THE REPUBLIC OF FIJI

MINISTRY OF AGRICULTURE, RURAL AND MARITIME DEVELOPMENT AND NATIONAL DISASTER MANAGEMENT

THE PROJECT FOR THE PLANNING OF THE NADI RIVER FLOOD CONTROL STRUCTURES

VOLUME Ⅱ MAIN REPORT

PART Ⅱ : FEASIBILITY STUDY

JULY 2016

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

YACHIYO ENGINEERING CO., LTD.
CTI ENGINEERING INTERNATIONAL CO., LTD.

GE
CR(1)
16-091

THE REPUBLIC OF FIJI
THE PROJECT FOR THE PLANNING OF THE NADI RIVER FLOOD CONTROL STRUCTURES

COMPOSITION OF FINAL REPORT

VOLUME I SUMMARY

VOLUME II MAIN REPORT

- **Part Ⅰ MASTER PLAN STUDY**
- **Part Ⅱ FEASIBILITY STUDY**

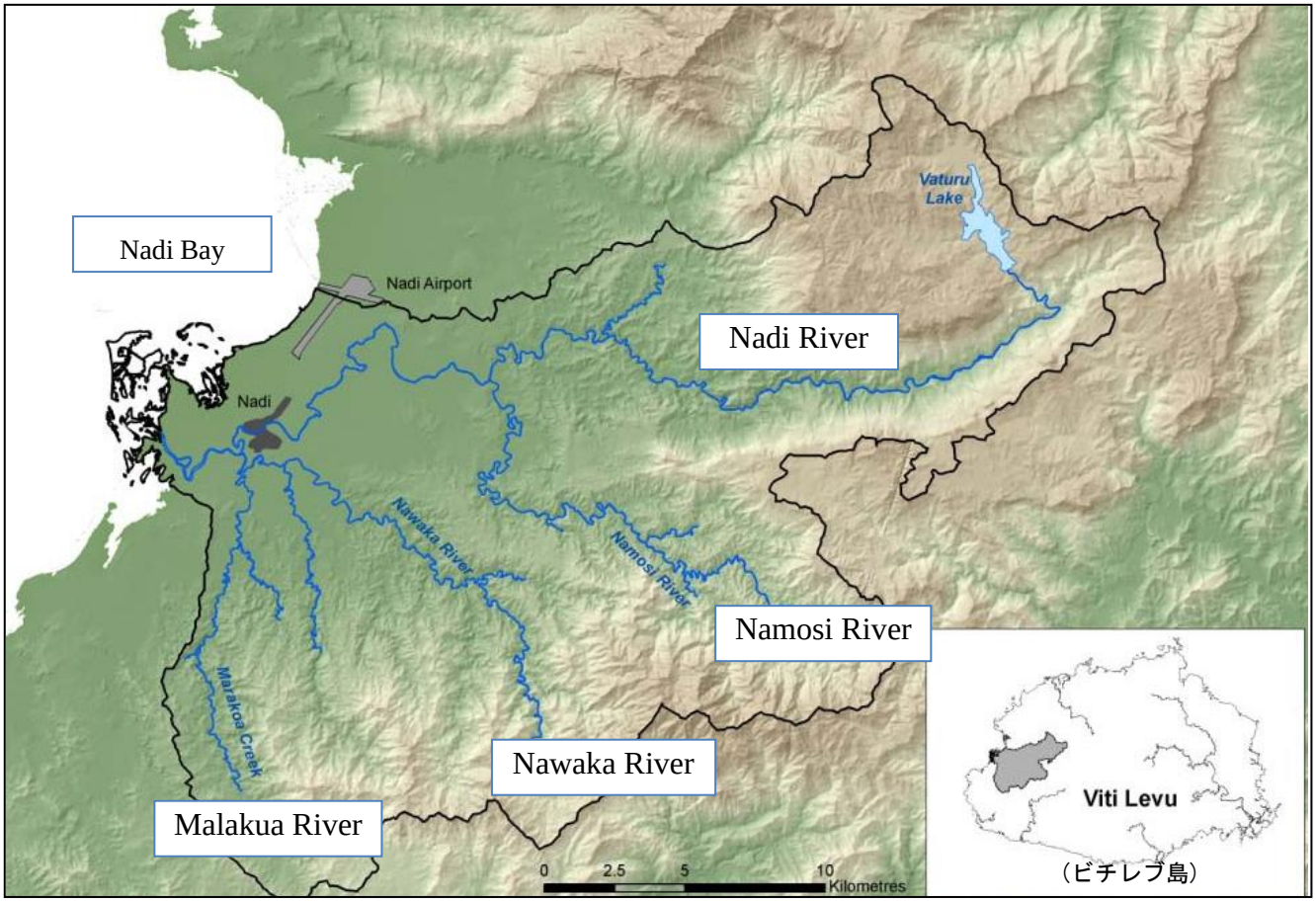
VOLUME Ⅲ DATA BOOK

- **Part Ⅰ DATA BOOK (1)**
- **Part Ⅱ DATA BOOK (2)**

Exchange Rate: FJD 1 = JPY 54.5, 1 USD=FJD 2.17

(As of April, 2016)

<Map of Project Area>



（出典）Integrated Water Resource Management Demonstration Project

Photo

Photo-1 Inception Report Meeting

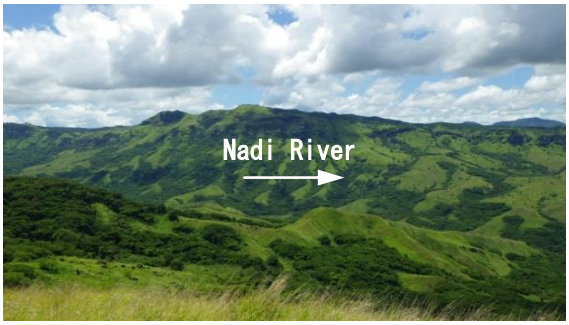


Photo-2 Nadi River Basin (Upstream)

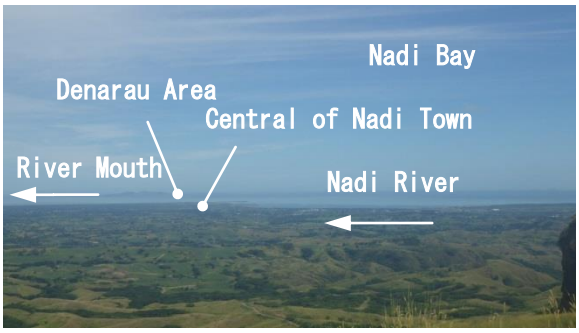


Photo-3 Nadi River Basin（Panoramic view）

Photo-4 Nadi River (River Mouth)

Photo-5 Central of Nadi Town

Photo-6 Nadi River (Middle Stream)

Photo-7 Nadi River (Upstream)

Photo-8 Vaturu Dam (Nadi River Upstream)

Photo-9　Nadi River（Nadi Town Bridge）

Photo-10 Nadi River（Nadi Town Bridge）during Flood

Photo-11　Nadi River（Old Queens Road Bridge）

Photo-12 Nadi River（Old Queens Road Bridge）during Flood

Photo-13 Nawaka River

Photo-14　Retention Dam（Nawaka River）

Photo-15　Counterpart Training in Japan

Photo-16 Seminar in Fiji

Executive Summary of
Flood Control Master Plan and Priority Project
in Nadi River Basin

1. Master Plan

【Basic Concept of Master Plan】

- In the Master Plan, based on the flood and river basin characteristics as well as properties in the upstream, midstream and downstream of the Nadi River, taking into account measures in an entire basin, comprehensive flood control plan consisting of dam, river improvement, retarding basins and ring dikes are proposed.
- Taking into account a long term and the large budget to complete the structural measures, and also taking into account the risk due to flood exceeding design scale, perfect protection measures for flood inundation are not feasible. Therefore, structural measures and non-structural measures such are proposed in the Master Plan..
- In the formulation of the Master Plan, it is an important to clarify priority protected areas from the view point of clarification on the contents of flood control plan and addressing a road map for the integration of short, middle and long term flood control plan. Therefore, Important Protected Area is set and it is prioritized to be mitigated from damage by flood.
- The Master Plan is formulated considering Environmental and Social Considerations and Social Acceptance for flood control

【Target Area of Master Plan】

Target area of Master Plan is Nadi River Basin with catchment area of 516 km^2.

