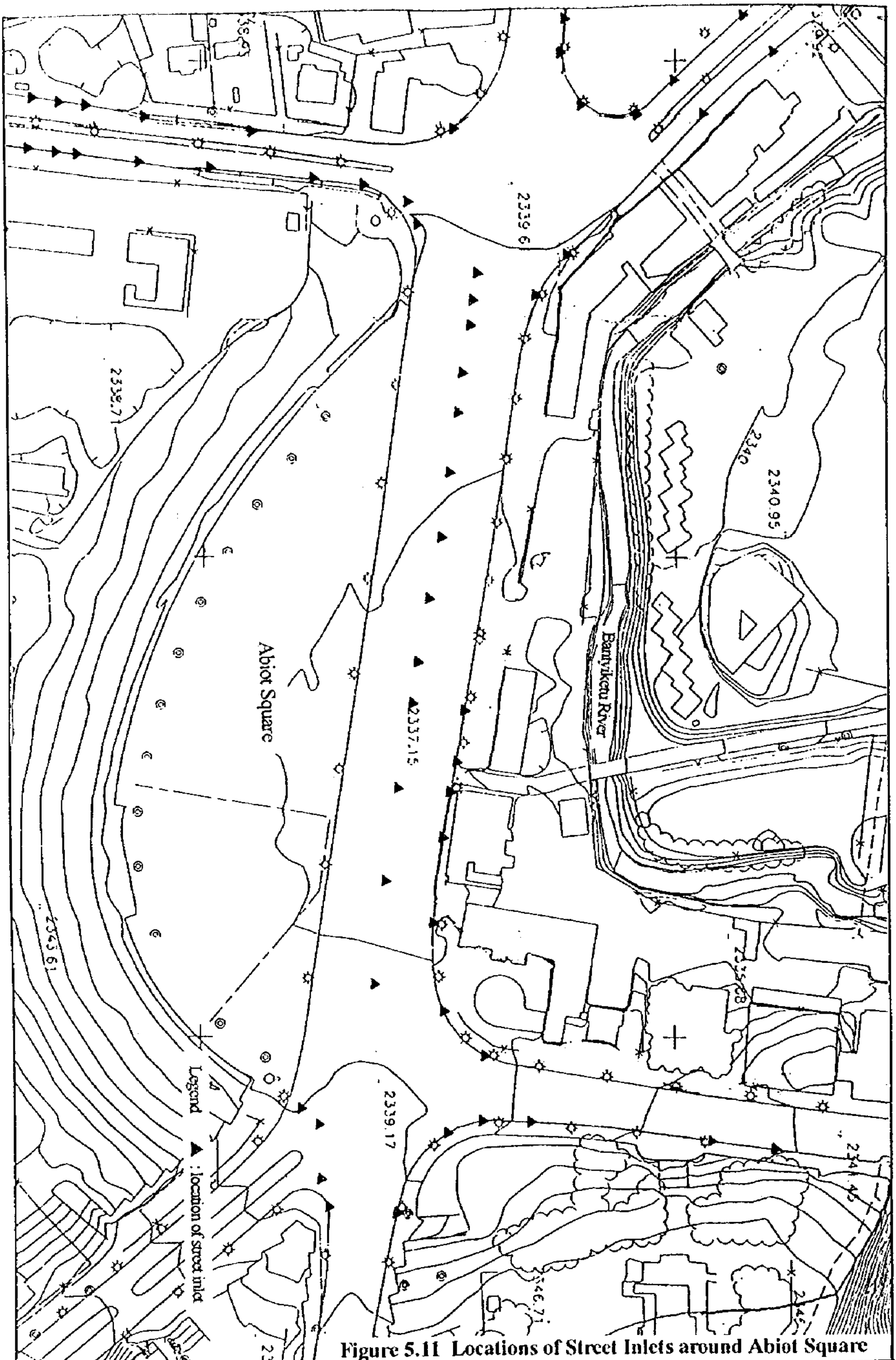


Figure 5.11 Locations of Street Inlets around Abiot Square

5.1.3 Social and Natural Environmental Conditions

(1) Bantyiketu River

Along the upstream reaches of the Bantyiketu river upstream of the Asmara Road, the surrounding area is the most important area in Addis Ababa. Politically and economically very important organs are located. They are Congress Hall of Federal Government, Headquarter of Military Force, Ministry of Defense, the palace of the president of the Federal Government, Ministry of Foreign Affairs, Railway Station, General Post Office, Africa Hall, the offices of ECA, UNDP, UNICEF, ILO, UNESCO, Hilton hotel, Ghion hotel, and others.

Besides the Africa Avenue leading to the international Bole Airport, the Asmara road leading to Asmara, the Debra Zeit road leading to Debra Zeit, Ras Biru Avenue leading to Djibouti meet in this area.

Along the reaches of the Bantyiketu river downstream of the Asmara Road, the surrounding area is mainly residential area. US Aid office is located along the Bantyiketu river on the right side very close to the river in this area. Around the confluence with the Kebena river, there exists the Maekelawi Park including the agricultural testing ground. Near the confluence with the Kebena river, the embassies of Djibouti and Zimbabwe are located rather close to the Kebena river upstream of the Bole road.

In the area along the Bantyiketu river, there exist no historical heritage nor cultural assets. The water intake exists near the Maekelawi Park for vegetable irrigation. Water use by local people along the river is scarcely found. There exist no fishing rights.

Since the water quality of the Bantyiketi river is very much deteriorated especially during dry season, there exist no important flora and fauna. There exist no important landscape along the river.

(2) Bantyketu Regulating Pond Site

The proposed Bantyiketu regulating pond site is located on the left side of the Bantyiketu river just downstream of the confluence of the Kechene and Kurtume rivers. The present situation of the area is an open area of grassland. Hot spring site is located

just downstream side of the area. On the left side of the area, the Finfine National Restaurant is located. Addis Ababa Tennis Club is located on the downstream side of the area. The Ghion Hotel as one of the main hotels of Addis Ababa is located on the further downstream side of the Tennis Club.

This site is located very close to the central area of the Addis Ababa. The site is facing the Yohanis Street connecting the Mennelik II Avenue and the Ras Dantew Street that play an important role for traffic in the city. The Yohanis Street has four-lane roadway paved with asphalt, median strip with some kinds of vegetation and the sidewalks of stone pavement on both sides. The width of roadway is 8.7 meters on one side, the width of the median strip is 5 meters and the width of sidewalk is 4 meters on one side. The volume of wheeled traffic is very heavy and pedestrians are many all day long.

There exist neither water right nor fishing rights.

There exist neither flora nor fauna to be preserved. There exist no important landscape at the site.

(3) Kostre Regulating Pond Site

The present situation of the proposed Kostre regulating pond site is a football ground for the people around the site. The surrounding area of the site is a residential area of middle-class and low-cost houses. The density of houses around the site is not dense.

In the area, there exist no historical or cultural assets. There exist neither water right nor fishing rights. Water use by local people around the area is scarcely found.

The site is facing the Dejazmach Haile Silase Street and Grez Inke Silase Bantyidagn Street. The Dejazmach Haile Silase Street has a roadway paved with asphalt and sidewalks of stone pavement on both sides. The site is rather far from the center of the city and accordingly the volume of wheeled traffic is not heavy except at commuter time.

There exist neither flora nor fauna to be preserved. There exist no important landscape at the site.

(4) Kechene Weir Site

On the right side of the proposed Kechene Weir site, there exists the graveyard of Medhane Alem. This is the graveyard for the villagers around the area for the Orthodoc Chistians. On the left side of the site, there exist a village of Wereda 10. The houses of the village are located on the rather highland along the Kechene river but some houses are located rather close to the river on the lowland. These houses are mainly low-cost houses.

In the area, there exist no historical or cultural assets. There exist neither water right nor fishing rights. Water use by local people around the area is washing.

The approach road to the site is Abere Gizaw Street. The road is paved with asphalt with the width of 4 meters. Since the area is located in rather rural area, the volume of wheeled traffic is light.

There exist neither flora nor fauna to be preserved. There exist no important landscape along the river.

5.2 River and Road Survey

5.2.1 Outline

The river cross section and road cross section surveys were conducted for priority projects consisting of flood control works and urban drainage improvement. The surveys consist of traverse survey, leveling and cross section survey for river cross sections, and leveling and cross section survey for road cross section.

The survey works for the Phase 2 study were carried out for the period from the beginning of December 1997 to the middle of January 1998 (around 1.5-month).

Figures 5.12 and 5.13 show the objective river stretches for river survey and road survey, respectively. The main work items and quantities are as follows.

a) For river cross section

- Traverse survey: 310 points
- Leveling: 8.5 km in long to connect existing bench marks
- Cross section survey: 160 sections in total with intervals of 20 to 100 meters

b) For road cross section

- Leveling: 5 km in long to connect existing bench marks
- Cross section survey: 50 sections in total with interval of about 100 meters

The verified reference benchmarks and polygonal points for the survey were established mainly referring the Blue Nile Geodetic Control Project (1957 to 1960) and Mapping Project for Urban Planning in Addis Ababa (1972 to 1973).

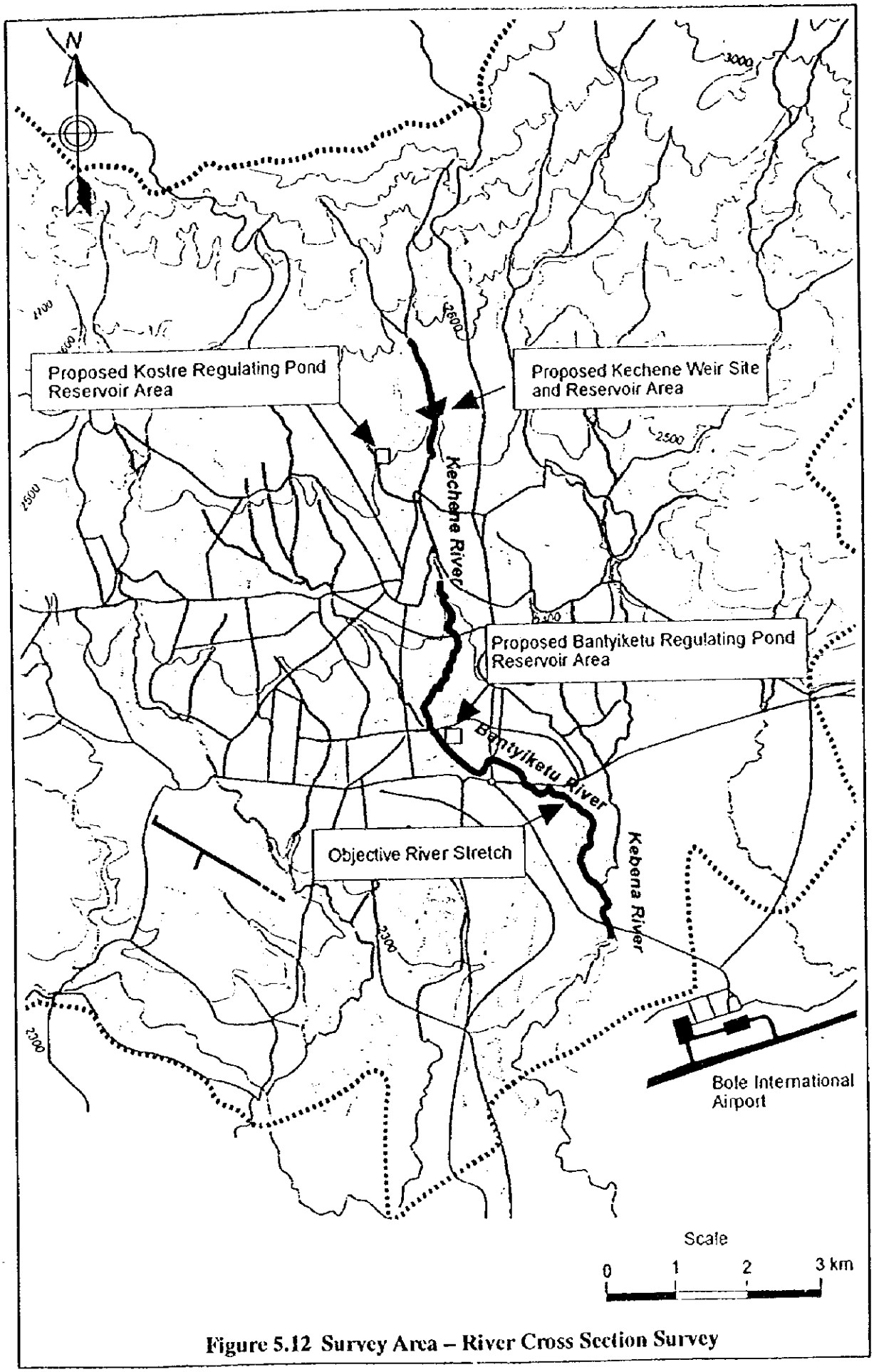


Figure 5.12 Survey Area – River Cross Section Survey

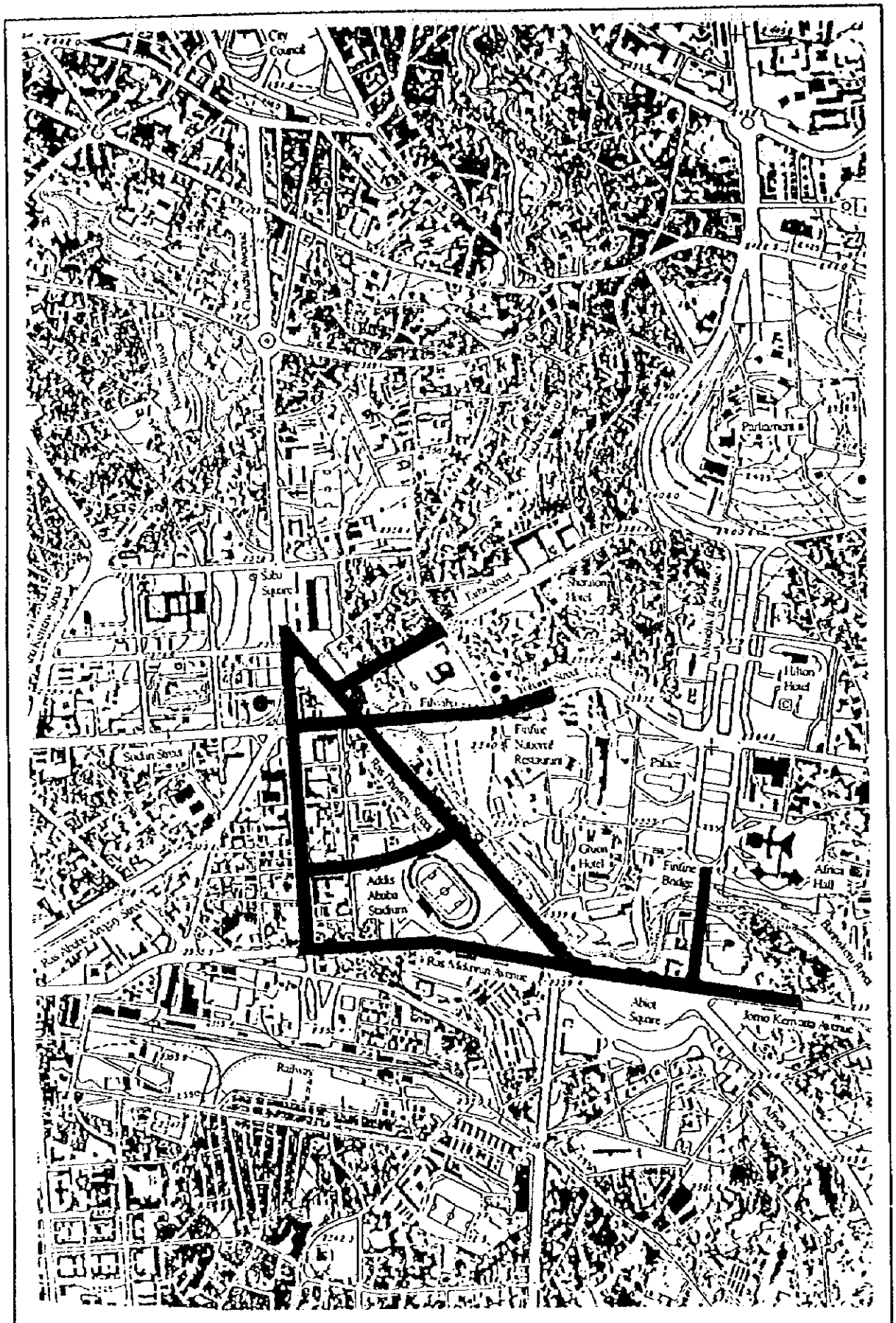


Figure 5.13 Survey Area – Road Cross Section Survey

5.2.2 Survey Results

The results of the survey works are compiled into the followings.

a) River Cross Section Survey:

- Location Maps of Surveyed River Cross Sections (Scale 1:2,000)
- Drawings of River Cross Sections (Scale: Horizontal 1:200, Vertical 1:200)
- Drawings of Longitudinal Profiles of Surveyed Rivers (Scale: Horizontal 1:20,000, Vertical 1:1,000)

b) Road Cross Section Survey:

- Location Maps of Surveyed Road Cross Sections (Scale 1:2,000)
- Drawings of Road Cross Sections (Scale: Horizontal 1:200, Vertical 1:50)
- Drawings of Longitudinal Profiles of Surveyed Roads (Scale: Horizontal 1:2,000, Vertical 1:100)

c) Reports and Survey Data

- Survey Report
- Descriptions of Control Points
- Field Measurement and Computation Sheets

5.3 Basic Planning Conditions of Priority Projects

5.3.1 General

The following are components of the flood control plans consisting of structural and non-structural measures, and urban drainage works in the selected priority projects for the feasibility study.

(1) Structural Measures

a) Bantyiketu river

- River channel improvement (widening of river bank, bank protection, construction of floodwall, repair of intake gate), and
- Construction of the Bantyiketu regulating pond.

b) Kechene river

- Construction of the Kostre regulating pond in the Kostre river, and
- Construction of the Kechene weir in the upper Kechene.

c) Urban Drainage Improvement

- Construction of road side ditches.

(2) Non-Structural Measures

a) Authorization of river zone and prohibition of illegal activities,
b) Setup of flood warning system and flood fighting system, and
c) Social education for river and flood.

5.3.2 Flood Control

(1) Objective Rivers and Stretches

Objective rivers of the priority projects are basically the Bantyiketu and the upper Kechene. Stretches of the lower Kebena and the lower Kechene rivers connecting to the Bantyiketu are incorporated into the plan from the viewpoint of transition. Accordingly, the following are objective rivers and stretches to be considered in the planning, as shown in Figure 5.14.

a) Lower Kebena river: just upstream of the Bole road bridge

b) Bantyiketu river: the confluence with the Kebena river - Filwiha bridge

c) Lower Kechene river: just upstream of Kechene 2nd bridge

d) Upper Kechene including Kostre river: respective proposed sites of weir and pond

(2) Design Discharge Distribution

Design discharges of the priority projects have been estimated in the Phase 1 Study with 30-year probable flood for the Bantyiketu (and Kebena rivers,) and 20-year probable flood for Kechene river. Figure 5.15 shows the design discharges distribution of the flood control works in the priority projects.