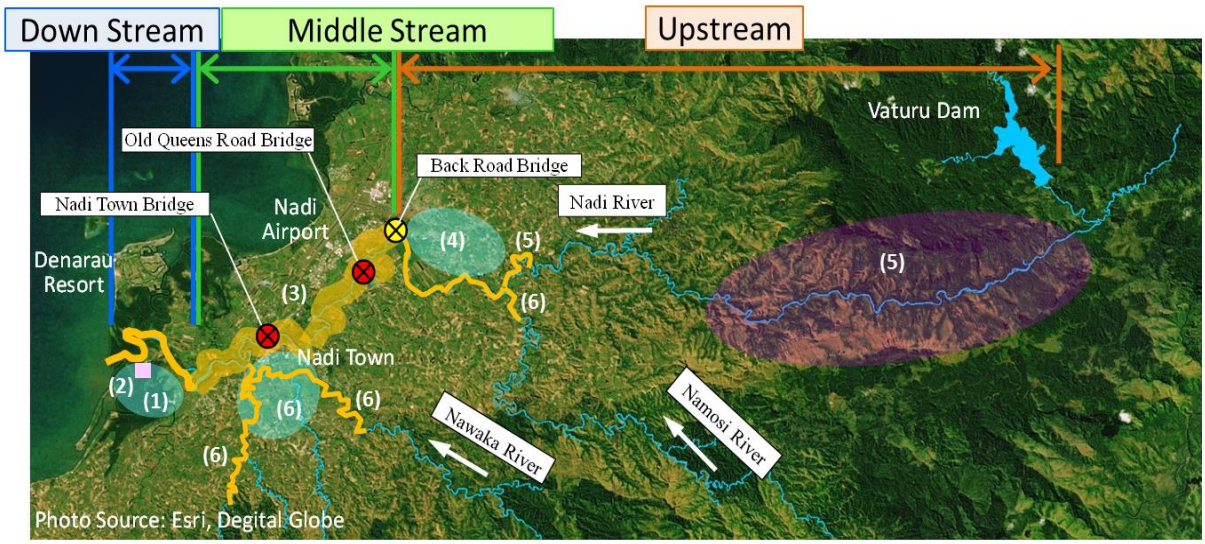
【Target Scale of Master Plan】

Design flood scale for Master Plan is set as 1/50 with regard to previous maximum flood event occurred in March 2012.

【Components of Master Plan】

(1) Structural Measures

Structural Measures as shown in Figure1 and Table1 are proposed in order to mitigate flood damage by targeted flood in Nadi River Basin.



(1)	: Retarding Basin in downstream incl. surrounding dike of retarding basin in downstream : River Improvement in downstream
(2)	: Ring Dike
(3)	: River Widening incl. Rebuilding of 2(two) bridges
(4)	: Retarding Basin A,B in upstream
(5)	: Dam : River improvement in upstream
(6)	: Retarding Basins in Tributaries incl. surrounding dike : River Improvement in Tributaries incl. Rebuilding of 4(four) bridges

Figure 1 Components of Master Plan (Structural Measures)

Table 1 Components of Master Plan (Structural Measures)

	River, Location		Component of the Master Plan		Quantities	Remarks
Structural Measures	1. Nadi River	Downstream	(1)	Retarding Basin and River Improvement in downstream	A=725 ha V=9,715 千m3	—
			(2)	Ring Dike	L=1.8 km	—
		Middlestream	(3)	River Widening[2)]	L=13 km	Including rebuilding of 2 (two) bridges
			(4)	Retarding Basin A	A=35 ha V=795 千m3	
				Retarding Basin B	A=178 ha V=6,920 千m3	—
		Upstream	(5)	Dam and River improvement in upstream	1	
	2. Tributaries	Nawaka Maralua Namosi River	(6)	River Improvement	L=21 km	Including rebuilding of 4 (four) bridges in tributaries
				Retarding Basins (13 sites)	A=340 ha V=11,600 千m3	

(2) Non-Structural Measures

Non-Structural Measures as shown in Table2 are proposed in order to corroborate and complement structural measures and mitigate damage by targeted flood.

Table 2 Components of Master Plan (Non-Structural Measures)

	Effect of Measure (Large Classification)	Major components
Non-Structural Measures	(1) Understanding disaster risk and risk avoidance	1-1) Strengthening of understanding flood risk with flood hazard map 1-2) Strengthening flood forecasting technology
	(2) Enhancing disaster preparedness for effective response	2-1) Strengthening disaster management system
	(3) Disaster risk management, risk avoidance	3-1) Technical assistant for land-use regulation 3-2) Strengthening river basin management
	(4) Economic disaster risk management	4-1) Strengthening economic disaster risk management by regional BCP
	(5) Evaluation and feedback	5-1) Establishing a system of evaluation of Pre-disaster activity / existing measures and feedback

【Implementation Schedule of Master Plan】

Proposed entire implementation schedule of the Master Plan projects is shown in Table3. Target implementation period of Master Plan is proposed as 30 years from the project commencement.

Table 3 Components of Master Plan and Implementation Schedule (Proposed)

	Work Item	20XX-20XX	20XX-20XX																														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Study on M/P																															
	Detailed Design																															
I. Structural Measures																																
I-A. Priority Project (Short Term Measures)																																
1	**River channel widening works in midstream section**																															
1)	River channel widening works in midstream section, L=13km																															
2	**Retarding basin works in upstream section**																															
1)	Retarding basin (A) works in right bank side in Nadi River, A=35ha																															
2)	Retarding basin (B) works in left bank side in Nadi River, A=178ha																															
3	**Ring dike**																															
1)	Ring dike, L=1.8km																															
4	**Shortcut in tributaries / Surrounding dike works in Nadi River**																															
1)	Shortcut in tributaries, A=0.5km																															
2)	Surrounding dike, L=4.5km																															
I-B. Middle Term Measures																																
1	**Retarding Basin in downstream section (A=km2)**																															
1)	Retarding Basin in downstream section, A=725ha																															
2	River improvement in tributaries																															
1)	Nawaka River, L=8.5km																															
2)	Malakua River , L=8.5km																															
3)	Namosi River , L=4.0km																															
I-C. Long Term Measures																																
1	**Dam construction in upstream in Nadi River (H= m)**																															
1)	Dam construction in upstream in Nadi River																															
II. Non-structural Measures																																
1	**Understanding disaster risk and risk avoidance**																															
1-1)	Strengthening of understanding flood risk with flood hazard map																															
1-2)	Strengthening flood forecasting technology																															
2	**Enhancing disaster preparedness for effective response**																															
2-1)	Strengthening disaster management system																															
2-2)	Strengthening emergency assistance system																															
3	**Disaster risk management, risk avoidance**																															
3-1)	Land use regulations																															
3-2)	Strengthening river basin management																															
4	**Economic disaster risk management**																															
4-1)	Strengthening economic disaster risk management by regional BCP																															
5	**Establishing a system of evaluation of Pre-disaster activity / existing measures and feedback**																															
5-1)	Establishing a system of evaluation of Pre-disaster activity / existing measures and feedback																															

Note: *including loan agreement, EIA, land acquisition, procurement of consultant (D/D, C/S), detailed design, preparation of PQ and tender document and so on.

2. Priority Project

【Basic Concept for selection of Priority Project】

- Taking into account a long term and the large budget to complete the structural measures, and also taking into account the risk due to flood exceeding design scale, perfect protection measures for flood inundation are not feasible. Therefore, Priority Project is selected in order to protect important area and mitigate flood damage.
- Regarding structural measures of Priority Project, components which mitigate flood damage in Important Protected Area is selected after setting Important Protected Area.
- Regarding non-structural measures of Priority Project, protection of human lives, understanding of disaster risks and evacuation are considered as a top priority. Based on this concept, components for understanding of disaster risks and evacuation are selected as Priority Project.

【Components of Priority Project】

(1) Structural Measures

Structural Measures as shown in Figure 3 and Table 4 are proposed in order to mitigate flood damage in Important Protected Area (Figure 2).

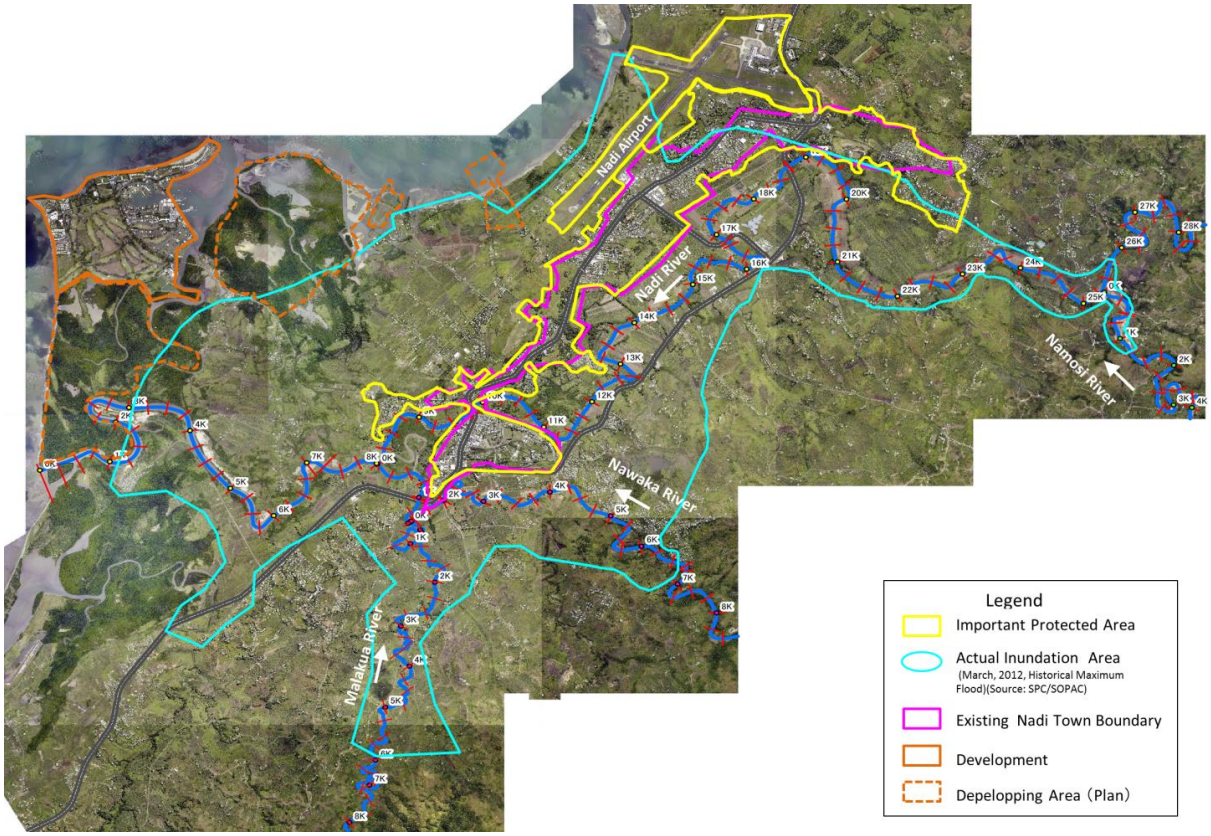


Figure 2　Important Protected Area

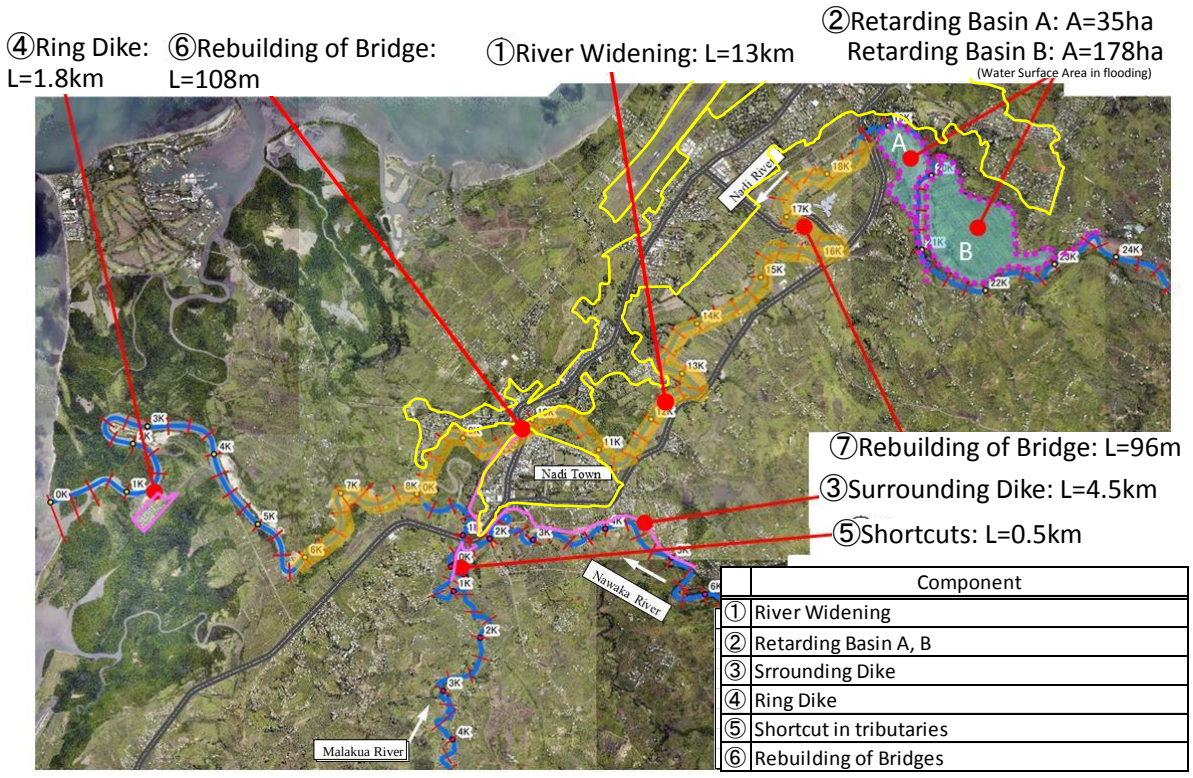


Figure 3 Components of Priority Project (Structural Measures)

Table 4 Components of Priority Project (Structural Measures)

	River, Location		Component of the Master Plan	Component of the Priority Project		Remarks
				Main Component	Quantities	
Structural Measures	1. Nadi River	Downstream	(1) Retarding Basin and River Improvement in downstream	—	—	—
			(2) Ring Dike	④ Ring Dike	L=1.8 km	—
		Middlestream	(3) River Widening[2)]	① River Widening Rebuilding of Nadi TOwn Bridge Rebuilding of Old Queens Road Bridge	L=13 km L=108 m L= 96 m	—
			(4) Retarding Basin A	② Retarding Basin A	A=35 ha V=795 千m3	
			Retarding Basin B	② Retarding Basin B	A=178 ha V=6,920 千m3	—
		Upstream	(5) Dam and River improvement in upstream	—	—	
	2. Tributaries	Nawaka Maralua Namosi River	(6) River Improvement	⑤ Shortsut of Tributaries ③-2 Surrounding Dike of Nadi Town	L=0.5 km L=4.5 km	Shortcut and Surrounding dike in tributaries are preceded to construction as part of the master plan
			Retarding Basins (13 sites)	—	—	

(2) Non-Structural Measures

Protection of human lives, understanding of disaster risks and evacuation are considered as a top priority, under condition that the progress of structural measures project will be at initial phase. Therefore, activities accompanied with development and disclosure of hazard maps and development of hydrological devices for awareness of flood risks are proposed as Priority project. In addition, in order to evaluate the effect of non-structural measures in the past or priority projects, and in order to connect to “Better disaster prevention”, evaluation and feedback system on the past projects is also proposed as Priority Project.

Table 5 Components of Priority Project (Non-Structural Measures)

	Category	Measures
Non-structural Measures	Understanding disaster risk and risk avoidance	・ Strengthening of understanding flood risk with flood hazard map ・ Strengthening flood forecasting technology, such as expansion of rainfall gauge, water level gauge and introduction of real-time monitoring camera
	Better Disaster Prevention	・ Establishing a system of evaluation of Pre-disaster activity / existing measures and feedback

【Selection of Implementation Project】

Integrated flood control facilities considering whole river basin have not been installed yet in spite of effectiveness of structural measures and implementation of structural measures such as dam, retarding basin, and river are required urgently. Therefore, structural measures of Priority Project are selected as Implementation Project.

【Objective of Implementation Project】

Objective of Implementation Project is to improve of vulnerability to flood in Nadi River Basin, mitigate flood damage specially in Important Protected Area and contribute to improve living environment of residents by developing flood control facilities such as river widening and retarding basin in Nadi River Basin, which has been damaged by severe flood.