(3) Treatment of Urgent Works in the Lower Kechene River

AFCPO has an urgent plan to construct floodwall on both river banks between the Kechene 1st and 2nd bridges, and repair of broken abutment of the Kechene 2nd bridge in the lower Kechene river.

The construction works have been scheduled to carry out by contracting system in 1998. The total length of floodwall amounts to 300 meters on the left and 340 meters on the right, respectively. These works are considered as definitive and therefore separated from the components of the priority projects.

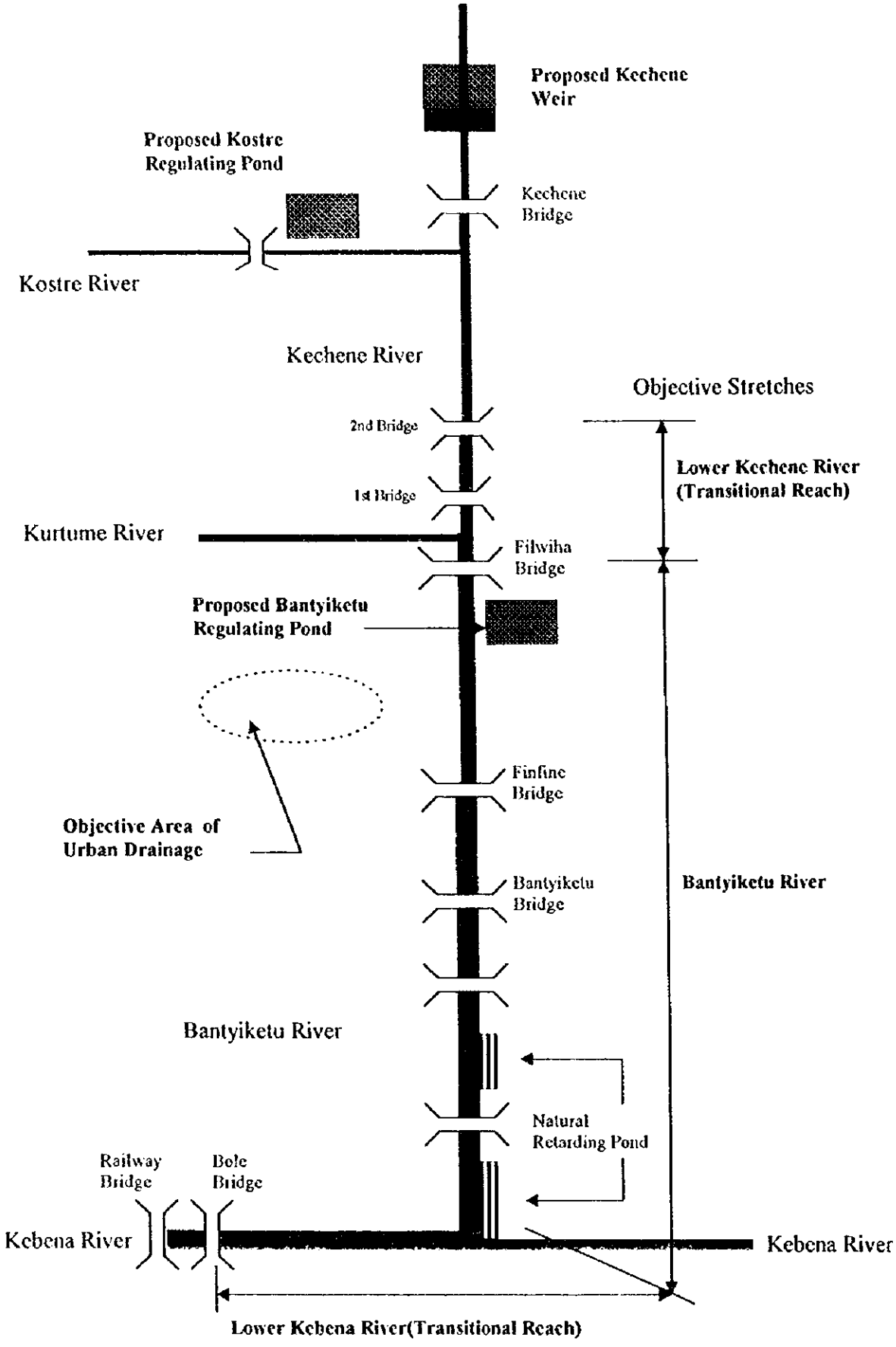


Figure 5.14 Objective River and Stretches of Priority Projects

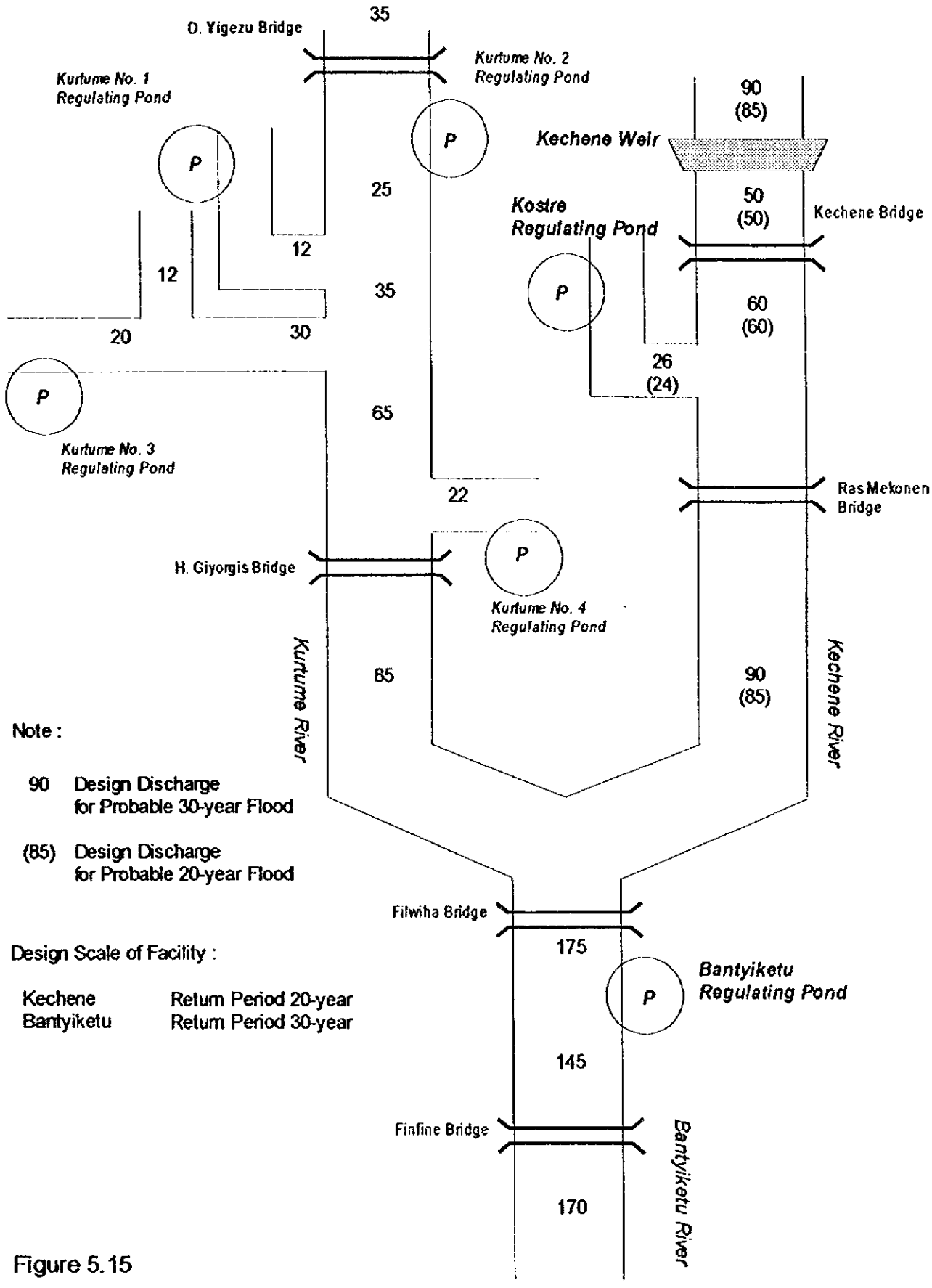


Figure 5.15

Design Discharge Distribution for Bantyiketu River System

5.3.3 Urban Drainage

Basic concept on drainage plan prepared here is that the drainage facilities are to be additionally constructed to the existing drainage facilities to decrease the inundation conditions in the objective area due to the insufficient conditions of the existing drainage facilities.

Rehabilitation of the existing drainage facilities may substantially decrease the present inundation conditions in the objective area. However, due to the lack of information of drawings of the present facilities, planning of the rehabilitation of the existing facilities could not be achieved in sufficient level. Besides, the project scale of the rehabilitation of the existing facilities may exceed the limited financial sources because all the existing facilities are constructed underground, and the costs of the inventory works and the demolishing works of present facilities may pile up too much.

The design discharge is to be determined on the condition that the rainfall intensity is 30 mm/hour corresponding to the return period of 1.5 years. Since the drainage improvement is to be achieved with additional drainage facilities, design runoff is to be drained by the existing facilities in combination with the planned additional facilities. Some portion of the runoff is to be drained by the existing facilities and the remaining portion is to be drained by the additional facilities.

5.4 Flood Control Plan

5.4.1 Design Criteria and Methodology

(1) River Channel Improvement

The existing river is to be partly channeled so as to convey the design flood safely by means of widening of the existing river channel, construction of earth dike and floodwall, protection of bank slopes, and reconstruction or modification of the related structures.

The following are major planning criteria to be applied.

a) Design high water level of the channel is set at an average river bank elevation from the viewpoint of smooth storm water drainage from riparian areas.

b) Longitudinal channel profiles are prepared based on the survey results of the river cross sections.

c) Required flow area for the design discharge is estimated by Manning formula.

d) Single section or composite section is employed depending on site conditions.

e) Freeboard above the design high water level for floodwall and dike is designed as follows:

- Earth dike: 0.6 m for discharge less than 200 m^3/sec and 0.8 m for discharge from 200 m^3/sec to 500 m^3/sec, and
- Floodwall: 0.6 m for discharge less than 200 m^3/sec.

f) The existing floodwalls are utilized as much as possible.

Water supply pipes and sewers are running along the river courses. In widening the existing channel, replacement or protection of these pipes is taken into account but minimized.

(2) Regulating Pond

In order to reduce flood peak discharge to downstream reaches, regulating ponds are introduced into the flood control plan. There are two proposed regulating ponds of the Bantyiketu regulating pond and the Kostre regulating pond as shown in Figure 5.16.

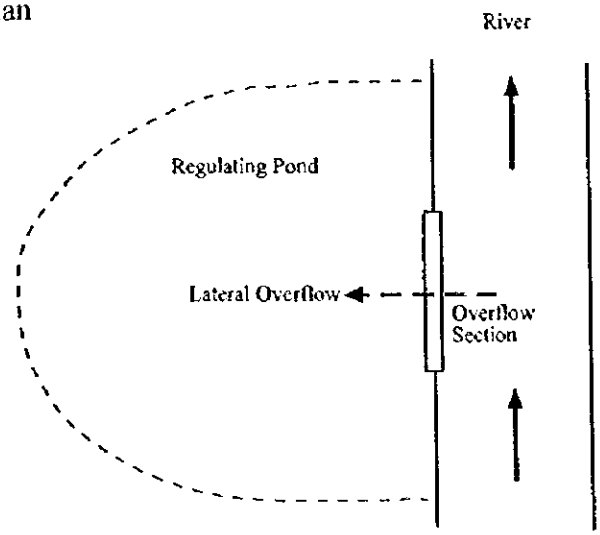
An elevation of side overflow dike is set around river water level equivalent to a flood water level occurring once in a year. After flood finishes, stored water in regulating pond is drained through a flap gate that no manipulation is required. The time of draining stored water is around a half-day. A concept of regulating pond is shown in Figure 5.16.

(3) Kechene Weir

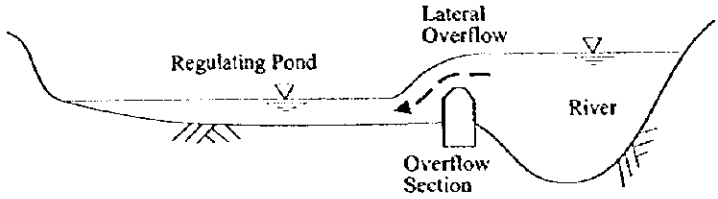
The Kechene Weir is proposed in the upper basin of the Kechene river. The site of the weir is proposed at valley area in the upper Kechene river. It consists of weir and orifice type outlets to reduce flood peak discharge by means of a reservoir in the upstream of weir. A concept of discharge regulation by reservoir is shown in Figure 5.17.

The weir facilitates a non-gated spillway at crest and orifice outlets near the bottom. Spillway is designed to spill out excessive discharge due to flood with much larger scale that design flood discharge. Orifice outlets are provided to reduce outflow discharge in combination with reservoir and designed on the basis of the design discharge.

Plan



Cross Section



Discharge Regulation

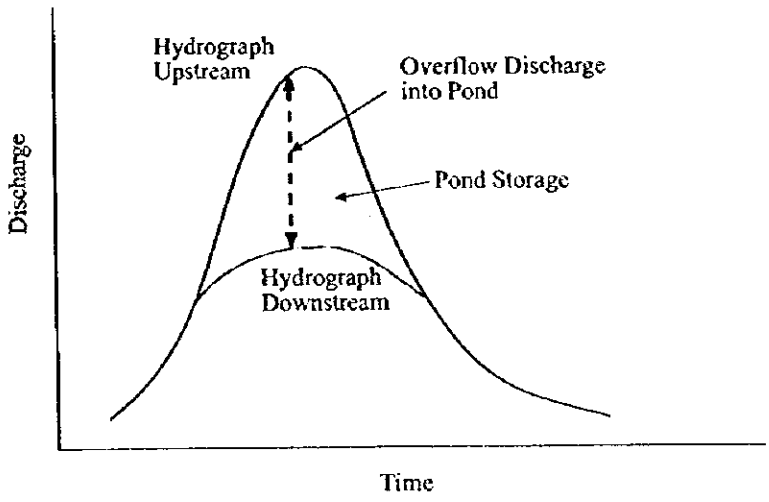
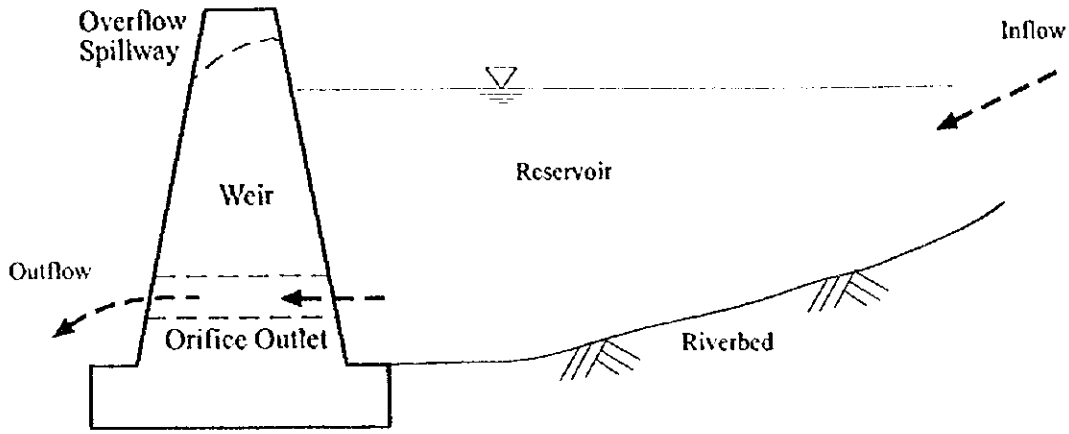


Figure 5.16 Concept of Regulating Pond

Longitudinal Profile



Discharge Regulation

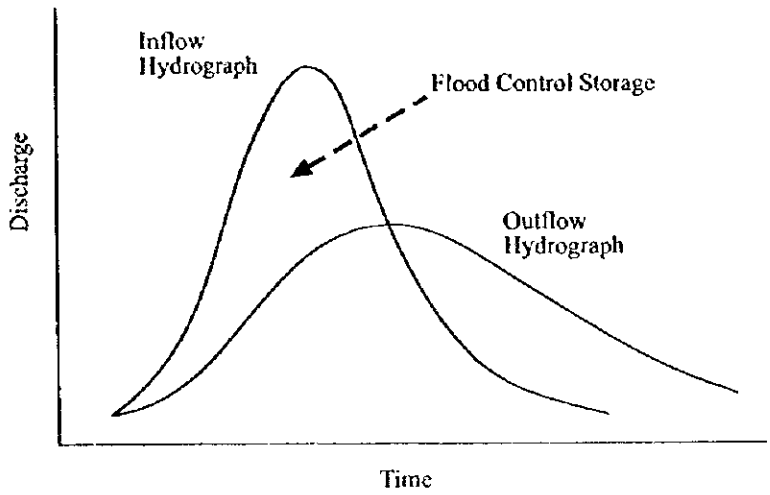


Figure 5.17 Concept of Reservoir by Weir

5.4.2 Structural Measures

(1) River Channel Improvement of Bantyiketu River

The design longitudinal profile of the Bantyiketu river is shown in Figure 5.18. The design riverbed gradient is determined to correspond with the present riverbed gradient as much as possible. The design high water level is obtained on the basis of water level calculation by Manning's formula using the design discharge. In the course of the calculation of the design high water level, standard cross sections are provided by location to make the design high water level adjusted within the average riverbank elevation with necessary free board. In compliance with these studies, the basic features of the river channel improvement are determined and summarized as follows.

Table 5.5 Basic Features of River Channel Improvement of Bantyiketu River

Reach No.	Distance (km)	Riverbed Gradient	Design Discharge (m^3/sec)	Features of River Channel	
				Width (m)	Depth (m)
1	From 1.42 to 2.06	1/140	170	17 / 25	3.6
2	From 2.06 to 3.34	1/140	170	18	3.6
3	From 3.34 to 3.99	1/125	145	15 / 31	3.6
4	From 3.99 to 5.15	1/140	145	16	4.1
5	From 5.15 to 5.26	1/140	175	17	4.1

Note: Distance is measured from the Bole railway bridge corresponding to the starting section of the river cross section survey.

The alignment of river channel is designed using the topographic maps with a scale of 1:2,000. The design of river channel alignment is carried out on the conditions that the present alignment is not to be modified in general but some heavy bending or eroded locations are to be improved to smooth alignment with floodwall or slope protection as required.