【Components of Implementation Project】

Components of Implementation Project is as shown in Figure 4 and Table 6, which are as same as structural measures of Priority Project.

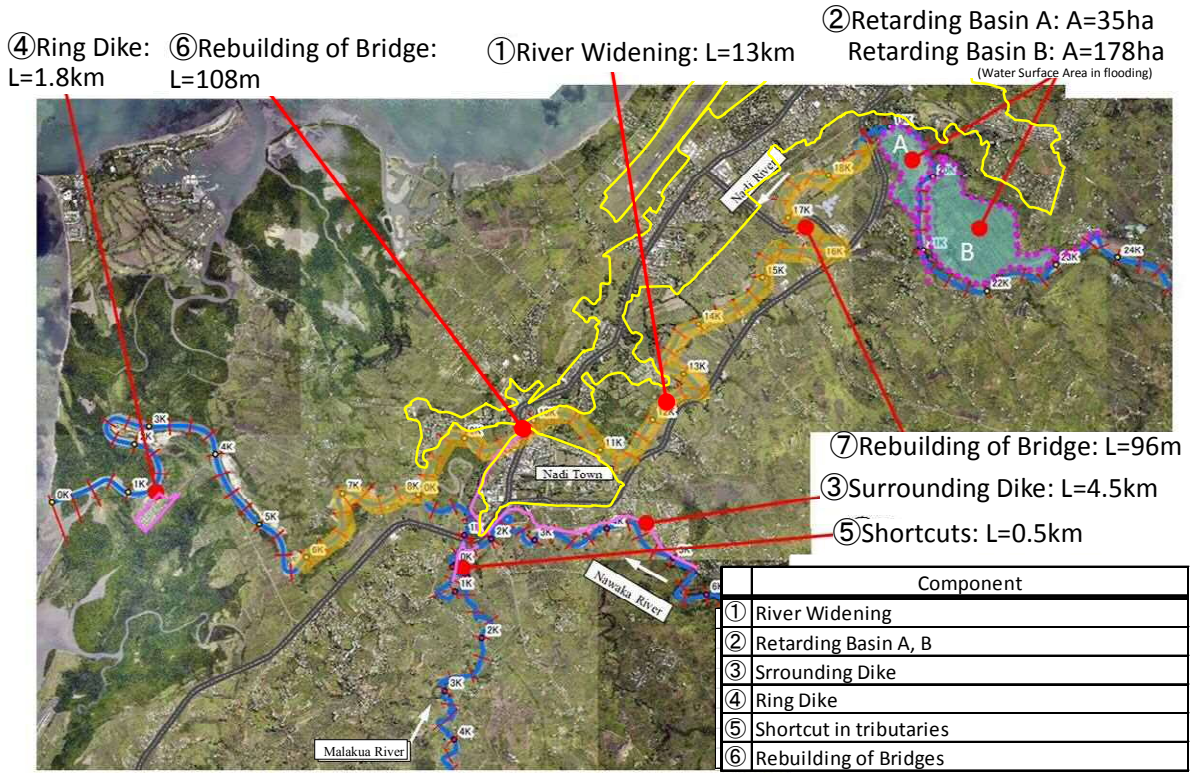


Figure 4 Components of Implementation Project (Structural Measures)

Table 6 Components of Implementation Project (Structural Measures)

	River, Location		Component of the Master Plan	Component of the Priority Project		Remarks
				Main Component	Quantities	
Structural Measures	1. Nadi River	Downstream	(1) Retarding Basin and River Improvement in downstream	—	—	—
			(2) Ring Dike	④ Ring Dike	L=1.8 km	—
		Middlestream	(3) River Widening[2)]	① River Widening Rebuilding of Nadi TOwn Bridge Rebuilding of Old Queens Road Bridge	L=13 km L=108 m L= 96 m	—
			(4) Retarding Basin A	② Retarding Basin A	A=35 ha V=795 千m3	
			Retarding Basin B	② Retarding Basin B	A=178 ha V=6,920 千m3	—
		Upstream	(5) Dam and River improvement in upstream	—	—	
	2. Tributaries	Nawaka Maralua Namosi River	(6) River Improvement	⑤ Shortsut of Tributaries ③-2 Surrounding Dike of Nadi Town	L=0.5 km L=4.5 km	Shortcut and Surrounding dike in tributaries are preceded to construction as part of the master plan
			Retarding Basins (13 sites)	—	—	

【Implementation Schedule of Implementation Project】

Implementation Schedule of Implementation Project is as shown in Table 8.

【Implementation Project 】

Implementation Project Cost is as shown in Table 9.

【Economic Feasibility of Implementation Project】

Total cost of the priority project is JPY21.0 billion (F$385million) and the average annual benefit is JPY 1.88billion (F$34.5million). These figures lead to EIRR 12.0%, B/C=1.2 and NPV JPY1.8billion (F$33million) respectively. This economic valuation is beyond the target investment rate of 10% in Fiji and show the adequate economic effect.

Table 7 Result of Economic Evaluation

Economic indicator	Result	Evaluation
Economic internal rate of return (EIRR)	12.0%	Since EIRR is well over 10% which is applied to the development assistance project in Fiji, the economic effectiveness is high.
Benefit-cost (B/C) ratio	1.20	Since the B/C ratio is over 1.0, the cost-effectiveness is high.
Net present value (NPV)	JPY 1.8 billion (FJD33 million)	Since the value is plus, the cost-effectiveness is high.

Source: JICA study team

【Conclusion and Recommendation】

Implementation Project proposed as one of the Priority Project is evaluate appropriate since it could mitigate severe flood damage and it is feasible technically, economically, socially and environmentally. Therefore, next steps such as securing budget and request for technical assistance as follows are recommended to be conducted by Fiji Government as soon.

(1) Implementation of the Priority Project and establishment of Implementation Structure

(2) Formulation consensus of Government and residents for the Implementation

(3) Commencement of loan procedure for project fund

(4) Commencement of negotiation for land acquisition and compensation

(5) Commencement of consultant procurement and environmental monitoring

(6) Establishment of legislation of flood control

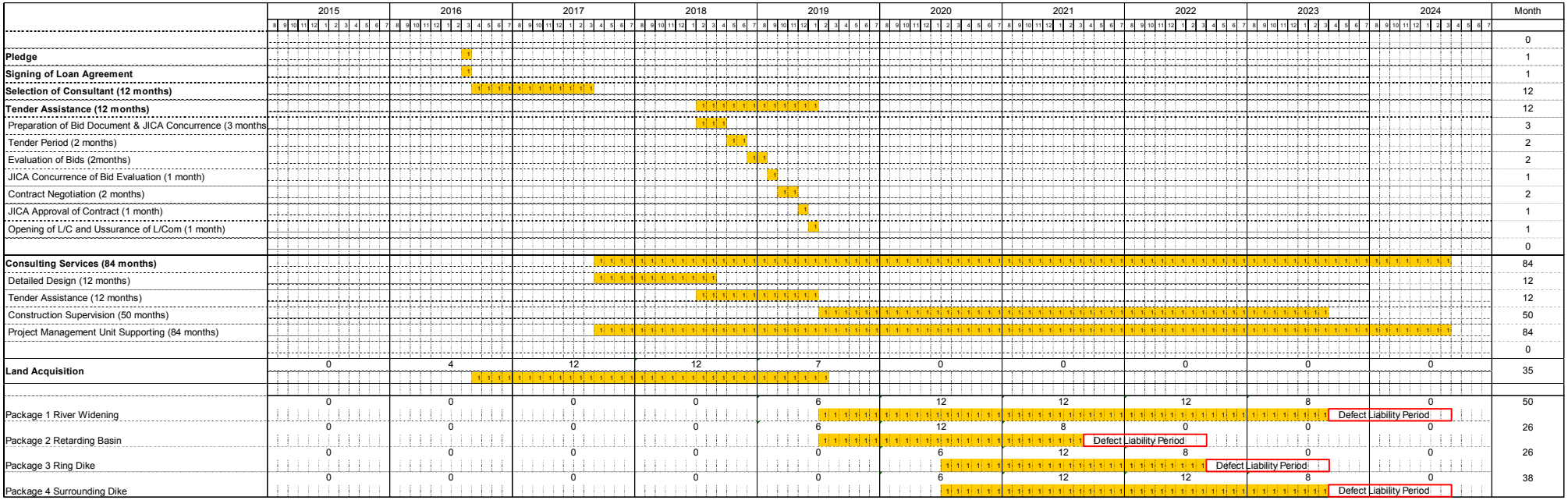
(7) Preparation and consolidation of organization responsible for flood control and capacity building

(8) Preparation of criteria and standard

(9) Permanent securement of maintenance budget for flood control

Table 8 Implementation Schedule of Implementation Project (Proposed)

Implementation Schedule



*Year in above table shows the fiscal year of Fiji (August 1st to July 31th of following year)

Table 9 Project Cost of Implementation Project

(FC&Total: Million JPY, LC: Million FJD)

Item		Total			
		FC	LC	Total	
		million (Yen)	million (F$)	million (Yen)	million (F$)
A. ELIGIBLE PORTION					
Ⅰ)	Procurement / Construction	6,778	134	14,074	258
	Package 1 River Widening, Rebuilding of Bridge	4,213	77	8,432	155
	Package 2 Retarding Basin	1,281	19	2,299	42
	Package 3 Ring Dike	40	1	76	1
	Package 4 Surrounding Dike	392	5	657	12
	Base cost for JICA financing	5,926	102	11,464	210
	Price escalation	529	26	1,940	36
	Physical contingency	323	6	670	12
Ⅱ)	Consulting services	933	18	1,893	35
	Base cost	828	14	1,579	29
	Price escalation	60	3	223	4
	Physical contingency	44	1	90	2
Total (Ⅰ + Ⅱ)		7,711	151	15,967	293
B. NON ELIGIBLE PORTION					
a	Procurement / Construction	0	0	0	0
	Base cost for JICA financing	0	0	0	0
	Price escalation	0	0	0	0
	Physical contingency	0	0	0	0
b	Land Acquisition	0	38	2,093	38
	Base cost	0	34	1,845	34
	Price escalation	0	3	148	3
	Physical contingency	0	2	100	2
c	Administration cost	0	17	903	17
d	VAT	0	30	1,625	30
e	Import Tax	0	0	0	0
Total (a+b+c+d+e)		0	85	4,621	85
TOTAL (A+B)		7,711	236	20,588	378
					0
C. Interest during Construction		351	0	351	6
	Interest during Construction(Const.)	350	0	350	6
	Interest during Construction (Consul.)	1	0	1	0
D. Front End Fee		32	0	32	1
GRAND TOTAL (A+B+C+D)		8,094	236	20,971	385
E. JICA finance portion (A)		7,711	151	15,967	293

US$1=2.17 F$, 1F$= JPY 54.5

略 語

ADB	Asian Development Bank	アジア開発銀行
ADRA	Adventist Development and Relief Agency	アドベンチスト開発救助機関
AusAID	Australian Agency for International Development	オーストラリア国際開発庁
BCP	Business Continuity Plan	事業継続計画
BOM	Bureau Of Meteorology	オーストラリア気象局
CBD	Convention on Biological Diversity	生物多様性条約
CCA	Climate Change Adaptation	気候変動適応
CCL	Climate Change Loan	気候変動対策円借款
CCM	Climate Change Mitigation	気候変動緩和
CHARM	Comprehensive Hazard And Risk Management	統合的ハザード・リスク管理
C/P	Counterpart	カウンターパート
CRED	Centre for the Research on the Epidemiology of Disaster	災害の疫学に関する研究センター
CWO	Commissioner Western Office	西部地域長官室
DEM	Digital Elevation Model	デジタル標高モデル
DF/R	Draft Final Report	ドラフトファイナルレポート
DIS	Drainage & Irrigation Section	排水・灌漑部門
DISMAC	Disaster Management Centre	災害管理センター
DMP	Disaster Management Plan	防災計画書
DOE	Department of Environment	環境局
DOFi	Department of Fishery	漁業局
DOF0	Department of Forest	森林局
DOL	Department of Lands	土地局
DO-N / DO	District Nadi Office / District Office	ナンディ地区事務所／地区事務所
DOW	Department of Works	公共事業局
DRCC	Disaster Ready Community Committee	災害自立型コミュニティ委員会
DRR	Disaster Risk Reduction	災害リスク軽減
DRRDM	Disaster Risk Reduction & Disaster Management	災害リスク軽減・災害管理
DTCP	Department of Town & Country Planning	都市／地方計画局
EDF	European Development Fund	ヨーロッパ開発基金
EIA	Environmental Impact Assessment	環境影響評価
EiE	Education in Emergencies	緊急時の教育
EOC	Emergency Operation Center	緊急対策室
EPGA	Environmental Programme Grant Aids	環境プログラム無償資金協力
EU	European Union	欧州連合
EWS	Early Warning System	早期警報システム
FBS	Fiji Bureau of Statistics	フィジー統計局
FMS	Fiji Meteorological Service	フィジー気象局
F/R	Final Report	ファイナルレポート

FRA	Fiji Road Authority	フィジー道路公社
F/S	Feasibility Study	フィジビリティ調査
FSC	Fiji Sugar Corporation	フィジー砂糖会社
GDP	Gross National Product	国民総生産
GEF	Global Environmental Facility	地球環境ファシリティ
GGP	Grant Assistance for Grassroots Human Security Projects	草根の無償／草の根・人間の安全保障無償資金協力
GIS	Geographical Information System	地理情報システム
GNI	Gross National Income	国民総所得
HFA	Hyogo Framework for Action	兵庫行動枠組み
IC/R	Inception Report	インセプションレポート
IDA	Initial Damage Assessment	初期損害評価
IDD	Irrigation & Drainage Division	灌漑・排水部門
IDM	Introduction of Disaster Management	災害管理の導入
IEE	Initial Environmental Examination	初期環境調査
IRC	International Red Cross	国際赤十字
IT/R	Interim Report	インテリムレポート
IWRM	Integrated Water Resource Management	統合水資源管理
JCC	Joint Coordination Committee	合同調整委員会
JICA	Japan International Cooperation Agency	独立行政法人　国際協力機構
KP	Kyoto Protocol	京都議定書
LRPD	Department of Land Resource Planning & Development	土地資源計画・開発局
LWRM	Land &Water Resource Management	土地水資源管理部
MDGs	Millennium Development Goals	ミレニアム開発目標
MFA&IC	Ministry of Foreign Affairs & International Co-operation	外務・国際協力省
MFSPNDS	Ministry of Finance Strategic Planning, National Development & Statistics	財務戦略計画・国家開発・統計省
MLGUDHE	Ministry of Local Government, Urban Development, Housing &Environment	地方行政・都市開発・住宅・環境省
MLMR	Ministry of Lands & Mineral Resources	土地鉱物資源省
M/M	Minutes of Meeting	会議議事録
MOA	Ministry of Agriculture	農業省
MOU	Memorandum Of Understanding	覚書
M/P	Master Plan	基本計画
MP Radar	Multi Parameter Radar	マルチパラメータ気象レーダ
MRMSNDM	Ministry of Rural & Maritime Safety & National Disaster Management	地域・海上保安・国家災害管理省
MTCP	Ministry of Town and Country Planning	都市計画省
MWTPU	Ministry of Works, Transport & Public Utilities	公共事業・運輸・公益事業省
NBCC	Nadi Basin Catchment Committee	ナンディ流域委員会
NCCP	National Climate Change Policy	国家気候変動政策
NDMC	National Disaster Management Council	国家災害管理評議会