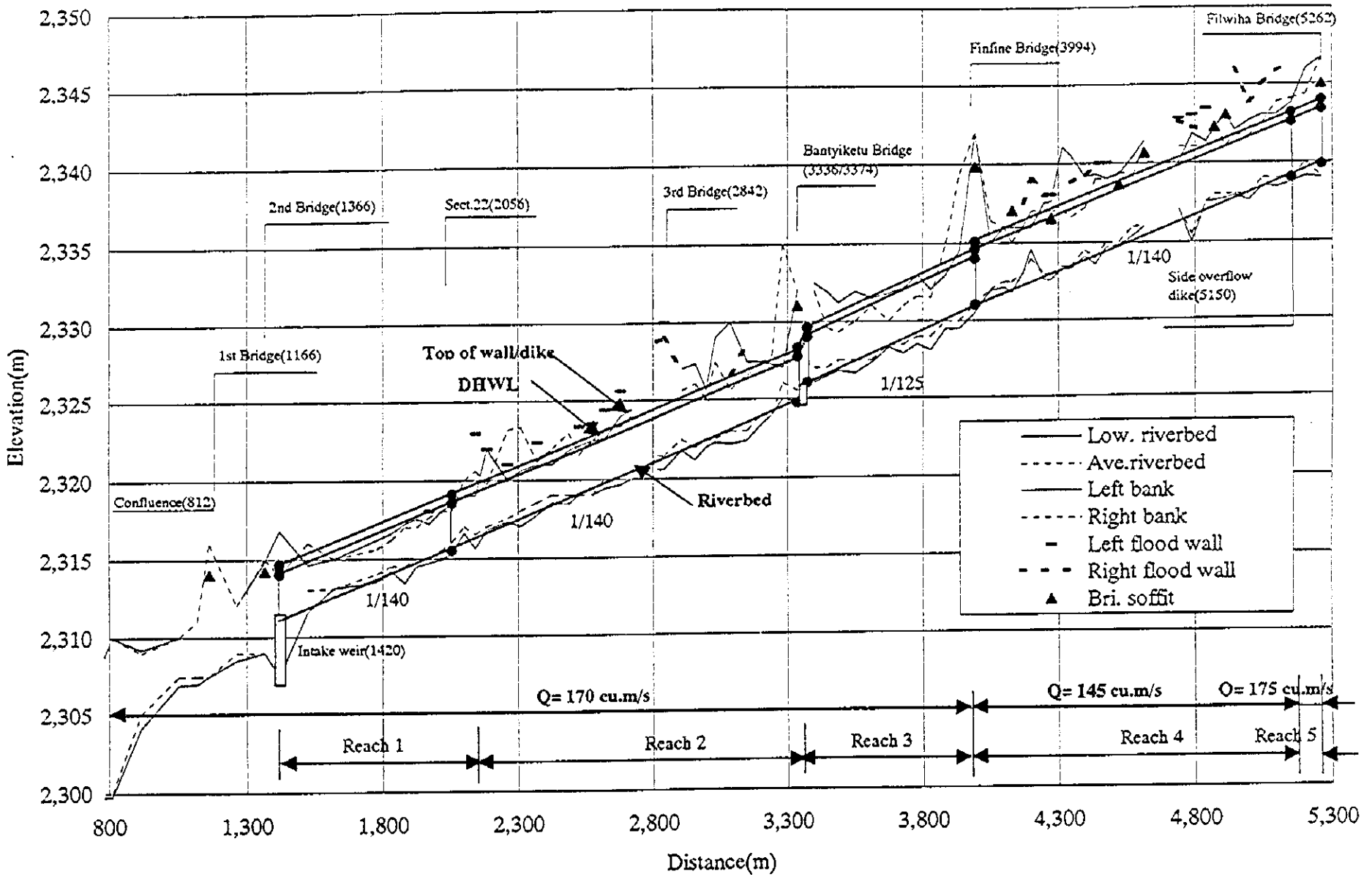


Figure 5.18 Longitudinal Profile of Bantyiketu River

The following river structures and related structures are provided depending on the present and designed conditions of the river channel.

a) Floodwall,
b) Slope protection,
c) Improvement of intake weir,
d) Improvement of aqueduct, and
e) Protection of water supply pipes (2 sets around 7th bridge).

Standard cross sections, alignment and design of structures are explained in detail in the succeeding section 5.6, Design of Facilities.

(2) Lower Kebena and Lower Kechene

The bank slopes of the lower Kebena just upstream of Bole bridge are prone to bank erosion. Slope protection works are taken up in the said reach. Figure 5.19 shows a tentative longitudinal profile of the lower Kebena. The existing channel has sufficient capacity for a design discharge. Based on this plan, both river banks are guarded by slope protection works.

Just upstream of the 2nd bridge in the lower Kechene river, both river banks have been eroded and riparian areas are subject to inundation and washing away. Accordingly, this reach is protected by construction of floodwall. Figure 5.20 shows a tentative longitudinal profile of the lower Kechene river. The existing Kechene river has sufficient flow capacity for a design discharge in most of the objective stretch. Therefore, the existing bank slopes are protected by construction of floodwall.

Standard cross sections, alignment and design of structures are explained in detail in the succeeding setion 5.6, Design of Facilities.

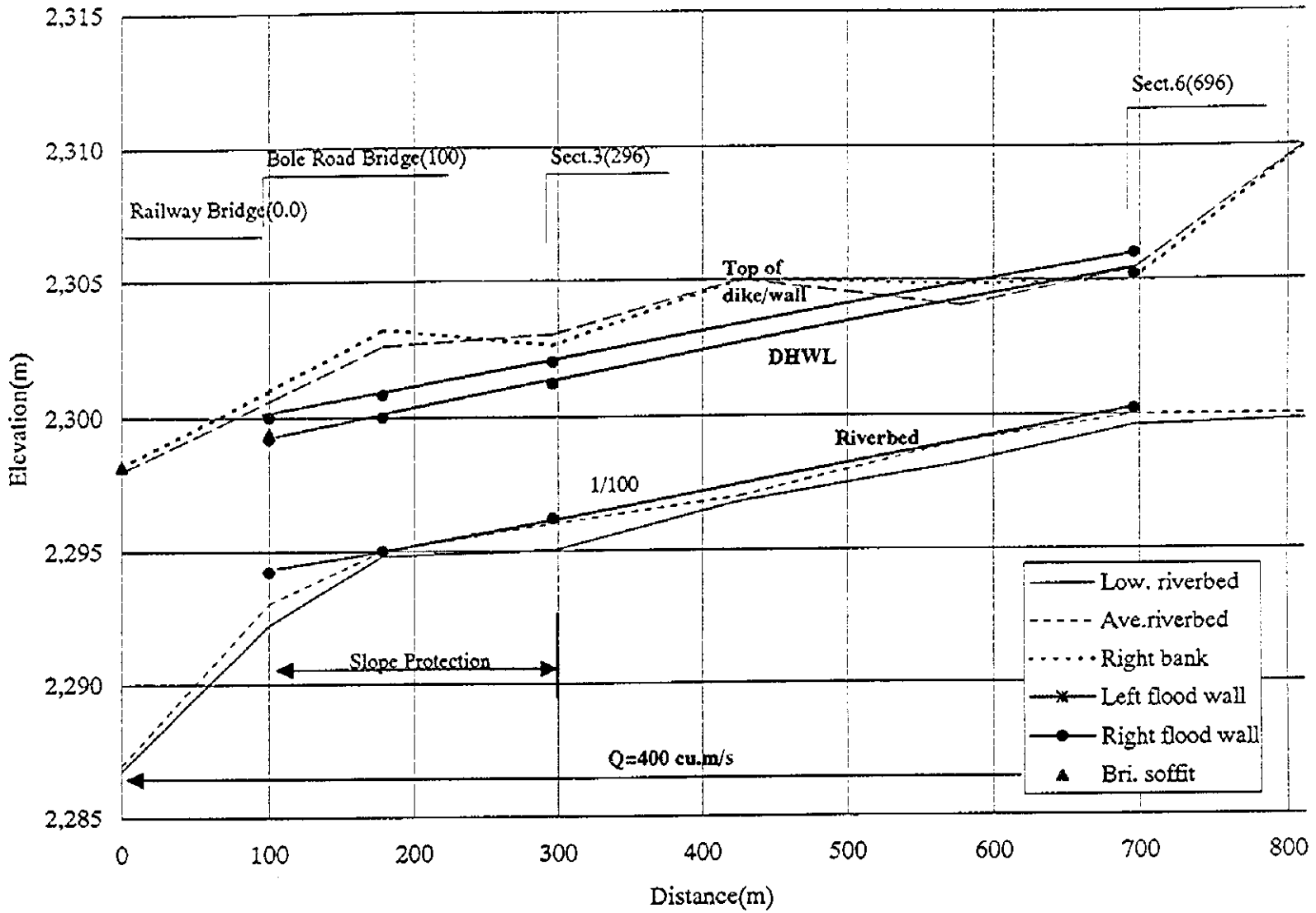


Figure 5.19 Longitudinal Profile of Lower Kebena River

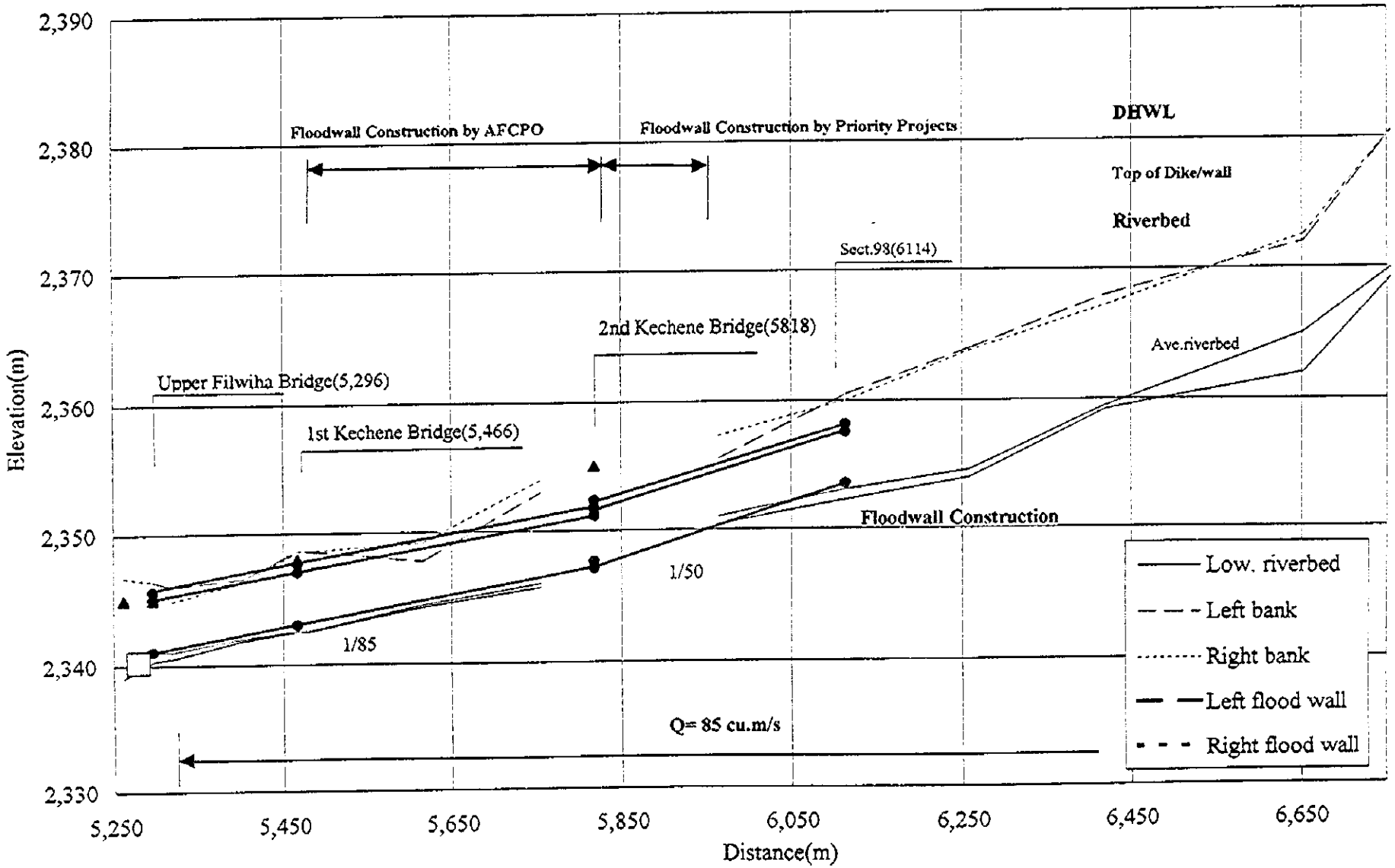


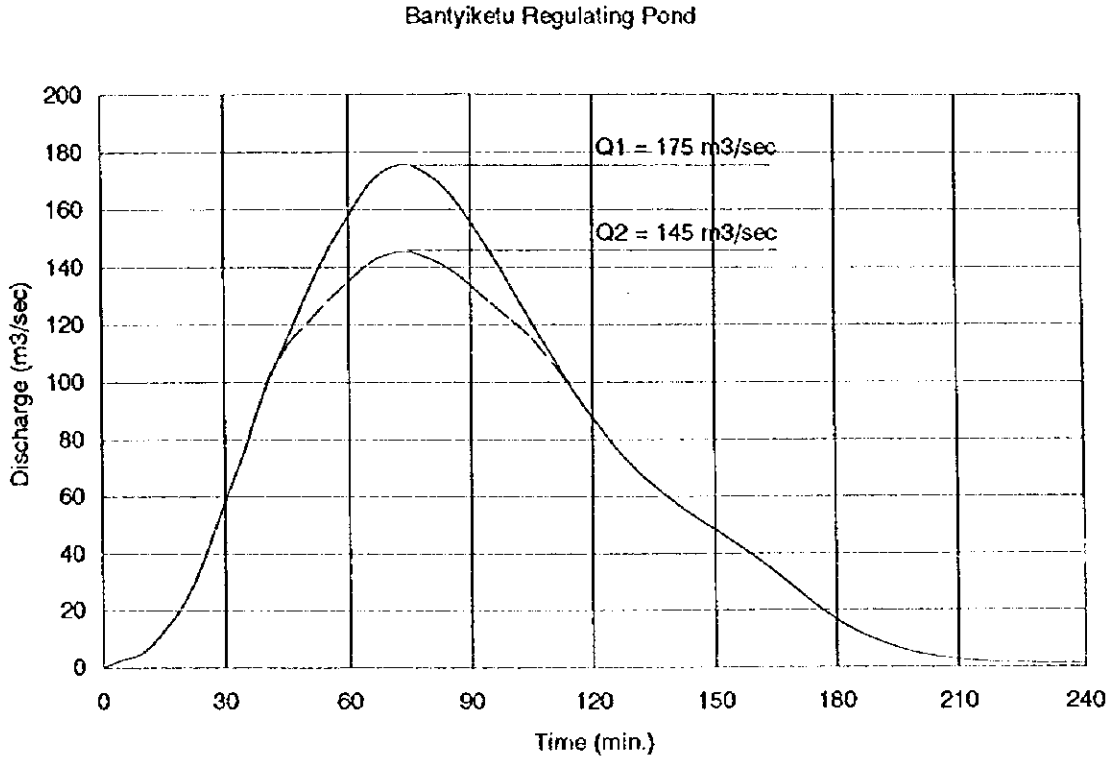
Figure 5.20 Longitudinal Profile of Lower Kechene River

(3) Bantyiketu and Kostre Regulating Ponds

The analysis is carried out to determine a required storage capacity of pond and dimensions (width and height) of lateral overflow section. Hydraulic calculation is therefore carried out on the basis of design river channel around regulating pond, and design discharges for river channel and lateral overflow section. As a result of hydraulic calculation, discharge hydrographs for the respective regulating ponds are shown in Figure 5.21 and the basic design features of regulating pond are obtained as follows.

Table 5.6 Basic Features of Regulating Pond

Bantyiketu Regulating Pond		
1) Design Discharge (Peak Discharge)	Probable 30-Year Flood	
	- Upstream River Channel	: 175 m^3/sec
	- Downstream River Channel	: 145 m^3/sec
	- Lateral Overflow	: 30 m^3/sec
2) Lateral Overflow Section	Length : 50 m	
	Height : 3.3 m	
3) Required Storage	73,000 m^3	
Kostre Regulating Pond		
1) Design Discharge (Peak Discharge)	Probable 20-Year Flood	
	- Upstream River Channel	: 28 m^3/sec
	- Downstream River Channel	: 14 m^3/sec
	- Lateral Overflow	: 14 m^3/sec
2) Lateral Overflow Section	Length : 30 m	
	Height : 4.5 m	
3) Required Storage	26,000 m^3	



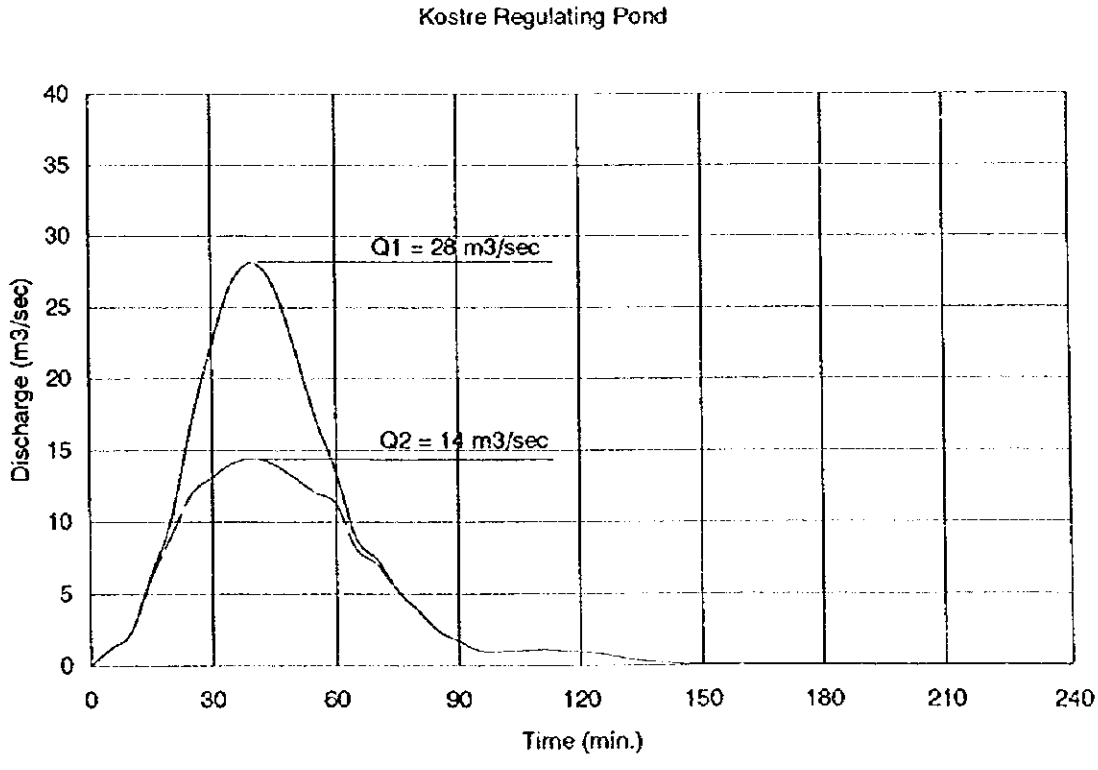


Figure 5.21 Flood Control Plan by Regulating Pond

(4) Kechene Weir

The flood control storage of reservoir is examined by inflow – outflow calculation. The design flood hydrographs of probable 20-year and 30-year flood are applied as reservoir inflow for the calculation. A relationship between reservoir water level and storage is obtained from the topographic maps with a scale of 1/2,000. The results of calculation are illustrated in Figure 5.22.

For construction of weir, it is necessary to provide an overflow spillway discharging excessive flood from reservoir. The probable 200-year flood is applied as design capacity of overflow spillway. Width and depth of overflow spillway to be provided at the crest of weir are determined from this design discharge.

The results give the basic features of the Kechene weir as follows.

Table 5.7 Basic Features of Kechene Weir

Reletionship between Water level, Water Surface Area and Reservoir Storage

Water Level (EL. m)	2,495	2,500	2,505	2510	2,515
Surface Area (m^2)	115	4,096	9,331	17,013	31,127
Storage (m^3)	60	10,600	44,200	110,100	230,500

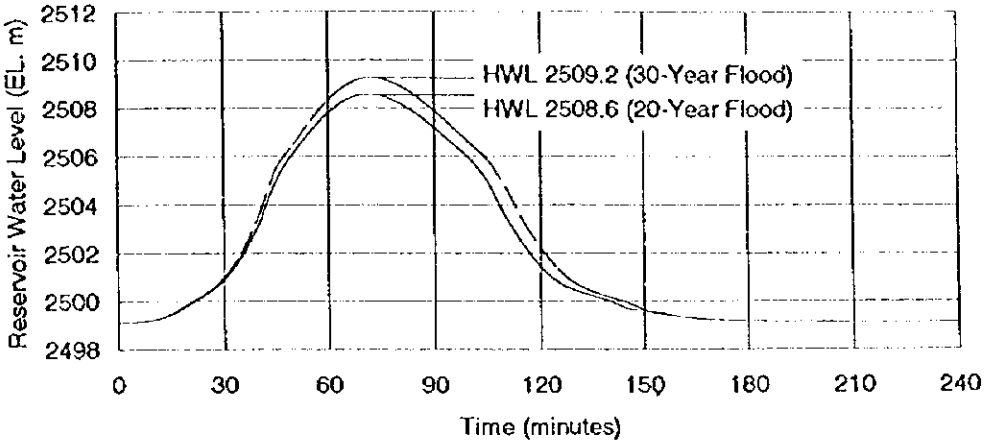
Flood Control Storage by Reservoir
Low Water Level of Reservoir : EL. 2,499 m
Orifice Outlet : 1.2 m × 1.2 m, 3 nos., Invert Level EL. 2,499 m

Design Flood	Peak Discharge Inflow (m^3/sec)	Peak Discharge Outflow (m^3/sec)	Design Flood Water Level (EL. m)	Reservoir Storage (m^3)
Probable 20-year Flood	85	49	2,508.3	83,000
Probable 30-year Flood	91	50	2,509.0	96,000

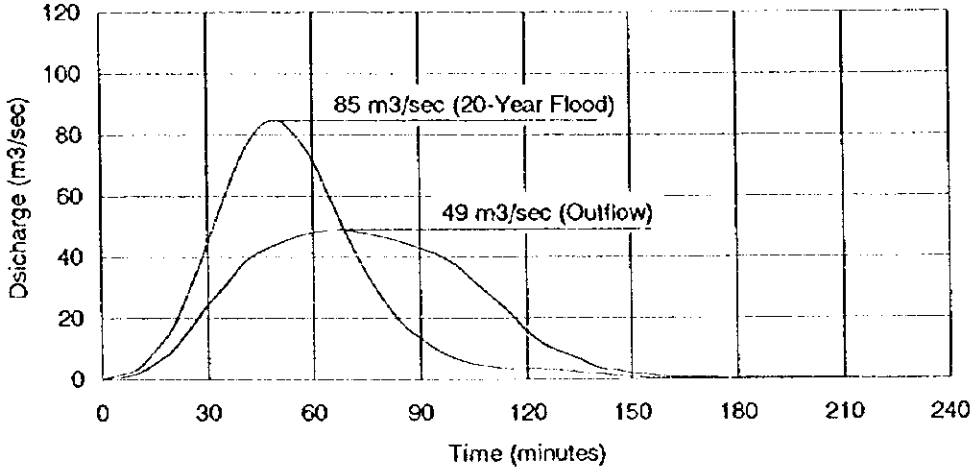
Spillway
Crest of Overflow Spillway : EL. 2,509.5 m
Width of Overflow Spillway : 20 m

Design Flood	Peak Discharge (m^3/sec)	Water Depth of Overflow Discharge	Highest Water Level (EL. m)
Probable 200-year Flood	120	2.5	2,511.5

Reservoir Water Level



Inflow - Outflow Hydrograph (20-Year Flood)



Inflow - Outflow Hydrograph (30-Year Flood)

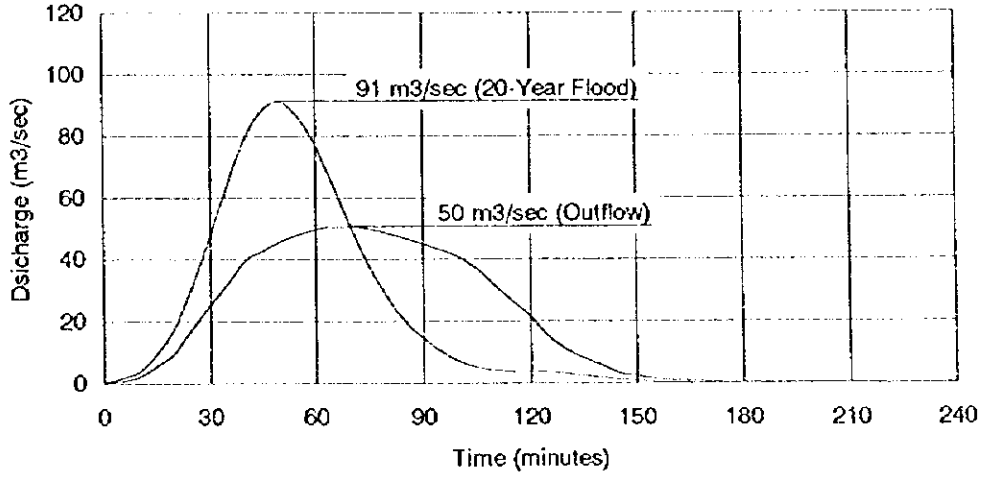


Figure 5.22 Flood Control Plan by Kechene Weir

(3) Proposed Structural Measures of Priority Projects

The followings are the major components of the structural measures of the priority projects. The conceptual figure of the proposed works is shown in Figure 5.23.

Table 5.8 Outline of Proposed Structural Measures

River Channel Improvement

Descriptions	Features
Bantyiketu River	
- Channel Excavation	20,500 m^3
- Embankment	400 m^3
- Floodwall	3,010 m^2
- Slope Protection	5,010 m^2
- Repair of Intake Weir	1
- Improvement of Aqueduct	1
- Protection of Sewerage Pipes	2
Lower Kebena River	
- Slope Protection	4,830 m^2
Lower Kechene River	
- Floodwall	540 m^2

Construction of Bantyiketu and Kostre Regulating Ponds

Descriptions	Features
Bantyiketu Regulating Pond	
- Reservoir Area	29,900 m^2
- Reservoir Volume	73,000 m^3
- Length of Lateral Overflow Dike	50 m
Kostre Regulating Pond	
- Reservoir Area	6,500 m^2
- Reservoir Volume	26,000 m^3
- Length of Lateral Overflow Dike	30 m

Construction of Kechene Weir

Descriptions	Features
- Reservoir Area	20,000 m^2
- Reservoir Volume	88,000 m^3
- Weir Height : Non-overflow section	19.5 m
- Weir Height : Overflow section	16.0 m
- Crest Length	120 m

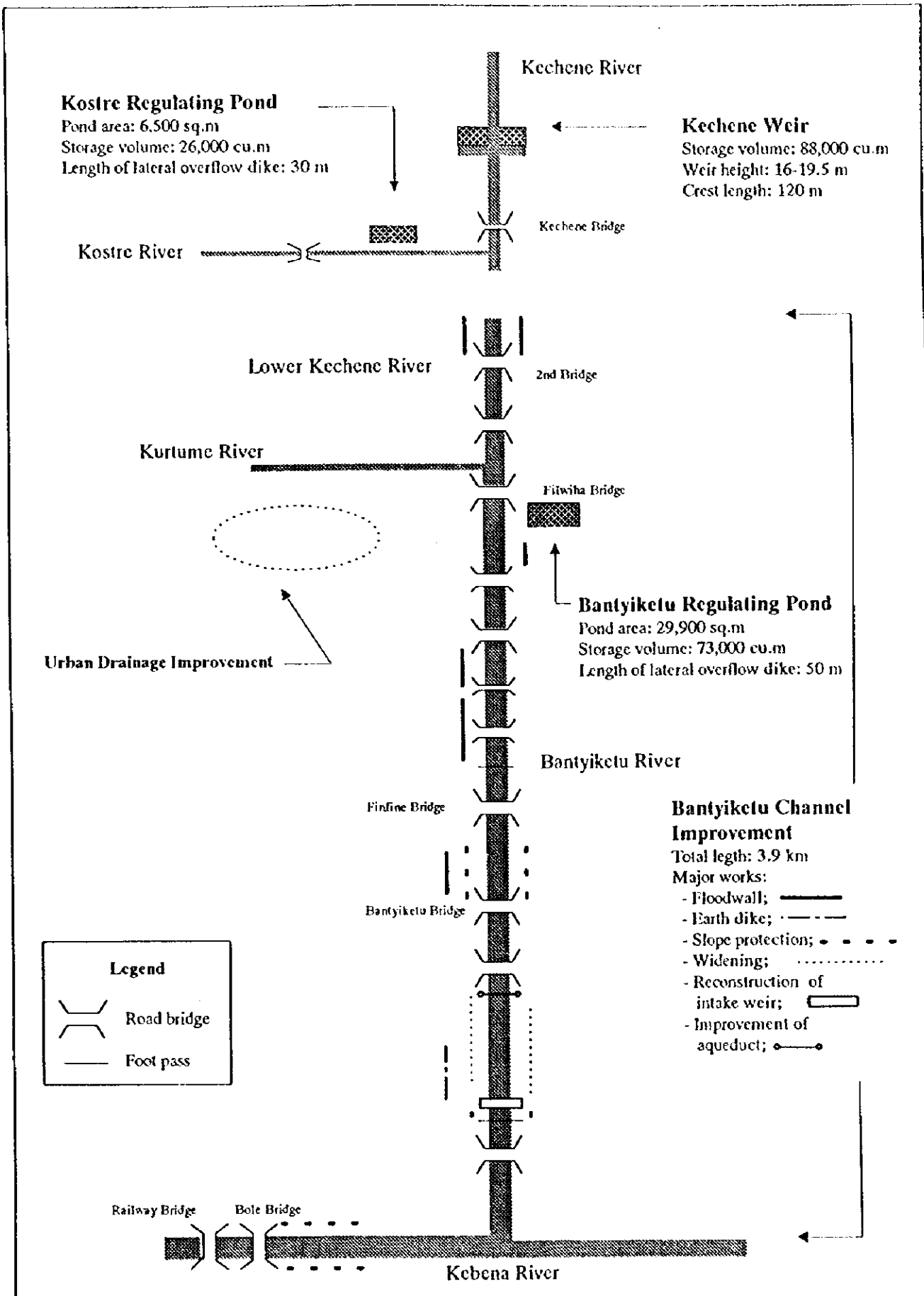


Figure 5.23 Outline of Proposed Works of Priority Projects

5.4.3 Non-Structural Measures

The non-structural measures proposed in the priority projects are 1) authorization of river zone and 2) social education for river and flood from the viewpoint of river management, and 3) flood warning system, and 4) flood fighting system in the viewpoint of flood risk management.

These measures need to be supported by appropriate institutional systems in accordance with the regulations and institutions of the Region 14 Administration, and by wide participation of inhabitants in flood control and prevention activities. Institutional support is to be managed by the proposed Addis Ababa River Board (AARB) and the Addis Ababa River Management Authority (AARMA), discussed in the succeeding section 5.8, Organization and Institution.

(1) River Zone

The river zone is established to administrate and manage the rivers and river structures in proper conditions. Objective rivers and stretches for the river zone are proposed in compliance with the future expansion of the urban area estimated from the land use plan by the Addis Ababa Master Plan.

1) Objective rivers and stretches

a) Bantyiketu river system : from confluence with Kebena river to head water
b) Kebena river system : from Aba Samuel lake to head water
c) West Akaki river system : from Aba Samuel lake to head water
d) Little Akaki river system : from confluence with West Akaki to head water
e) Hanku river system : from confluence with Kebena river to head water

2) Cross-sectional boundary of river zone

The following are cross-sectional boundary of the river zone and shown in Figure 5.24.

a) In case without flood protection wall
5 meters from present or proposed river bank line.
b) In case with flood protection wall
5 meters from flood protection wall.

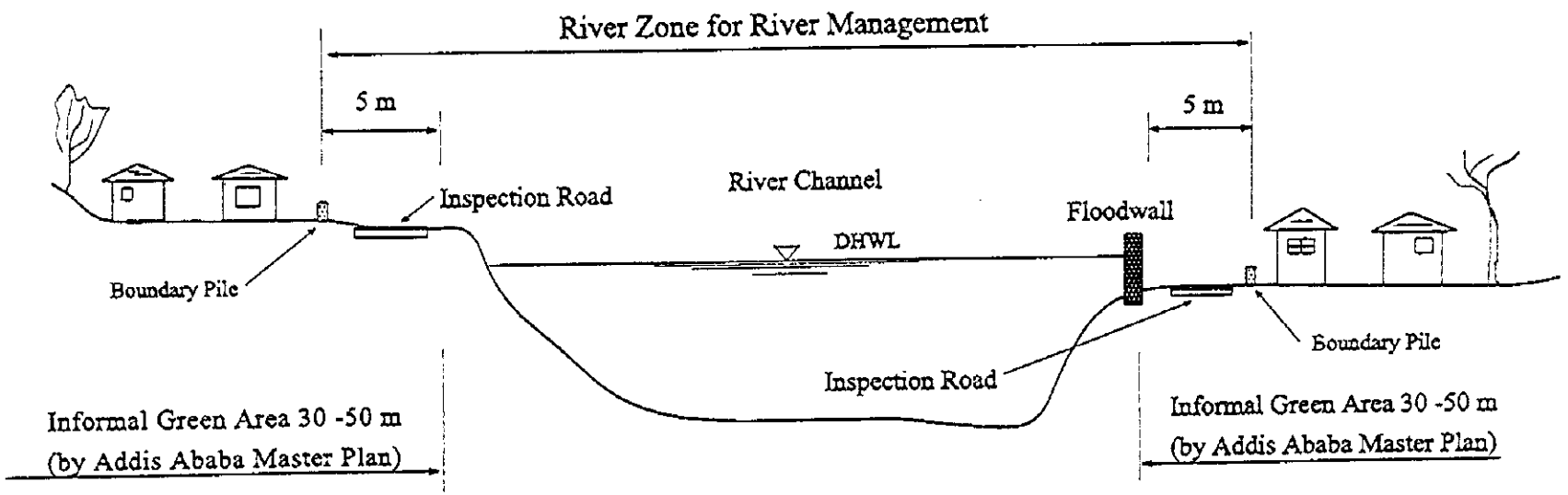


Figure 5.24 **Concept of River Zone for River Management**

For the above purpose, an institutional support with bylaw is required for an overall river management system. River Management and O/M Division is in charge of this matter. The following are required institutional support items.

a) Designation of the highest responsible administrator (President) in the river management for rivers and river structures,
b) Rivers, river stretches and river widths to be designated,
c) Regulation of land use in the riverine area,
d) Permission system for utilization and construction of facilities in the river zone, and
e) Regulation and penalty for illegal activities such as utilization of river zone without permission, garbage and soil dumping.

(2) Social Education

At present, many illegal activities have been observed in the river areas. These are dumping garbage and soil to river areas, and utilization of river areas and construction of private facilities without permission. AARMA is newly to manage such illegal ones.

Kebele and each community are principally responsible for the social education that is directed by AARB and AARMA (mainly by Administration Division). The social education is, at all times, programmed with community organizations. The programs are as follows.

a) Seminar for community leaders,
b) Seminar for people in each community,
c) Campaign through TV and radio,
d) Designation of River Day and annual River Festival (Love River),
e) Annual demonstration of flood fighting activity and
f) Commendation system for outstanding community.

(3) Flood Warning System

In order to mitigate the damage due to flooding as much as possible, a simple flood warning system is setup in Survey and Investigation Division of AARMA. AARMA takes charge of issuance of warning under the direction of AARB. The warning system comes into force firstly in the concerned area of the priority projects, as a pilot one. Then, the system is one after another applied to other areas.

Warning is issued based on the rainfall amount observed at the 3 rainfall observatory stations to be newly installed in the mountainous area and information obtained from National Meteorological Services Agency. In addition, 3 staff gauges are installed in the Kechene and Bantyiketu rivers. AARMA (Manager) is to issue warning by siren in accordance with the flowchart as shown in Figure 5.25.

(4) Flood Fighting System

In order to mitigate the flooding damage during flooding, a flood fighting system is established. The flood fighting system consists of flood prevention works mainly for prevention of the damage due to overtopping by using sandbags and evacuation of the concerned people for emergency case. In the same manner with the flood warning system, the flood fighting system is initiated in the concerned areas of the priority projects.

Each community of Kebele principally operates the system under the direction of AARB and AARMA (mainly by Survey and Investigation Division), as shown in Figure 5.26.

For this purpose, existing community organizations are assigned to this system as flood fighting teams. These communities actually operate the fighting system on the sites in cooperation with other organizations concerned such as NGO and Wereda Disaster Relief Cell. Participation of inhabitants is an essential requisite for this system and self-defense by communities is a basic factor of this system.

A communication and information system among AARMA (mainly by Survey and Investigation Division), Zone/Wereda, Kebele and each community is established. The flowchart of communication and information in the system is shown in Figure 5.26.

In order to operate the system effectively, periodical demonstrations (training) of the flood fighting system are required from the viewpoint of popularization and sustainability.

In the riparian areas, 5 storage houses for flood fighting are installed to keep necessary materials and equipment for activity use.