NDMO	National Disaster Management Office	国家災害管理室
NEOC	National Emergency Operation Centre	国家緊急オペレーション・センター
NIWA	The National Institute of Water and Atmospheric Research	水・大気研究国立機関
NTC	Nadi Town Council	ナンディ町議会
NZAID	New Zealand Agency for International Development	ニュージーランド国際開発庁
O&M	Operation and Maintenance	運用維持管理
OCHA	Office for the Coordination of Humanitarian Affairs	国連人道問題調整事務所
ODA	Official Development Assistance	政府開発援助
OJT	On the Job Training	実地訓練
PCIDRR	The Pacific Community-focused Integrated Disaster Risk Reduction	大洋州コミュニティ統合的災害リスク削減
PDM	Project Design Matrix	プロジェクトデザインマトリックス
PDN	Pacific Disaster Net	大洋州災害ネット
PDRMP	Pacific Disaster Risk Management (Training) Programme	大洋州災害リスク管理（研修）プログラム
PDRMPN	Pacific Disaster Risk Management Partnership Network	大洋州災害リスク管理パートナーシップ・ネットワーク
PHT	The Pacific Humanitarian Team	大洋州人道チーム
PIFACC	Pacific Islands Framework for Action on Climate Change	大洋州気候変動行動枠組み
PMO	Prime Minister Office	首相府
PMU	Project Management Unit	プロジェクト・マネジメント・ユニット
P/R	Progress Report	プログレスレポート
PRMS	Planning & Resource Management Section	計画・資源管理部門
PRSP	Poverty Reduction Strategy Paper	貧困削減戦略文書
PWD	Public Works Division	公共事業部
RAP	Resettlement Action Plan	住民移転計画
R/D	Record of Discussion	討論議事録
RES	River Engineering Section	河川エンジニアリング部門
SOP	Standard Operation Procedure	標準作業手順書
SOPAC	South Pacific Applied Geoscience Commission	太平洋諸島応用科学委員会
SPC	Secretariat for the Pacific Community	太平洋コミュニティ事務局
SPCZ	South Pacific Convergence Zone	南太平洋収束帯
SPREP	South Pacific Regional Environment Programme	大洋州環境プログラム事務局
TC	Tropical Cyclone	熱帯性サイクロン
TLTB	iTauke Land Trust Board	イ・タウケイ土地信託委員会
ToT	Training of Trainers	指導員研修
UNCCD	United Nations Convention to Combat Desertification	国連砂漠化防止条約
UNDP	United Nations Development Programme	国連開発計画
UNESCAP	United Nations Economic & Social Commission for Asia & the Pacific	国連アジア太平洋経済社会委員会
UNFCCC	United Nations Framework Convention on Climate Change	国連気候変動枠組条約
UNICEF	United Nations International Children's Emergency Fund	国連国際児童緊急基金
UNISDR	United Nations International Strategy for Disaster	国連国際防災戦略

	Reduction	
UNOCHA	United Nations Office for Coordination of Humanitarian Affairs	国連人道問題支援室
USAID	United State Agency for International Development	米国国際開発庁
WAF	Water Authority of Fiji	フィジー水公社
WB	World Bank	世界銀行（世銀）
WMO	World Meteorological Organization	世界気象機関
WMS	Watershed Management Section	流域管理部門

THE REPUBLIC OF FIJI
THE PROJECT FOR THE PLANNING OF
THE NADI RIVER FLOOD CONTROL STRUCTURES

FINAL REPORT
VOLUME II MAIN REPORT

Part II: Feasibility Study

Table of Contents

List of Table

List of Figure

Appendix

Chapter 17 Components of Feasibility Study

The components of FS study are as shown in Table 17-1 and Figure 17-1.

The purpose of the Priority Project is to prevent inundation in Important Protected Area which is located along the Nadi River (see area which is surrounded by yellow line in Figure 17-1)

Table 17-1 Components of the Feasibility Study

	River, Location		Component of the Master Plan	Component of the Priority Project		Remarks
				Main Component	Quantities	
Structural Measures	1. Nadi River	Downstream	(1) Retarding Basin and River Improvement in downstream	—	—	—
			(2) Ring Dike	④ Ring Dike	L=1.8 km	—
		Middlestream	(3) River Widening[2)]	① River Widening Rebuilding of Nadi TOwn Bridge Rebuilding of Old Queens Road Bridge	L=13 km L=108 m L= 96 m	—
			(4) Retarding Basin A	② Retarding Basin A	A=35 ha V=795 千m3	
			Retarding Basin B	② Retarding Basin B	A=178 ha V=6,920 千m3	—
		Upstream	(5) Dam and River improvement in upstream	—	—	
	2. Tributaries	Nawaka Maralua Namosi River	(6) River Improvement	⑤ Shortsut of Tributaries ③-2 Surrounding Dike of Nadi Town	L=0.5 km L=4.5 km	Shortcut and Surrounding dike in tributaries are preceded to construction as part of the master plan
			Retarding Basins (13 sites)	—	—	

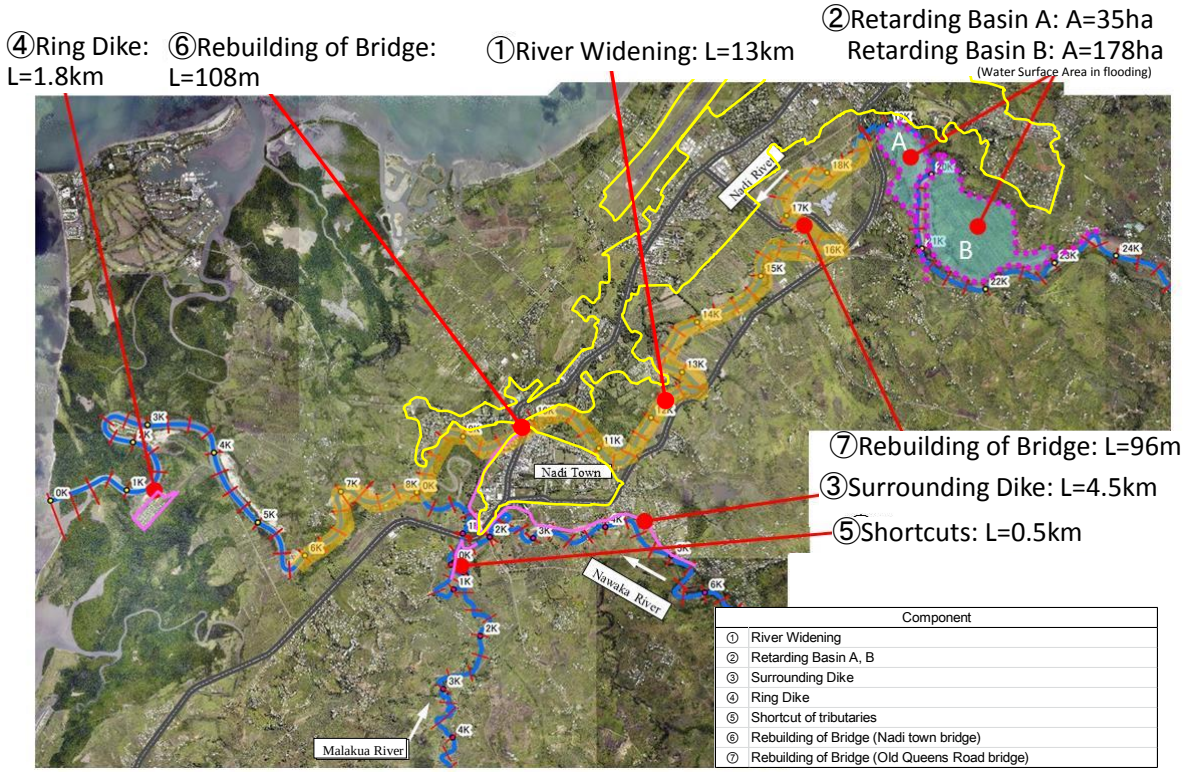


Figure 17-1 Components of the Feasibility Study

Chapter 18 Preliminary Design

18.1 River Widening

This project (the Priority Project) is intended to implement the river improvement project to prevent flooding in the Important Protected Area which is located in the Nadi River Basin. the components of the Priority Project are as described before in Chapter 18.

River Widening is intended to flow down 1,800 m3/s flood discharge which is equal to the design flood with occurrence probability of 1/50 with the water level[1] between the top of dike and HWL at the Back Road Bridge point in the middle section

[Upper]: Discharge before Flood Control
[Lower]: Design Discharge after the Priority Project

※Flow volume after the priority project include natural flood volume at outside section of Important Protected Area

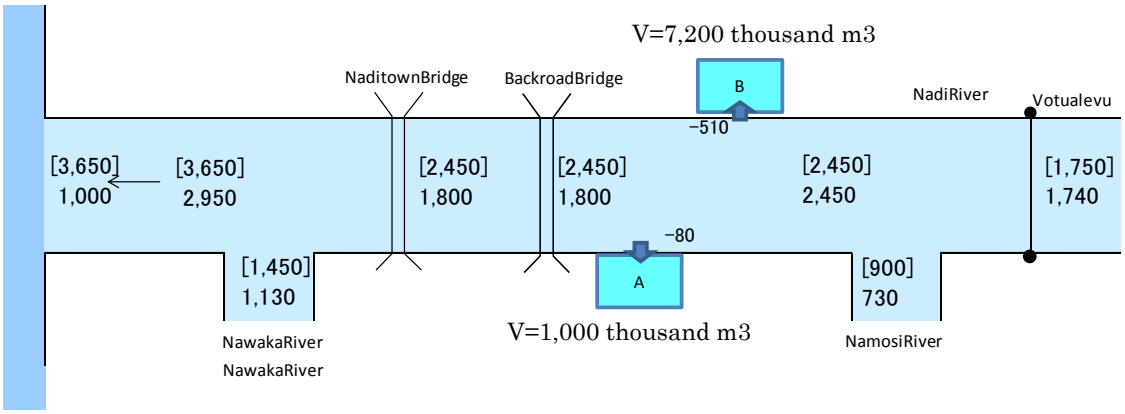


Figure 18-1 Designed Discharge Distribution at the Priority Project

18.1.1 Applicable standards for design

There are no Fiji own technical standards and guidelines for flood control and river facilities. Therefore, it is required to refer to some sort of technical standards and guidelines for design.