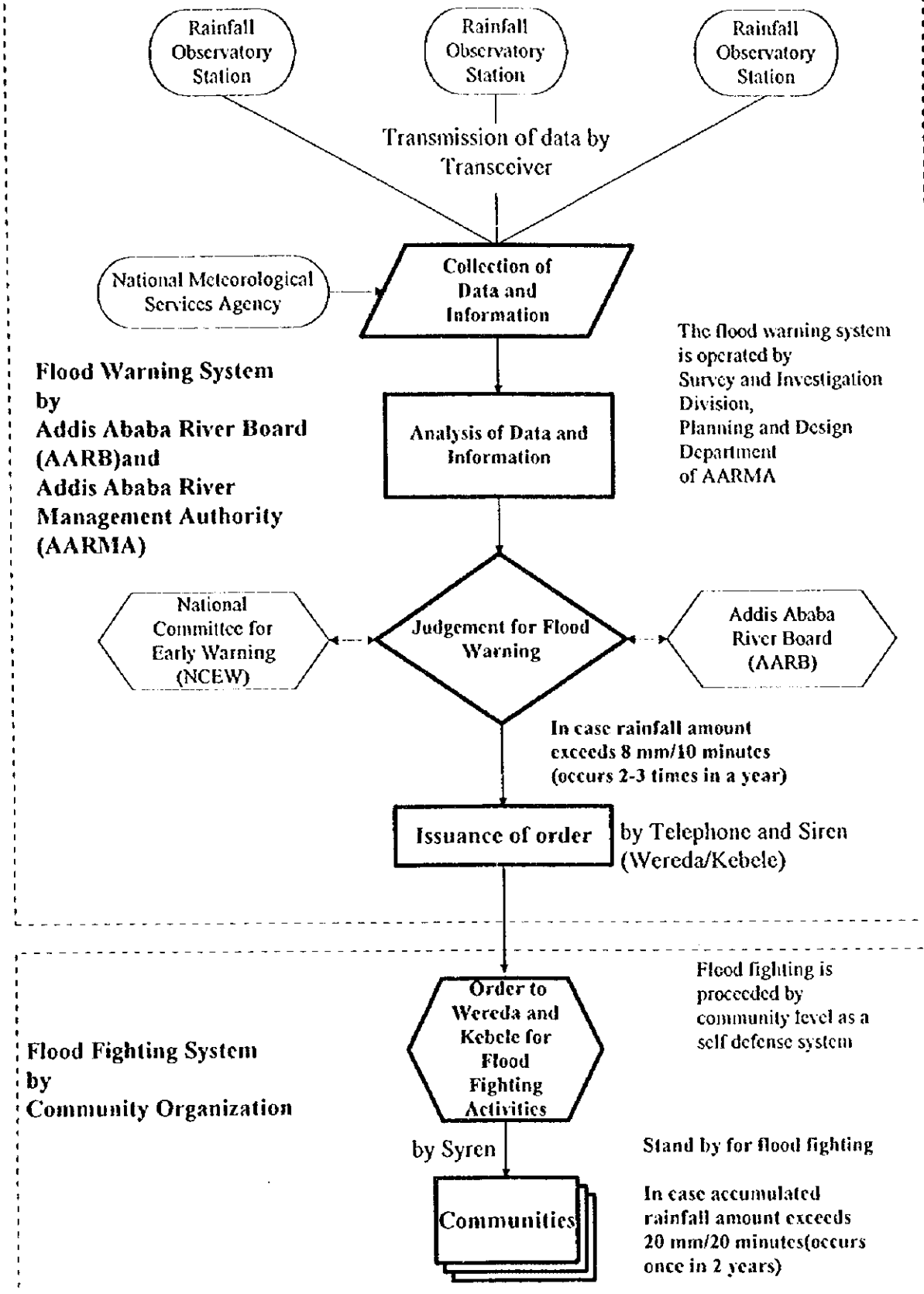


Figure 5.25 Outline of Flood Warning System

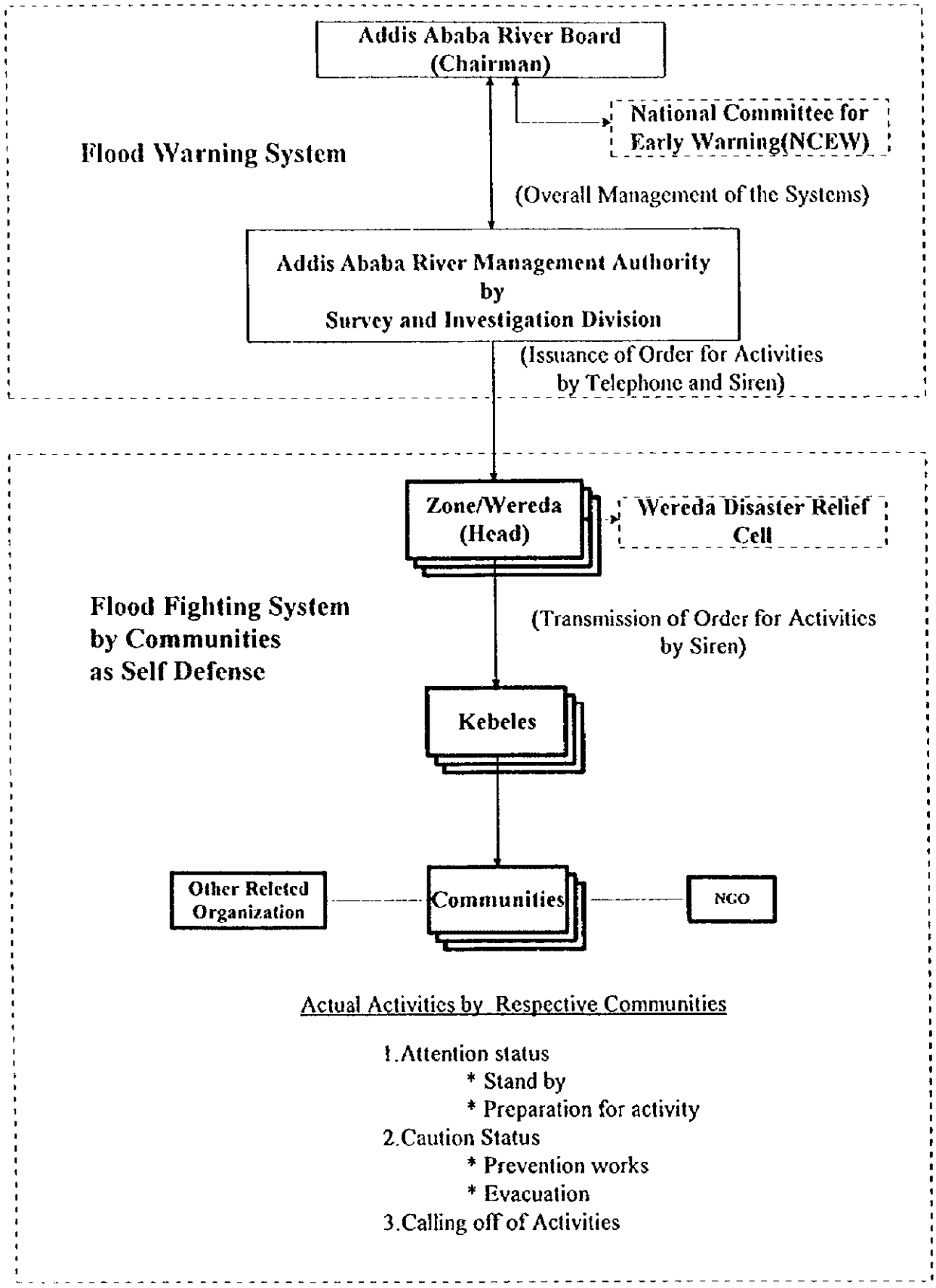


Figure 5.26 Community Organization and Communication Chart for Flood Fighting

5.5 Urban Drainage Plan

5.5.1 Basic Policies

Basic policies of drainage improvement plan in the target area are proposed for each sub-basin as follows:

(1) Northern Basin

The run-off from the Northern basin should be trapped just at the northern side of the Saba Square before entering into the rather low-lying area to decrease the drainage discharge to the Bantyiketu river from the target area.

(2) Eastern Basin

1) Sub-basin-E1

The run-off from the sub-basin-E1 should be trapped before passing over the Finfine bridge to decrease the drainage discharge to the Bantyikeri river from the target area.

2) Sub-basin-E2

The run-off from the sub-basin-E2 should be collected in front of the Finfine National Restaurant on the Yohanis Street and be leaded to the Bantyiketu river along the planned Bantyiketu Regulating Pond.

3) Sub-basin-E3

There exists no serious drainage problem in this area. Accordingly no plan of drainage improvement is proposed.

(2) West-southern Basin

1) Sub-basin-WS1

The run-off from the sub-basin-WS1 should be trapped on the Ras Danitew Street and be drained to the Bantyiketu river before joining the run-off from the sub-basin-WS2 to decrease the drainage discharge to the Bantyiketu river from the low-lying target area.

2) Sub-basin-WS2

The run-off from the sub-basin-WS2 should be discharged to the Bantyiketu river by additional drainage ditch around the Addis Ababa Stadium and along the Ras Danitew

Street before joing the run-off from the sub-basin WS2 to decrease the drainage discharge from the Abiot Square to the Bantyiketu river.

3) Sub-basin-WS3

The run-off from the sub-basin-WS3 should be discharged to the Bantyiketu river by additional drainage ditch along the Ras Mekonen Avenue from the Abiot Square.

5.5.2 Urban Drainage Plan

On the basis of the above-mentioned basic policy, the urban drainage plan is formulated as follows. Locations of the proposed drainage facilities are shown in Figure 5.27.

(1) Northern Basin

A drainage ditch with grating across the Churchil Avenue is planned on the northern side of the Saba Square. Then the trapped road surface water is planned to be leaded to the Kurtume river before flowing into the culvert under the Churchill Avenue. The design discharge for the new facilities is 0.7 m^3/sec.

(2) Eastern Basin

1) Sub-basin-E1

A drainage ditch with grating across the Menelik II Avenue is planned on the northern side of the Finfine bridge. Then the trapped road surface water is planned to be leaded to the Bantyiketu river just at the bridge site. The design discharge for the new facilities is 0.7 m^3/sec.

2) Sub-basin-E2

A drainage ditch is planned across the Yohanis Street and the road which meets the Yohanis Street in front of the Finfine National Restaurant, and the collected surface water is planned to be leaded to the Bantyketu river along the planned Bantyiketu regulating pond. In consideration of the existing conditions that the existing drainage pipeline is running underneath the planned regulating pond, the existing facilities need to be demolished and replaced with a new facilitie. Accordingly the design discharge for the new facilities is the design run-off from the objective run-off basin. The design discharge for the new facilities is 1.4 m^3/ssec.

(3) West-southern Basin

1) Sub-basin-WS1

A drainage ditch with grating across the Ras Danitew Street is proposed about 125 meters southern side of the crossroads of the Yohanis Street and the Ras Danitew Street. This facility is to drain the run-off water to the Bantyiketu river on the upstream side of the Cottage Restaurant about 60 meters downstream of the confluence of the Kechene and Kurtume rivers. The design discharge for the new facilities is 1.5 m^3/s.

2) Sub-basin-WS2

A drainage ditch with grating is planned across the street just northern side of the Addis Ababa Stadium, across the Ras Danitew Street, along the street and along the lane to the Addis Ababa Tennis Club to the Bantyiketu river. The design discharge for the new facilities is 1.5 m^3/s.

3) Sub-basin-WS3

Two drainage ditches with grating are planned; one across the street that meets the Ras Mekonin Avenue on the western side of the Abiot Square, across the Ras Danitew Street, and to the Bantyiketu river, the other across and along the Ras Mekonin Avenue. The latter ditch is to be connected to the street inlet that is presently located along the Ras Mekonin Avenue just over the drainage culvert connected to the Bantyiketu river. The design discharges for the new facilities are 1.1 m^3/s for the former and 0.5 m^3/s for the latter.

(4) Summary of Urban Drainage Plan

The basic features of the urban drainage plan are summarized in Table 5.9.

Table 5.9 Summary of Urban Drainage Plan

Drainage Basin	Sub-basin	Drainage Area (km^2)	Design Discharge (m^3/sec)	Features
Northern Basin		0.25	0.7	- Drainage Ditch with Grating and Leading Channel to River - Width : 0.8 m - Depth : 0.6 m - Length : 65 m
Eastern Basin	E1	0.23	0.7	- Drainage Ditch with Grating and Leading Channel to River - Replacement of Existing Drainage Pipeline - Width : 0.8 m - Depth : 0.8, 1.0 and 1.2 m - Length : 17 m
	E2	0.25	1.4	- Drainage Ditch with Grating and Leading Channel to River - Width : 0.8 m - Depth : 0.8 m - Length : 452 m
	E3	0.25	-	(Drainage improvement not required)
West-southern Basin	WS1	0.53	1.5	- Drainage Ditch with Grating and Leading Channel to River - Width : 0.8 m - Depth : 0.8 m - Length : 110 m
	WS2	0.54	1.5	- Drainage Ditch with Grating and Leading Channel to River - Width : 0.8 m - Depth : 1.3 and 1.55 m - Length : 187 m
	WS3	0.39 (Western)	1.1	- Drainage Ditch with Grating and Leading Channel to River - Width : 0.8 m - Depth : 0.8, 1.0 and 1.2 m - Length : 138 m
		0.17 (Eastern)	0.5	- Drainage Ditch with Grating Connecting to Existing Culvert - Width : 0.8 m - Depth : 0.5 and 0.75 m - Length : 93 m

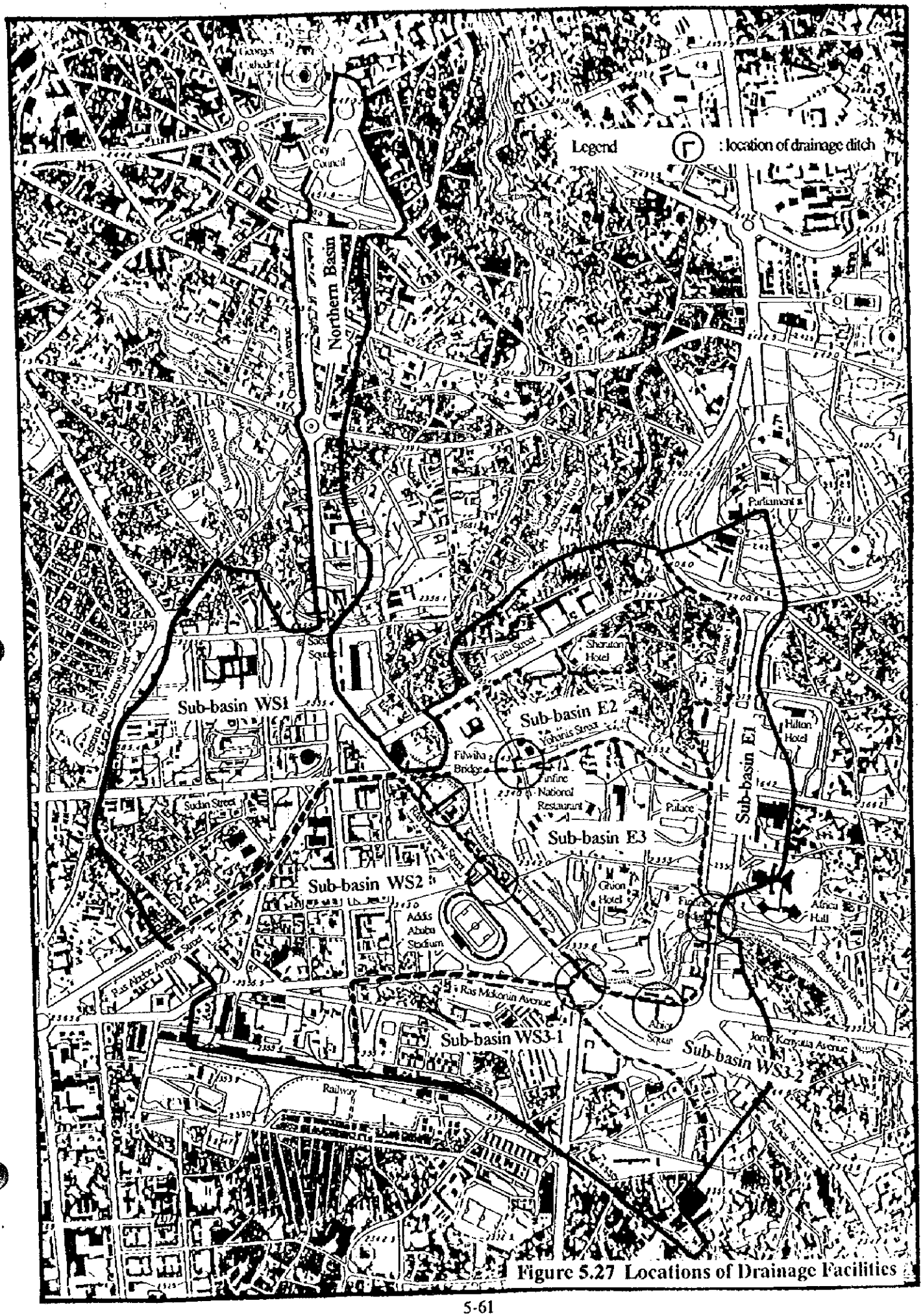


Figure 5.27 Locations of Drainage Facilities

5.6 Design of Facilities

5.6.1 Basic Concept and Methodology

In the feasibility study, the following flood control and urban drainage facilities are designed.

Table 5.10 Facilities of Priority Project

Facility	Location	Remarks
Flood Control Facilities		
1. River Improvement		
(1) Earth Dyke	Near the Kebena and Bulbula Vegetable Garden in a downstream stretch along the Bantyiketu river	
(2) Flood Wall	Eight sites at the Bantyiketu river ; a site at the Kechene river	
(3) Slope Protection Work	Immediately upstream from the Bole Bridge along the Kebena river ; Immediately downstream from the existing irrigation intake weir of the Kebena and Bulbula Vegetable Garden ; Immediately upstream from the Bantyiketu bridge (Total 3 sites along the Bantyiketu river)	
(4) Other structures		
1) Irrigation Intake Weir	In the Kebena and Bulbula Vegetable Garden in a downstream stretch of the Bantyiketu river	Due to riverbed excavation, the height of the existing weir is to be lowered. The new weir is to be built upstream from the existing weir site.
2) Aqueduct of a Water Supply Pipe of AAWSA	Near the Asmera Road along the Bantyiketu river	The aqueduct is to be reconstructed to secure freeboard against the design discharge.
3) Crossings of Sewerage Pipe beneath Riverbed	Near the National Hotel along the Bantyiketu river	The two crossings are to be reconstructed due to riverbed excavation.
2. Regulating Pond	One at the Kostre river (a tributary of the Kechene river) and the other at Bantyiketu river	
3. Flood Control Weir	In an upstream stretch of the Kechene river	
Urban Drainage Facilities		
1. Drain Ditches	At the Finfine bridge; At the Abiot square; Near the Addis Ababa Stadium; Near the Finfine National Restaurant; Near the Saba Square	

Basic concepts of design are that structures have to be 1) durable, 2) operated unmanned, 3) free from maintenance, and 4) be made of locally available materials.