In this situation, comparing river characteristics in Japan and those in Fiji, flood characteristics and river characteristics of river basins in Japan and that of Nadi River basin in Fiji are to be similar considering that there are mountains in upstream basin, water flows from upstream and flows out to sea through low-lying areas in a short time. In addition, Natural science and technology and a variety of engineering required to design (hydraulics, physics, soil, geotechnical engineering, river engineering, concrete engineering, etc.), is considered one of the universal that does not depend on the countries and regions. Therefore, in this design, it is considered to be applicable to refer the Japanese of design standards and guidelines[1].

Therefore, in this design according to the following river facilities, [Structural Ordinance for river facilities (1976.7.20)], [Revised Edition, Ministry of Construction, Technical Criteria for River Works, Editorial Supervisor: River Bureau, Ministry of Construction, Editor: Japan River Association] and are referred.

18.1.2 Plan and Area

(1) Planned Area

River widening is conducted from 5.75k point near Narewa village to 24.0k point near Votualevu village.

This area is determined through flood analysis in order to prevent inundation in the Important Protected Area. Earth dike is not included in order to mitigate negative impact by the dike of main stream to other area including tributaries so that only river widening is conducted from 5.75k to 8.0k. Whole plan of river widening is as described in Figure 18-3.

---

[1] When the Master Plan will be completed, since the upstream dam is constructed, the discharge of 1,800m3/s can flow down in the river channel section with free-board. In the Priority Project the discharge is permitted to flow down with the water level between the top of dike and HWL considering that this stage is a step to the Master Plan.

[2]See [Draft Final Report: Main Report, Part I: Master Plan Study, Chapter 4, 4.1.1]

(2) Plan

Alignment of river widening is set considering current alignment of river channel and flood flow. Width of river widening is set basically same width from center line between right bank side and left bank side from the point of view of fairness.

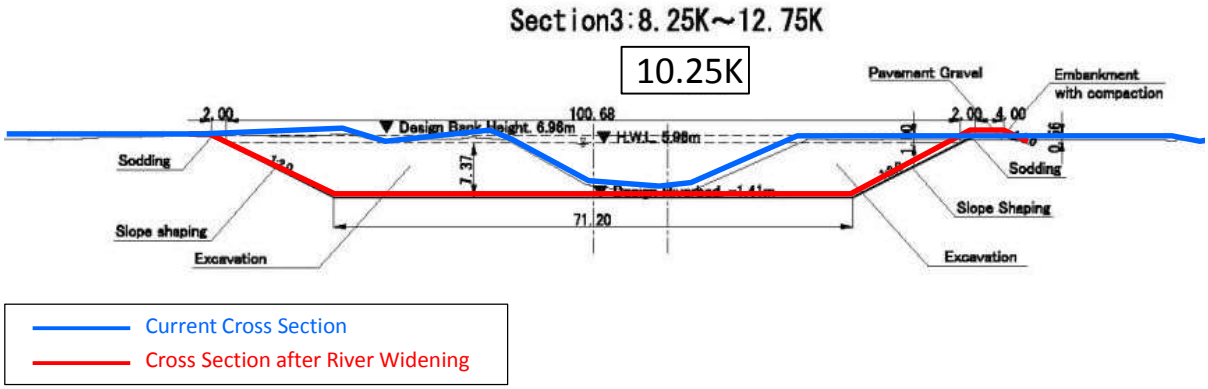


Figure 18-2 Basic Concept of river Widening

Alignment of river channel is sifted or loosed in order not to exceed design flood water revel when flood water level exceeds design high water level due to effect by curvature at current alignment and there are important areas to be protected behind the river. (Exception-1)

Alignment is loosed to the extent that does not deviate from the current river channel alignment extremely for excessive bending portion such as a U-shaped or S-shaped curve (Exception-2) and alignment is newly set for extreme crank shape curve in light of the continuity of the upstream and downstream alignment (Exception-3).

Alignment of river channel is straighten and smoothen from 22.75k to 24.25k in order to intake flood water smoothly to the retarding basin at overflow dike securing a required length and elevation (Exeption-4).

Alignment is sifted to the other side to the extent that there is no hindrance to a safe flow of flood water from the viewpoint of reducing the number of house relocations if houses are present only one side of the river channel (Exception-5)

Based on the above, plan of river widening is as shown in from Figure 18-3 to Figure 18.6.

In Figure 18-4~Figure 18.6 there are two kind of river alignment, blue and yellow lines, the blue line shows the present river alignment and yellow line shows the alignment after river improvement.