In design, Ethiopian standards, criteria and design practices are used as much as possible. For facilities or part of facilities including earth dyke, slope protection work, an irrigation intake weir and a flood control weir, of which no relevant Ethiopian standards and criteria are available, Japanese standard and criteria are to be applied. The standards and criteria applied in design are as follows.

a) Ethiopian Building Code Standard (1995 edition) published by Ministry of Works and Urban Development
b) EBCS-1, Basis of Design and Actions on Strucutures
c) EBCS-2, Structural Use of Concrete
d) EBCS-7, Foundations
e) EBCS-8, Design of Structures for Earthquake Resistance
f) Design Standard of River and Sabo Structures (September 1997 edition) published by the Ministry of Construction, Government of Japan
g) Free Frame Method of Slope Protection, Guideline of Design and Construction, (Third edition) published in January 25, 1996, by Free Frame Association, Japan
h) Guideline of Drainage Facilities (June 1987 edition) published by Japanese Road Association, Japan
i) Standard Design Drawings of Civil Structures No.1 (Drain Ditch, Pipe Culvert, Box Culvert) published by the Ministry of Construction, Government of Japan

5.6.2 Flood Control Facilities

(1) River Channel Improvement

The locations of facilities related to river channel improvement such as earth dyke, flood wall, slope protection work, an irrigation intake weir, an aqueduct of a water supply pipe of AAWSA and crossing of sewerage pipe beneath riverbed are shown on Figures 5.28 to 5.31.

The Lower Kechene river meanders significantly upstream from the 2nd bridge. Gnerally, at the outermost points of meandering sections, water rise is expected to take place due to centrifugal force and in the Lower Kechene river, the water rise is

estimated at about 1.5 meters for the design discharge (85 m^3/s). However, the existing flow capacity of the Lower Kechene river far exceeds the design discharge and all houses along this stretch of the Lower Kechene river are built on banks more than 5 meters higher than riverbeds. Therefore, all houses situated at outermost points of meandering sections are considered to be immune from inundation caused by water rise due to centrifugal force, and no structural measures are conceived for such water rise.

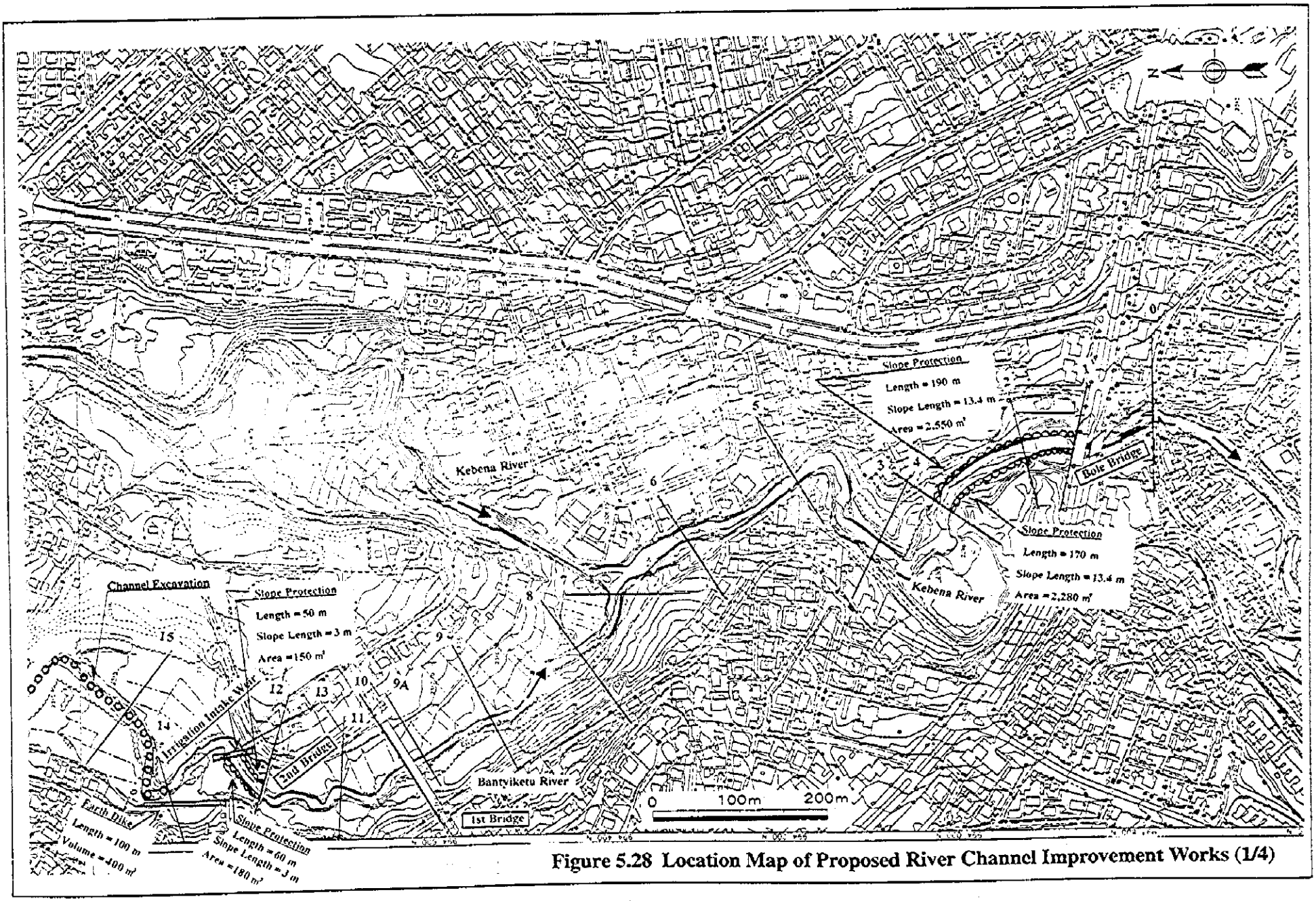


Figure 5.28 Location Map of Proposed River Channel Improvement Works (1/4)

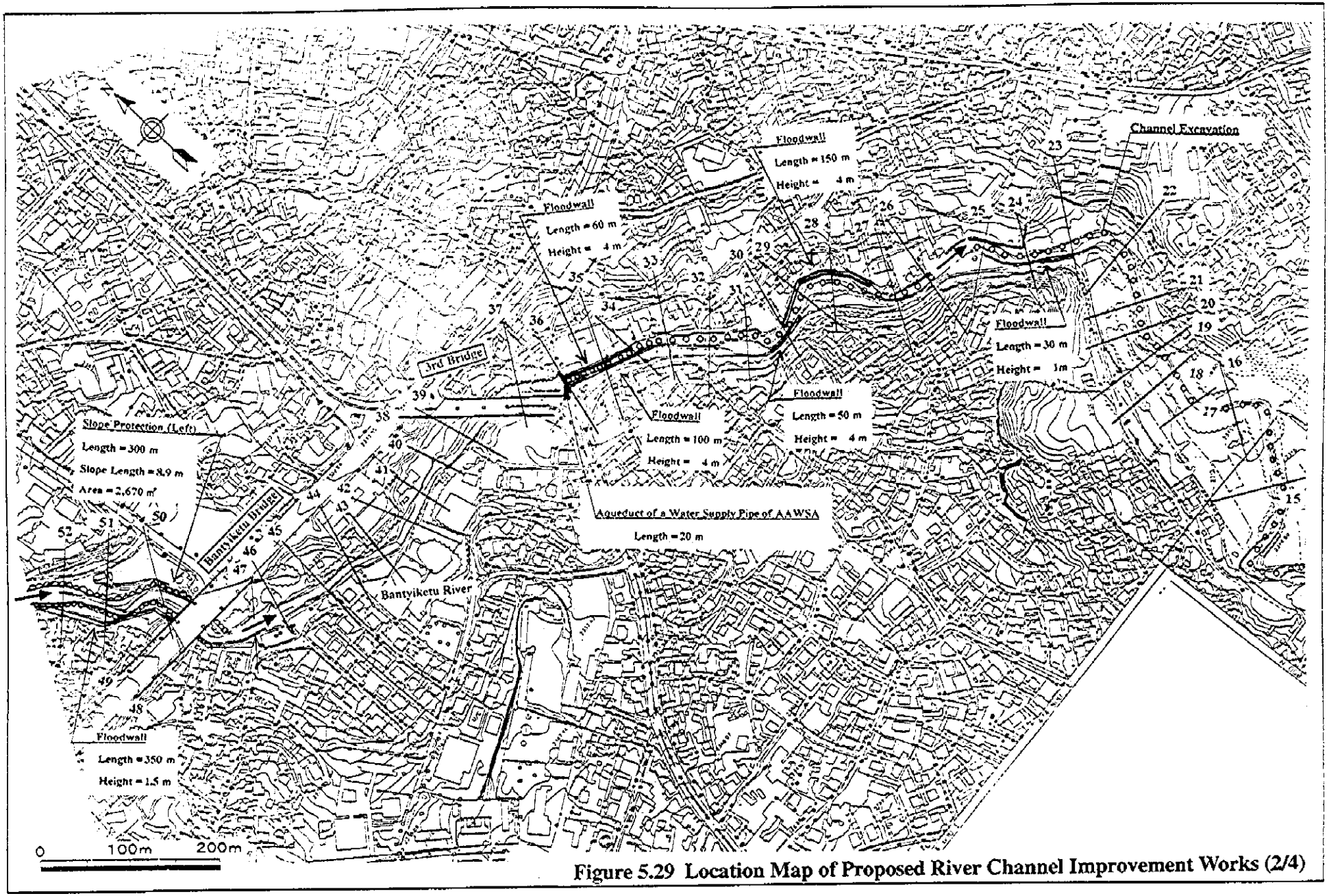


Figure 5.29 Location Map of Proposed River Channel Improvement Works (2/4)

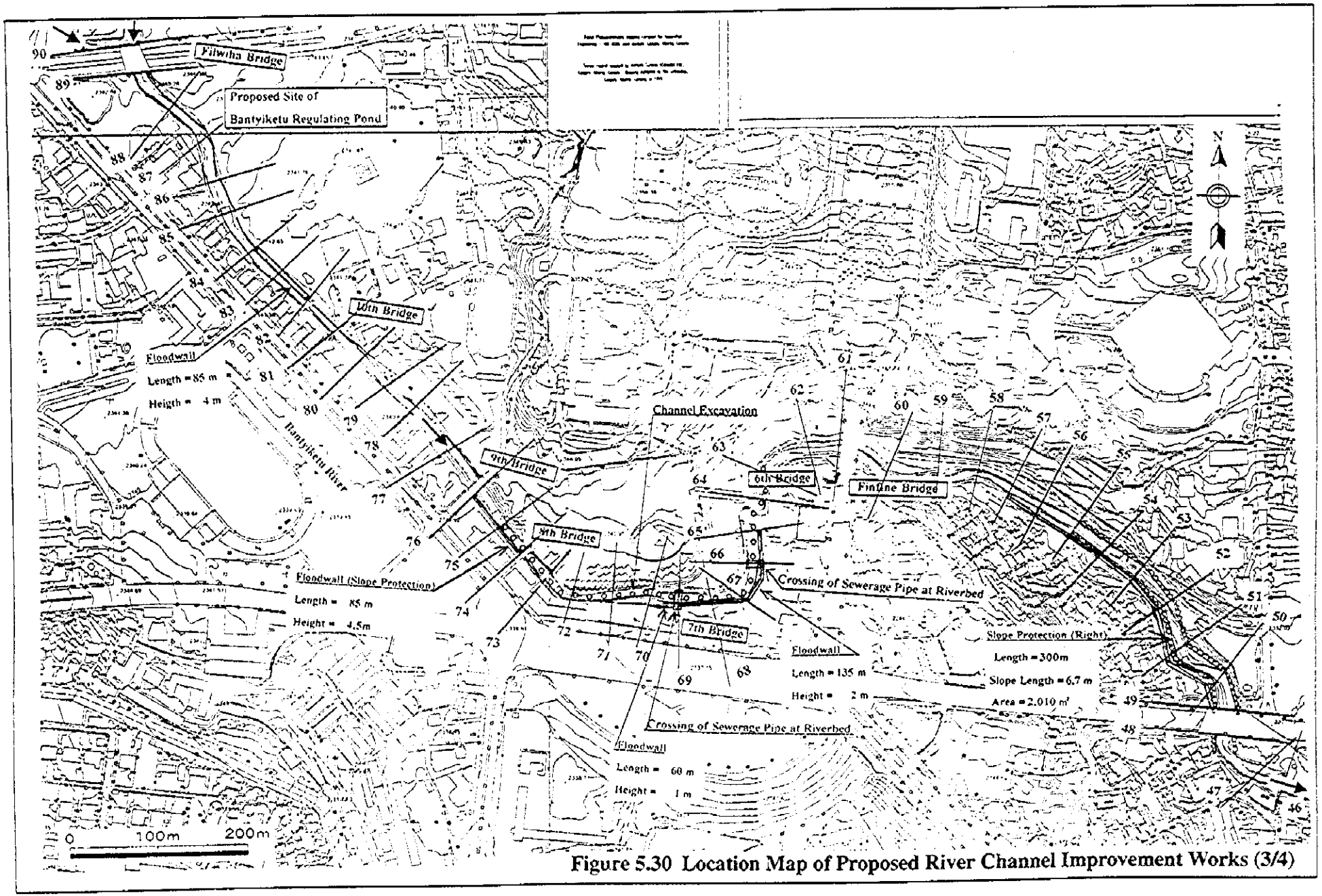


Figure 5.30 Location Map of Proposed River Channel Improvement Works (3/4)

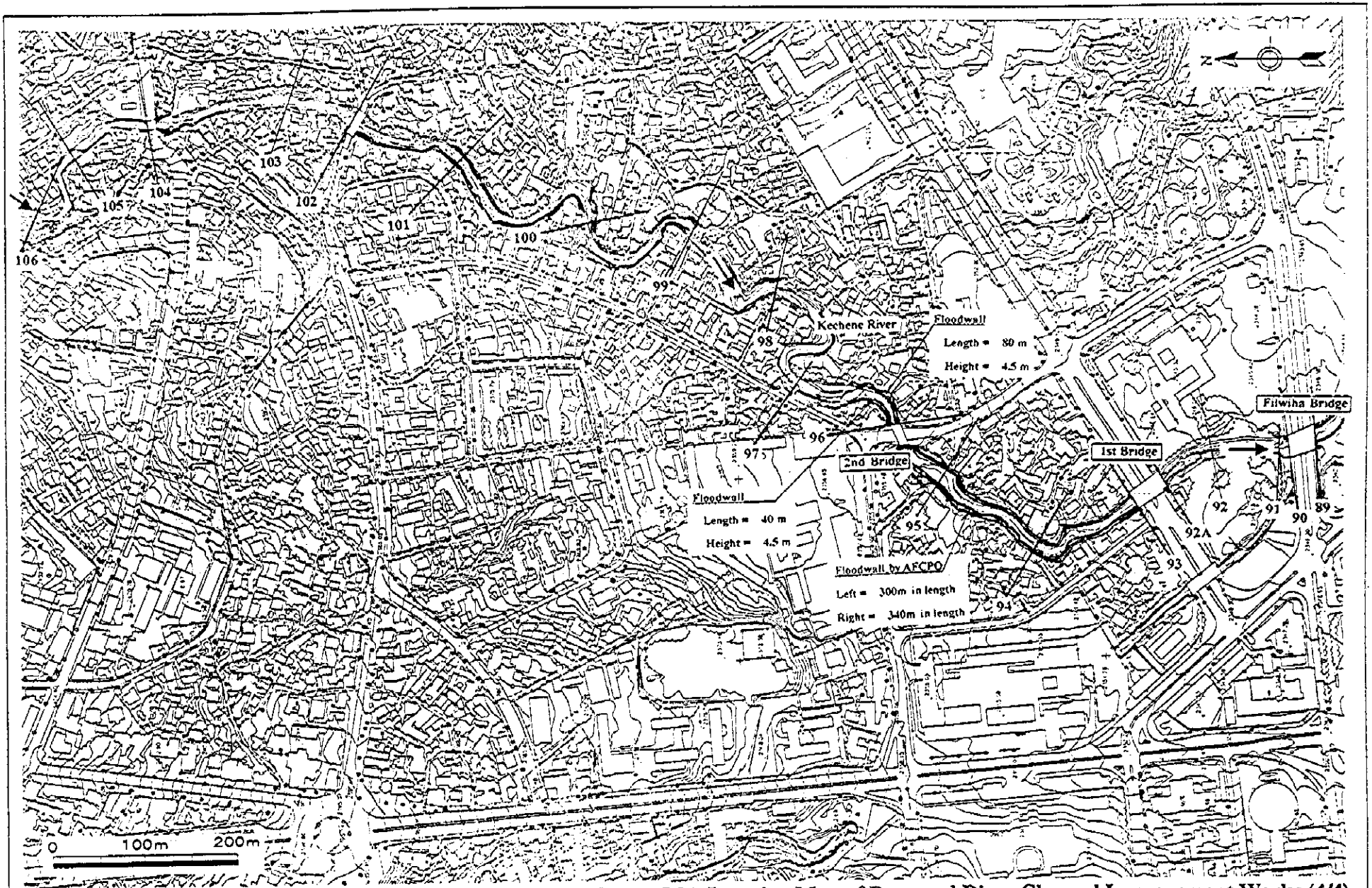


Figure 5.31 Location Map of Proposed River Channel Improvement Works (4/4)

1) Earth Dyke

The proposed earth dyke is to be built at the right bank of the Bantyiketu river, near the Kebena and Bulbula Vegetable Garden. Its major features are as shown below.

Table 5.11 Major Features of Earth Dike

	Major Features	Remarks
Crest Elevation	0.6m of freeboard above design high water level	In compliance with Design Standard of River and Sabo Structures published by the Ministry of Construction, Government of Japan
Crest Width	3 m	(do)
Slope	1 (Vertical) to 2.0 (Horizontal)	(do)
Height	About 1m	
Length	About 100m	
Material of Dyke	Material available near the proposed construction site	In compliance with EBCS-7, Foundations, Ethiopian Building Code Standard published by Ministry of Works and Urban Development
Material of Revetment	Gabion Mattress	

The earth dyke is proposed in the brim of a natural flood retarding basin situated immediately upstream from the existing irrigation intake weir of the Kebena and Bulbula Vegetable Garden and flow velocity during floods is expected small. Hence, gabion mattresses are to be used for revetment of earth dyke. The typical cross-section of earth dyke is shown on Figure 5.32.

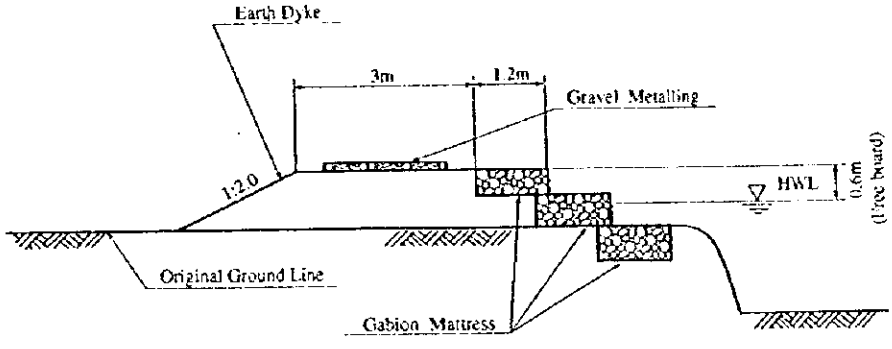


Figure 5.32 Typical Cross Section of Earth Dyke

2) Flood Wall

The floodwalls are designed based on the current design practice of the Addis Ababa Flood Control and Prevention Project Office (AFCPO). These are to be made of wet masonry and be built at eight sites of the Bantyiketu river and at a site of the Kechene river and their major features are as follows. The typical cross-section of floodwall is shown on Figure 5.33.

Table 5.12 Major Features of Flood Wall

	Major Features	Remarks
Crest Elevation	0.6m of freeboard above design high water level	In compliance with Design Standard of River and Sabo Structures published by the Ministry of Construction, Government of Japan
Height	1m to 4m at the Bantyiketu river 4.5 m at the Kechene river	
Length	About 1,100 m at the Bantyiketu river About 120 m at the Kechene river	
Slope	Vertical at the same side with river	In compliance with AFCPO's design practice
	1 (Vertical) to 0.4 (Horizontal)	Determined from the stability analysis in compliance with AFCPO's design practice
Material	Wet masonry	In compliance with AFCPO's design practice

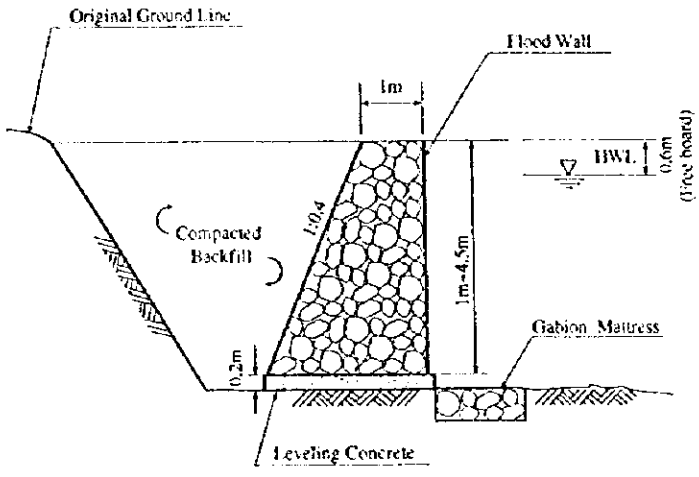


Figure 5.33 Typical Cross Section of Flood Wall

3) Slope Protection Work

Slope protection work is proposed to protect from torrent during floods the mild slopes of silty or clay soils at three sites in residential areas. These are immediately upstream from the Bole Bridge along the Kebena river, immediately downstream from the existing irrigation intake weir of the Kebena and Bulbula Vegetable Garden and immediately upstream from the Bantyiketu bridge. Major features of slope protection work are shown below.

Table 5.13 Major Features of Slope Protection

Major Features		Remarks
Method of Slope Protection	Free Frame Method	
Frame		
Cross-sectional Dimensions	0.3m × 0.3m (Square)	In compliance with Free Frame Method of Slope Protection, Guideline of Design and Construction, published in January 25, 1996, by Free Frame Association, Japan
Length between a center of frames	2.3m	(do)
Reinforcing bars in a cross section	D16 × 4 pieces	(do)
Reinforcing bars for stirrup	D13	(do)
Anchor Pin (Reinforcing bar)	D16, L=1m	Placed at every node and a middle of nodes along frames
Filling between frames	Concrete of 15 cm in thickness	
Filter mat	Made of non-woven polyester	
Weep hole	1 piece every $2m^2$; Made of galvanized steel with inside diameter of 5cm	In compliance with Design Standard of River and Sabo Structures published by the Ministry of Construction, Government of Japan

Flood flows at the three sites are expected to become too turbulent and swift to apply gabion mattress. Revetment of wet masonry, though it is rigid, is less flexible so that there is a great chance of creating voids behind revetment. For this reason, the free frame method is proposed for slope protection. Extensively used for the protection of slopes along rivers, reservoirs, roads in Japan, the free frame method forms grids of cement mortar with square cross-sections, armored by reinforcing bars, and places concrete of about 15 cm in thickness between grids. To prevent loss of soils behind the slope protection work by suction, mats made of non-woven polyester is placed

underneath. Weep holes of galvanized steel are provided. The typical plan and cross-section of slope protection work is shown on Figure 5.34.

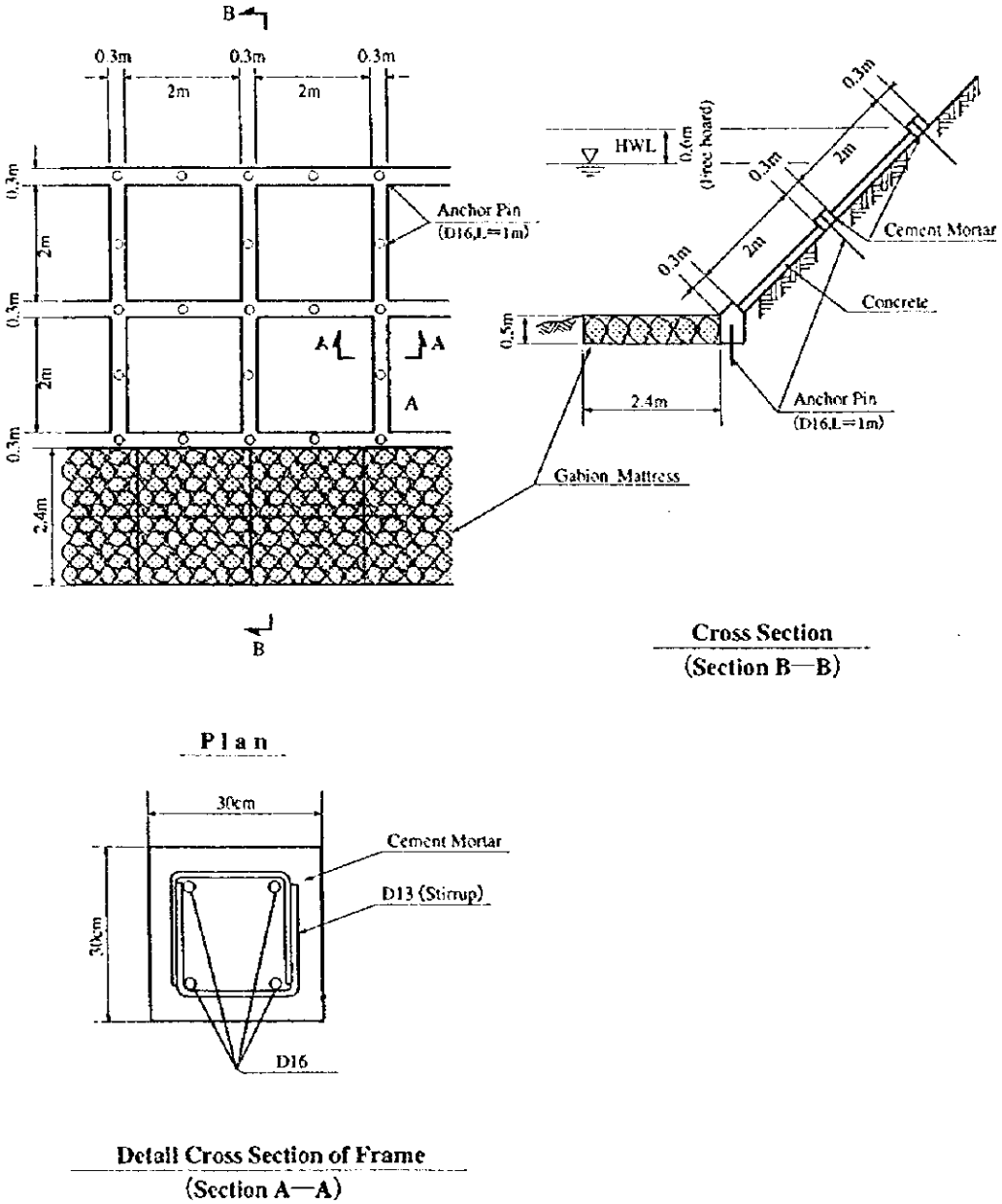


Figure 5.34 Typical Plan and Cross Section of Slope Protection

4) Other structures

a) Irrigation Intake Weir

There exists an irrigation intake weir made of wet masonry, about 5 meters in height and about 20 meters in crest length, in a downstream stretch of the Bantyiketu river to divert water to the Kebena and Bulbula Vegetable Garden.

The crest elevation of overflow section of the existing weir is estimated at 2,312.9 meters based on the topographic survey and has to be lowered to design riverbed elevation of 2,311 meters determined by this study. For this reason, the crest of the existing irrigation intake weir is to be demolished and a new weir made of wet masonry is to be built about immediately upstream from the existing weir site to insure water supply to the Kebena and Bulbula Vegetable Garden. Major features of a new irrigation intake weir and a new irrigation canal are as follows.

Table 5.14 Major Features of Irrigation Intake Weir

Irrigation Intake Weir	
Height	2 m
Crest Length	30 m
Construction Material	Wet Masonry
Irrigation Canal	
Inside Dimensions	2 m wide × 2 m high (The same as existing one)
Length	10 m
Construction Material	Wet Masonry

b) Aqueduct

There exists an aqueduct of water supply pipe of Addis Ababa Water and Sewerage Authority (AAWSA) crossing the Bantyiketu river near the Asmera Road. As of January 1998, grasses and trashes carried by floods are seen hung on the aqueduct, which may indicate that current flow area at the location is not sufficient enough in terms of safety of the aqueduct.

The aqueduct is to be reconstructed in order to secure a specified freeboard above the design high water stage for probable 30-year flood.

As of December 1997, flood walls are under construction along the left bank of the aqueduct by financing from the Ethiopian Social Rehabilitation and Development Fund

(ESRDF), the Region 14 Administration and the Kebele 34 to protect areas along the left bank from flooding and inundation. By the construction of new flood walls, the aqueduct is not affected but a footpath furnished above the aqueduct becomes defunct. Hence, the reconstruction of the aqueduct contemplated by this study excludes the reconstruction of the footpath.

c) Crossings of sewerage pipe beneath riverbed

There are three sites where existing sewerage pipes of Addis Ababa Water and Sewerage Authority (AAWSA) cross riverbed, namely, two sites near the National Hotel along the Bantyiketu river and a site immediately upstream from the Filwiha bridge, at the confluence of the Kechene river and the Kurtume river. Among the three sites, the two crossings near the National Hotel along the Bantyiketu river have to be reconstructed because riverbed at the sites is to be excavated down to design riverbed determined by this study. Like the existing crossings, the new sewerage pipes are to be wrapped with reinforced concrete for protection, where they cross the riverbed.

(2) Bantyiketu and Kostre Regulating Ponds

The proposed Bantyiketu regulating pond is to be built at the left bank, immediately downstream from the Filwiha bridge along the Yohanis street, amid a busy downtown area. The foundation rock at the proposed site of the regulating pond is considered to be basalt, the same as the rock outcropped at the adjacent riverbed and its depth below ground surface is about 3 meters, lying as deep as the outcropping rock at the riverbed. A sewerage pipe of Addis Ababa Water and Sewerage Authority (AAWSA) underlying the proposed site is to be relocated.

The proposed Kostre regulating pond is to be constructed at the left bank of the Kostre river, a tributary of the Kechene river, immediately downstream from a bridge along the Dejazmach Haile Silase street. Geologically, the foundation rock at the proposed site of the regulating pond is considered to be basalt, the same as the rock outcropped at the adjacent riverbed and its depth below ground surface is about 5 meters, lying as deep as the outcropping rock at the riverbed.

The regulating ponds are constructed by excavation of the ground in riparian areas. Along the riverside of the pond, a side overflow dyke and an outlet facility are built. The side overflow dyke is built by excavation and reshaping of the present ground and

armoring by wet masonry along its surface. In order to drain impounded water to the outlet facility, drain ditches are constructed along the rim of the bottom of the pond.

The outlet facility of the Kostre regulating pond is made of wet masonry, furnished with a flap gate. The flap gate is selected for fulfilling unmanned operation. Floods are designed to flow into the pond through the side overflow dyke and are returned through the flap gate to the river when the river water has receded. The flap gate made of stainless steel is proposed from the aspect of maintenance-free policy.

For the purpose of avoiding scouring, gabion mattresses are placed on both the riverbed and the pond's bed next to the side overflow dyke as well as the riverbed adjacent to the outlet facility.

The plans of both the Kostre and the Bantyiketu regulating ponds are shown on Figure 5.35 and Figure 5.36, respectively.

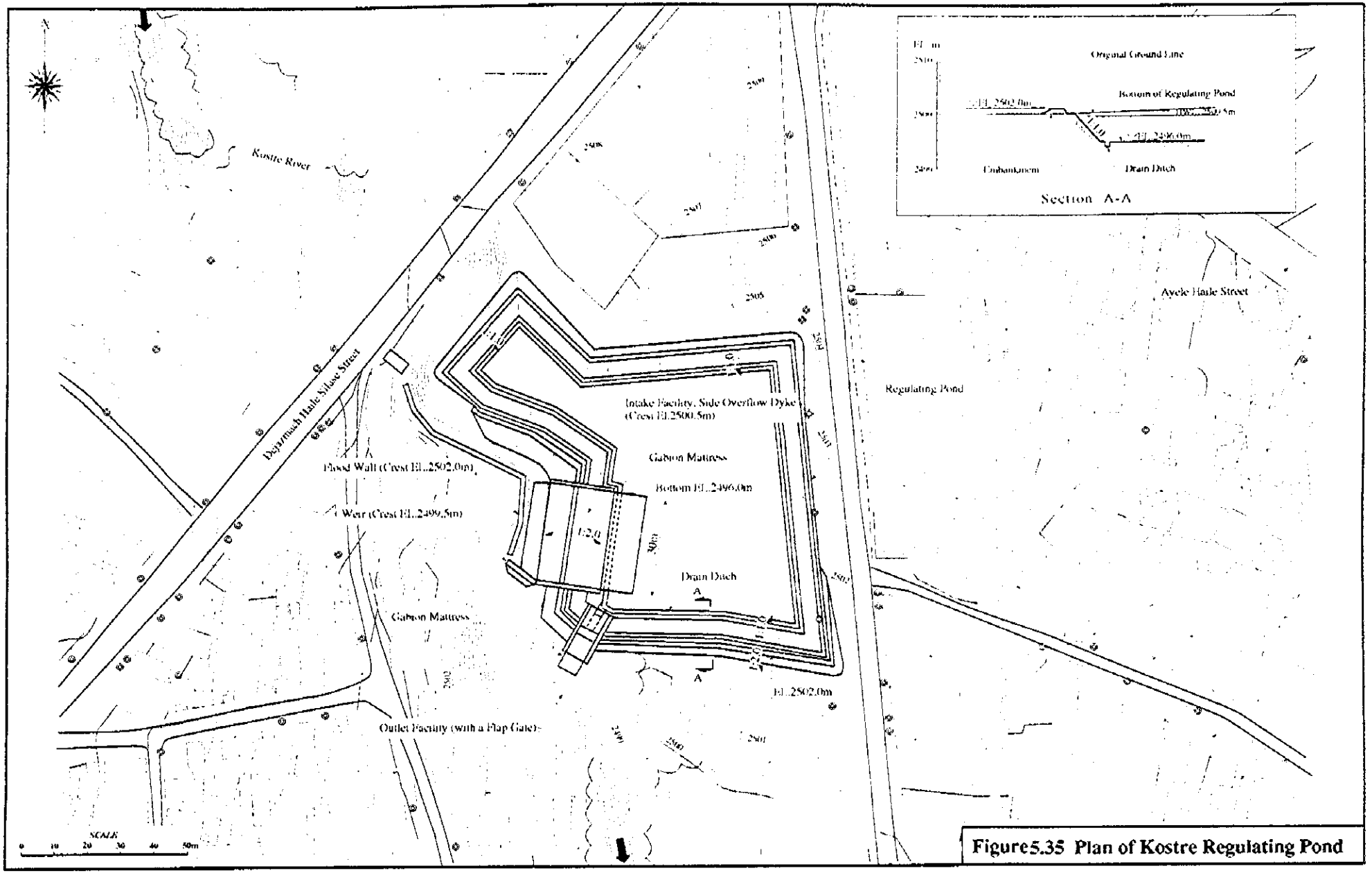


Figure5.35 Plan of Kostre Regulating Pond

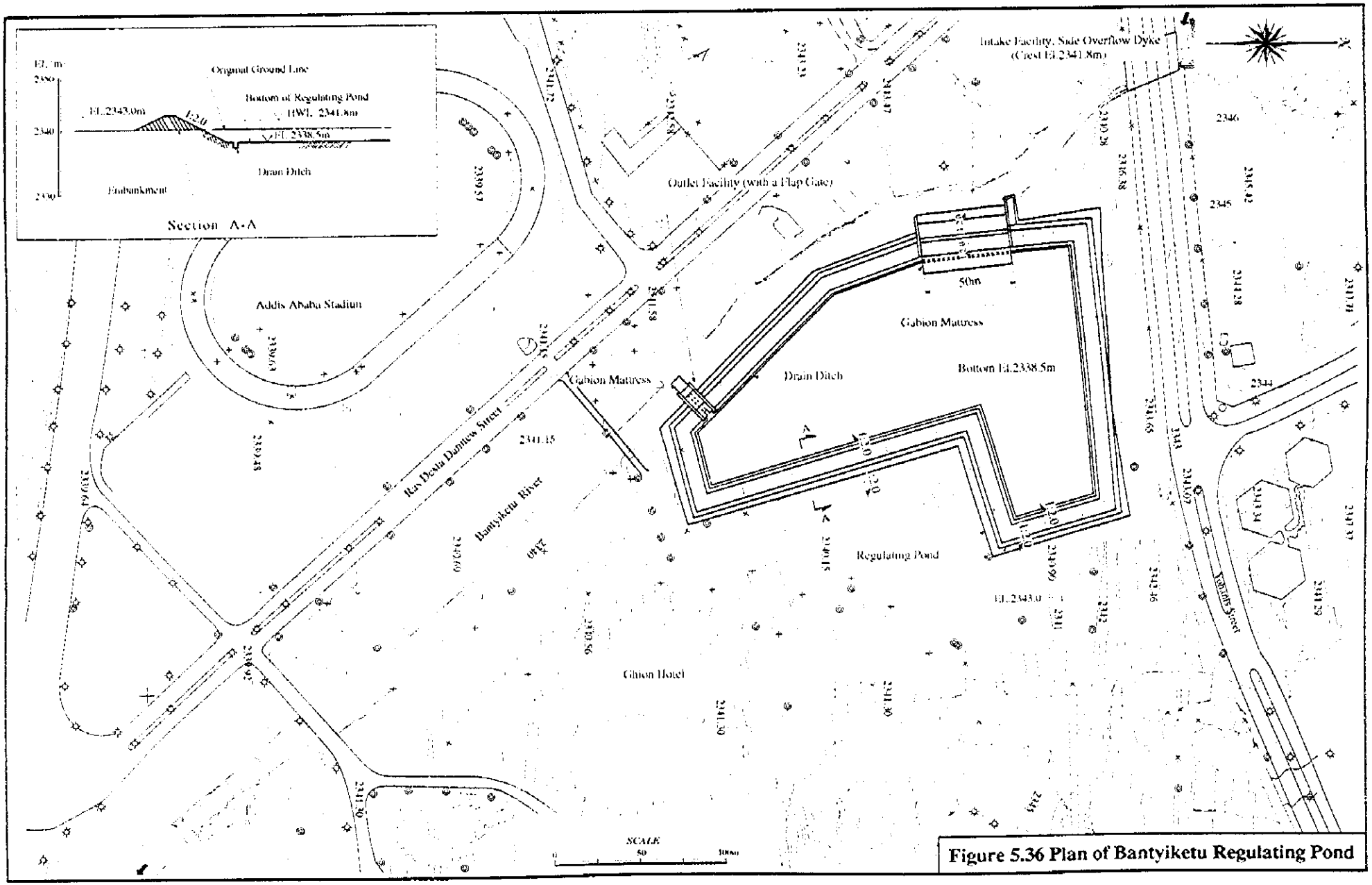


Figure 5.36 Plan of Bantyiketu Regulating Pond

Dimensions obtained from the hydraulic analyses in Sec.5.4.2 (3) are finalized by scrutinizing topographic maps from structural aspects. The major features of the two ponds are tabulated as follows.

Table 5.15 Major Features of Regulating Pond

		Bantyiketu pond	Kostre pond
Reservoir storage volume		73,000 m^3	26,000 m^3
Surface area at highest water stage		29,900 m^2	6,500 m^2
Bottom elevation of pond		2338.5 m	2496.0 m
Side overflow dyke	Crest elevation	2341.8 m	2500.5 m
	Crest length	50 m	30 m
	Height above bottom of pond	3.3 m	4.5 m
	Height above riverbed	4.8 m	3.5 m

(2) Kechene Weir

The proposed Kechene weir has 5 km^2 of catchment area, located in the upstream stretch of the Kechene river, adjacent to a cemetery named Medhane Alem.

Geologically, the proposed weir site is underlain by basalt, without distinct joints/cracks and with sufficient strength to be suitable for foundation of the proposed weir. The basalt is overlain by sandstone at the left abutment and tuff at the right abutment, both of which are highly weathered and jointed and as deep as maximum 5 meters from the ground.

The weir is designed based on Design Standard of River and Sabo Structures (September 1997 edition) published by the Ministry of Construction, Government of Japan. The seismic coefficient to determine the slope of both upstream and downstream faces of the weir in stability analysis is derived from EBCS-8, Design of Structures for Earthquake Resistance, Ethiopian Building Code Standard (1995 edition) published by Ministry of Works and Urban Development and is estimated at 0.1.

The proposed weir consists of a main weir, a sub weir and a stilling basin. A sub weir is situated at the downstream end of a stilling basin. The type of both the main weir and the sub weir is concrete gravity. The stilling basin is made of reinforcing concrete.

Downstream from the sub weir, gabion mattresses are furnished on the riverbed to prevent scouring and erosion.

To make operation unmanned, the emergency spillway at the crest of the main weir and the non-emergency spillway near the bottom of the main weir are ungated. The emergency spillway is designed for probable 100-year flood and spilling takes place only in the event of floods larger than the design flood with recurrence period of 30 years. The non-emergency spillway consists of three square orifices, the size of 1.2 m × 1.2 m each, near the bottom of the weir, is to discharge floods equal to or smaller than the design flood with recurrence period of 30 years, as well as instream flow required in downstream areas.

In this context, the reservoir remains empty most of the time even during rainy season because of the non-emergency spillway. And the reservoir water rarely rises to as high elevation as the crest of overflow section of the main weir and stays less than two hours in such a high water stage even such a rise takes place. The stability of the main weir without impounding water in the reservoir is emphasized in design.

Major features of the proposed weir are as follows.

Table 5.16 **Major Features of Kechene Weir**

	Type	Concrete Gravity
Crest Elevation	Non-overflow Section	2,512.5 m
	Overflow Section	2,509.0 m
Reservoir Regulating Volume	Gross (Between EL.2,493.0 m and EL.2,509.0 m)	96,000 m^3
	Effective (Between EL.2,499.0 m and EL. 2,509.0 m)	88,000 m^3
Lowest Elevation		2,493.0 m
Maximum Height	Non-overflow Section	19.5 m
	Overflow Section	16.0 m
Crest Length		120 m
Slope of Upstream Face	Between EL.2,512.5 m and EL.2,509.0 m	Vertical
	Below EL.2509.0 m	1 (Vertical) to 0.2 (Horizontal)
Slope of Downstream Face	Between EL.2,513.0 m and EL.2,509.0 m	Vertical
	Below EL.2509.0 m	1 (Vertical) to 0.7 (Horizontal)
Emergency Spillway	Type	Ungated
	Crest Length	20 m
Non-emergency Spillway	Type	Ungated
	Number of Orifices	3
	Threshold Elevation	2,499.0 m
	Dimensions of an Orifice	Square of 1.2 m × 1.2 m

For making it easy for local people to cross the river at the proposed weir site, a bridge of two spans, the length of a span about 10 meters, are to be provided at the emergency spillway. In addition, guard rails are to be furnished along the upstream and downstream sides of the weir crest to secure the safety of pedestrians.

The plan, downstream view and longitudinal profile of the weir are shown on Figure 5.37 and Figure 5.38. These figures and the reservoir storage volume curve are depicted on or on the basis of the 1/2,000-topographical maps published in 1995 for Addis Ababa Water Supply Project Stage III A, as well as a river cross section at the weir axis made by topographic survey.

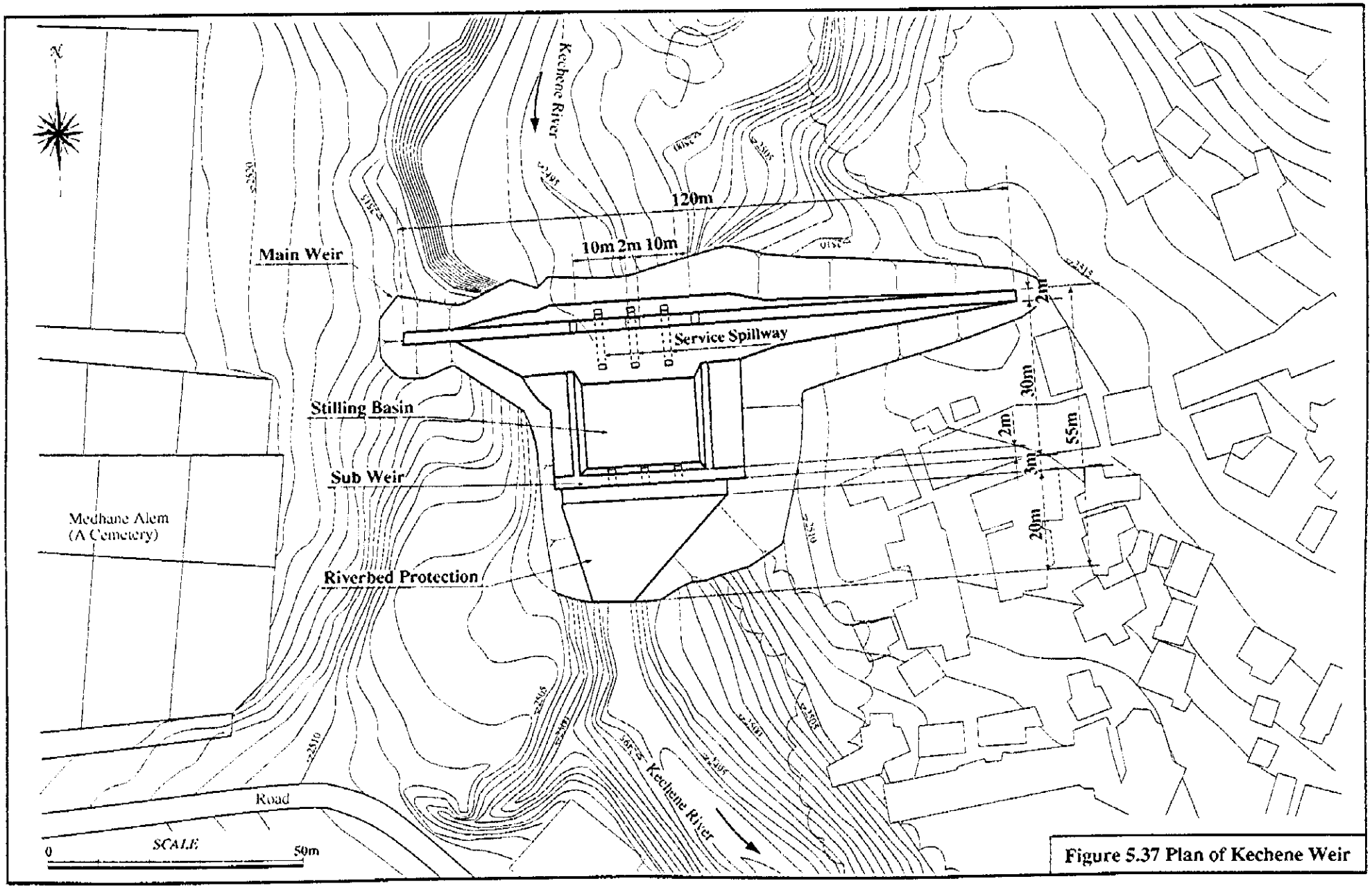
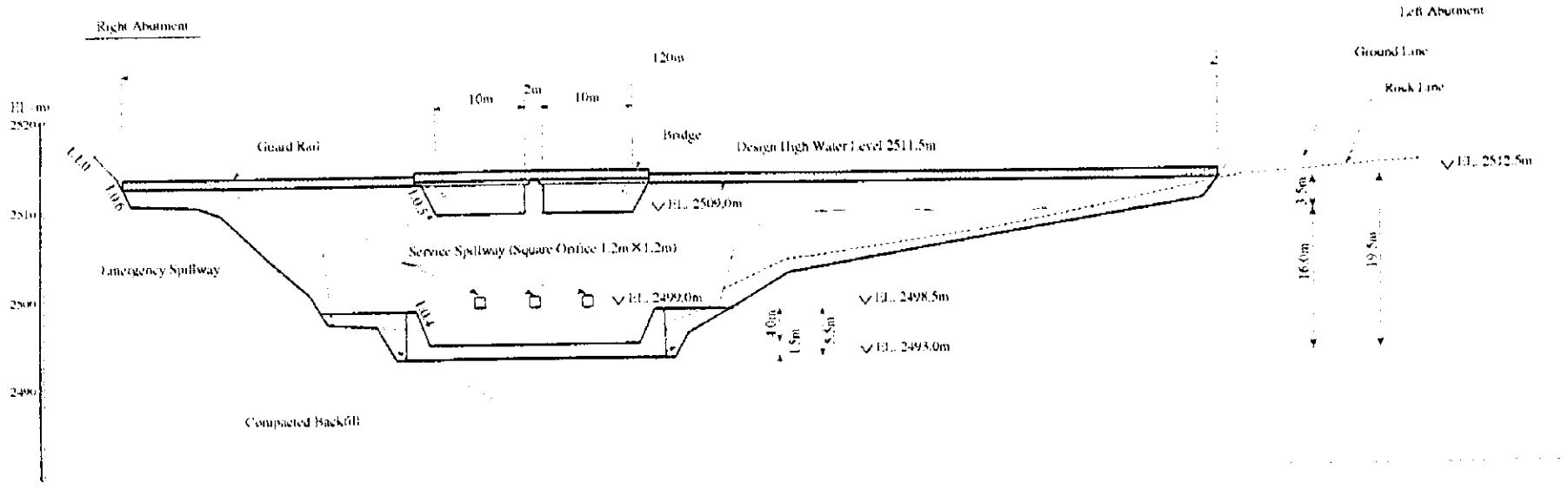
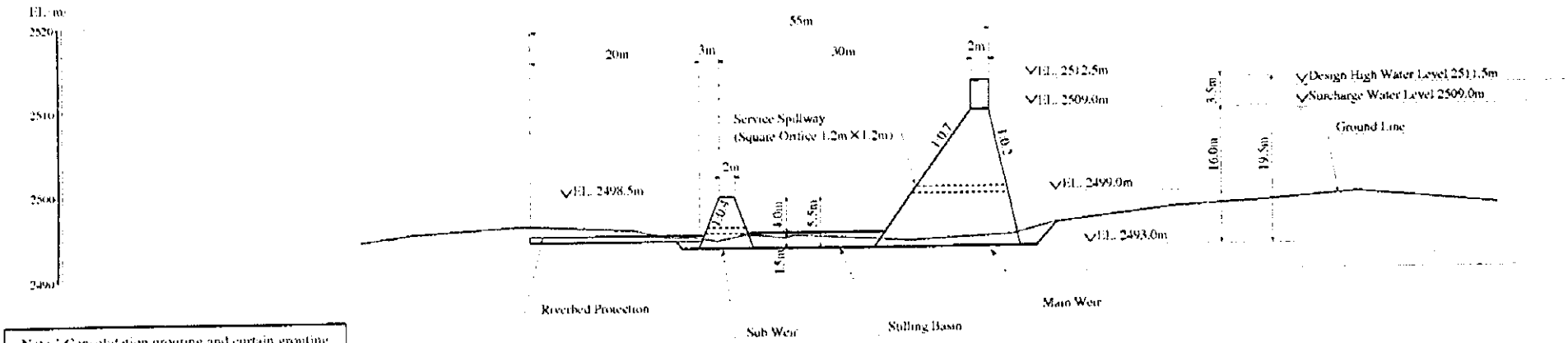


Figure 5.37 Plan of Kechene Weir

DOWN STREAM VIEW OF MAIN WEIR



LONGITUDINAL PROFILE



Note : Consolidation grouting and curtain grouting are to be applied to foundations if their necessity is substantiated by geological investigations.

Figure 5.38 Down stream View and Longitudinal Profile of Kechene Weir

5.6.3 Urban Drainage Facilities

For all of the seven drainage basins, two kinds of drain ditches are contemplated depending on its purposes and loading conditions as follows.

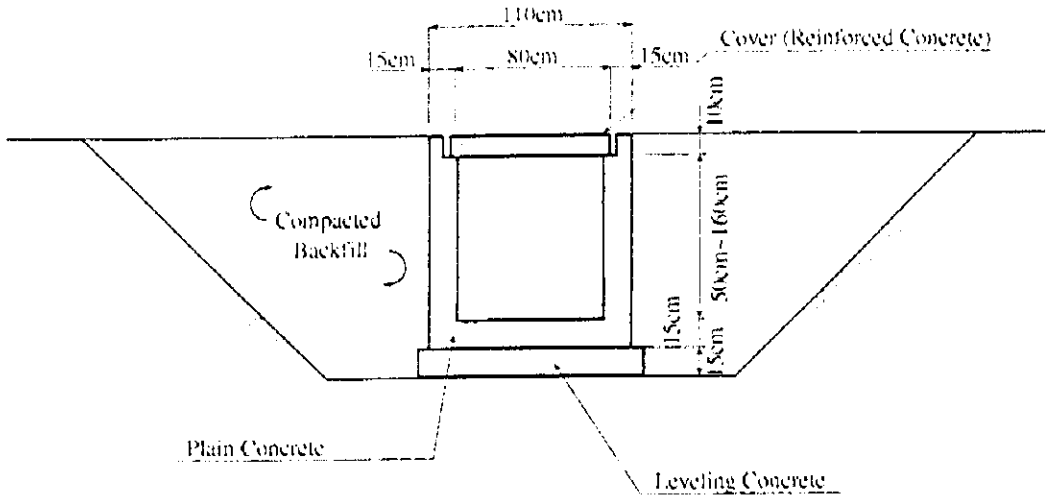
Table 5.17 Type of Drainage Ditches

Purpose	Loading Condition	Structural Descriptions
Trapping of water on road surfaces	Load attributed to automobiles acts	- Top of drain ditches is covered with grating made of galvanized steel - Side walls and floor of drain ditches are made of reinforced concrete
Conveying and drainage of trapped water to river	Load attributed to automobiles does not act	- Top of drain ditches is covered with a lid made of reinforced concrete. - Side walls and floor of drain ditches are made of unreinforced concrete

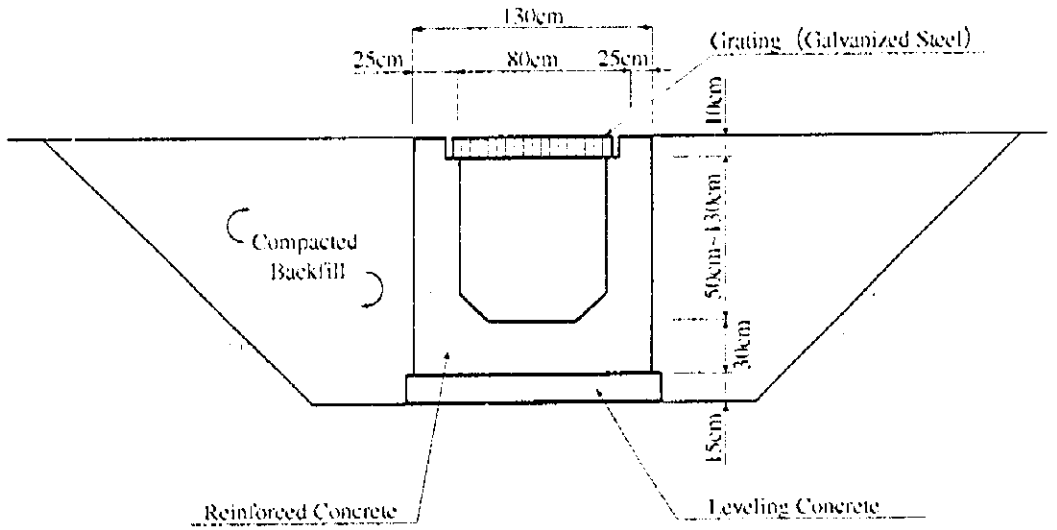
Thickness of side walls, floors and lids of drain ditches and the pattern of reinforcing bars, as well as thickness of leveling concrete, are determined on the basis of Standard Design Drawings of Civil Structures No.1 (Drain Ditch, Pipe Culvert, Box Culvert) published by the Ministry of Construction, Government of Japan

Only for Sub-basin E2 where water on road surface is trapped in front of the Finfine National Restaurant along the Yohanis street and is drained out into the Bantyiketu river, a flap gate of stainless steel is to be furnished at its outlet because the design high water stage is higher than the elevation of the outlet.

Typical cross-sections of the two kinds of drain ditches are shown on Figure 5.39.



Standard Drain Ditch



Drain Ditch at Road Crossing

Figure 5.39 Typical Cross Sections of Drain Ditches