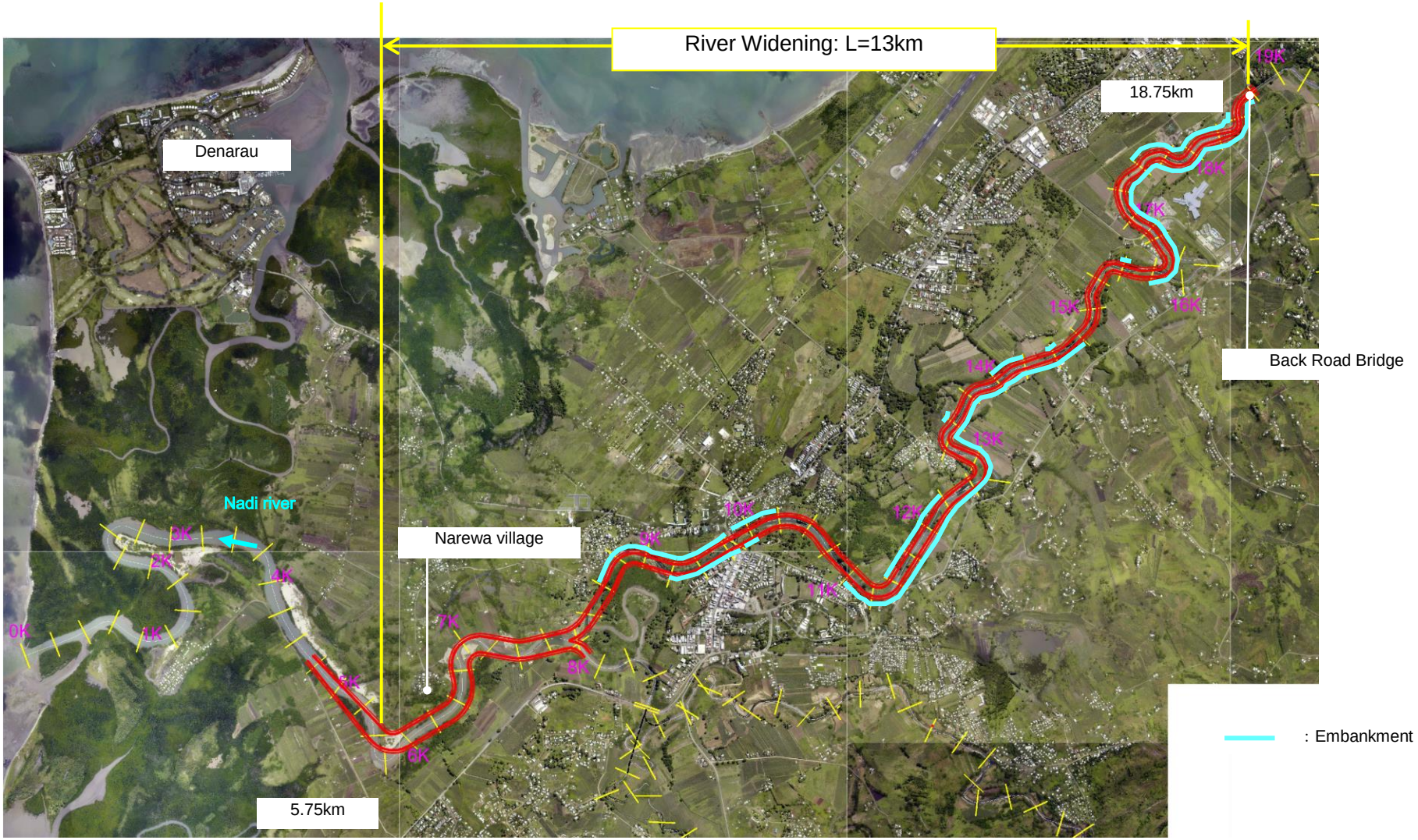


Figure 18-3 Whole Plan of River Widening

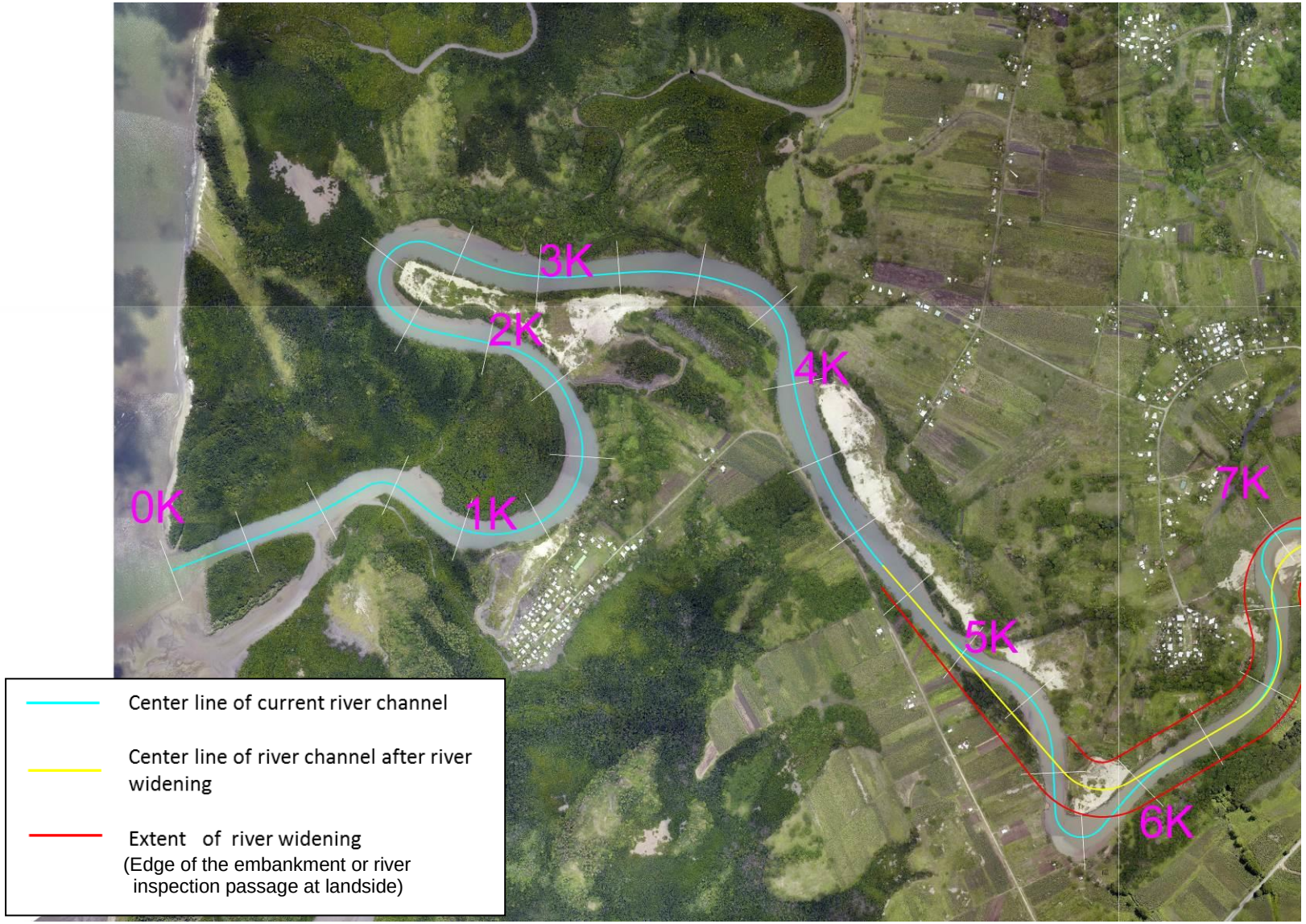


Figure 18-4 Plan of River Widening (1)

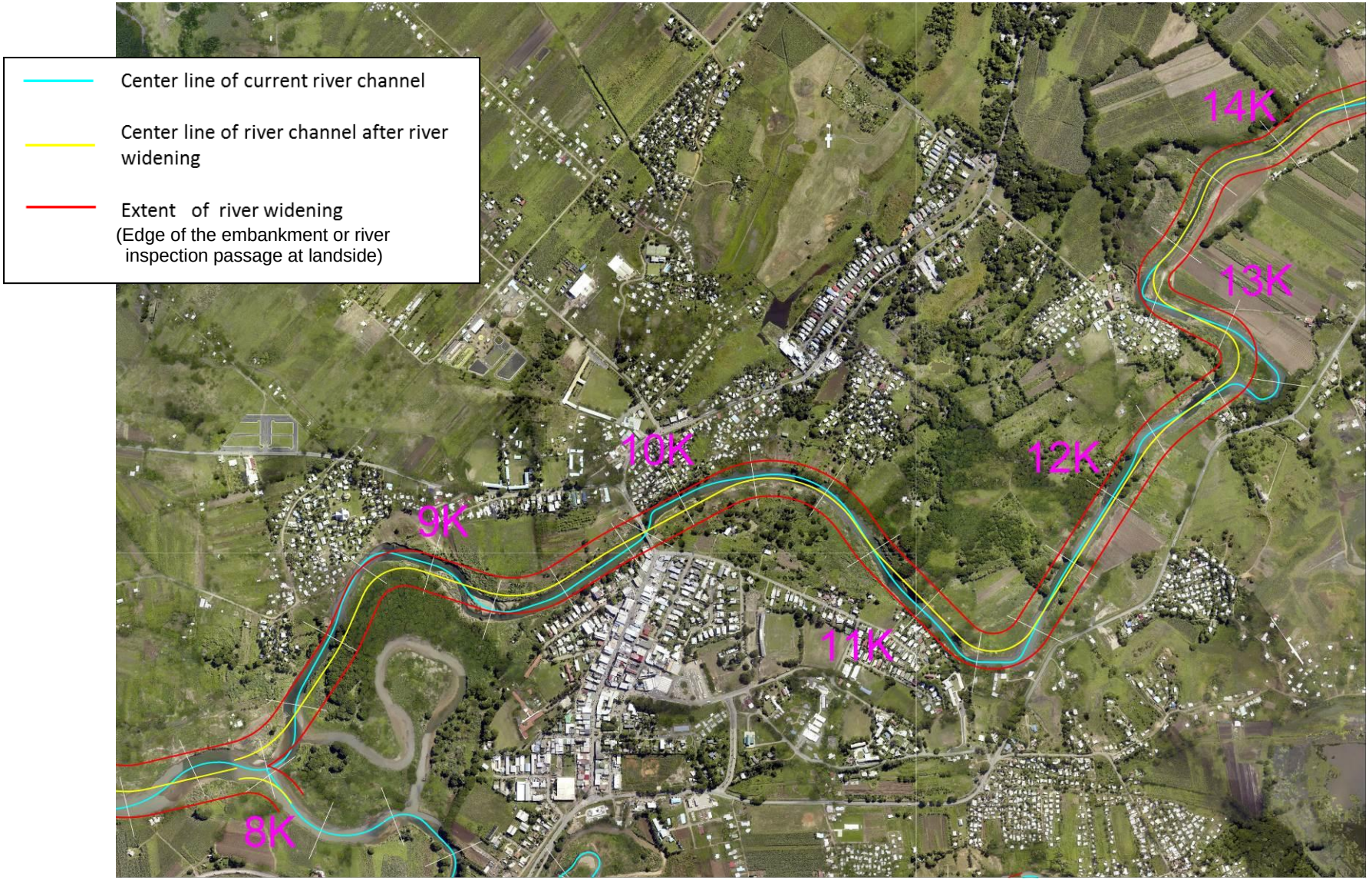


Figure 18-5 Plan of River Widening (2)

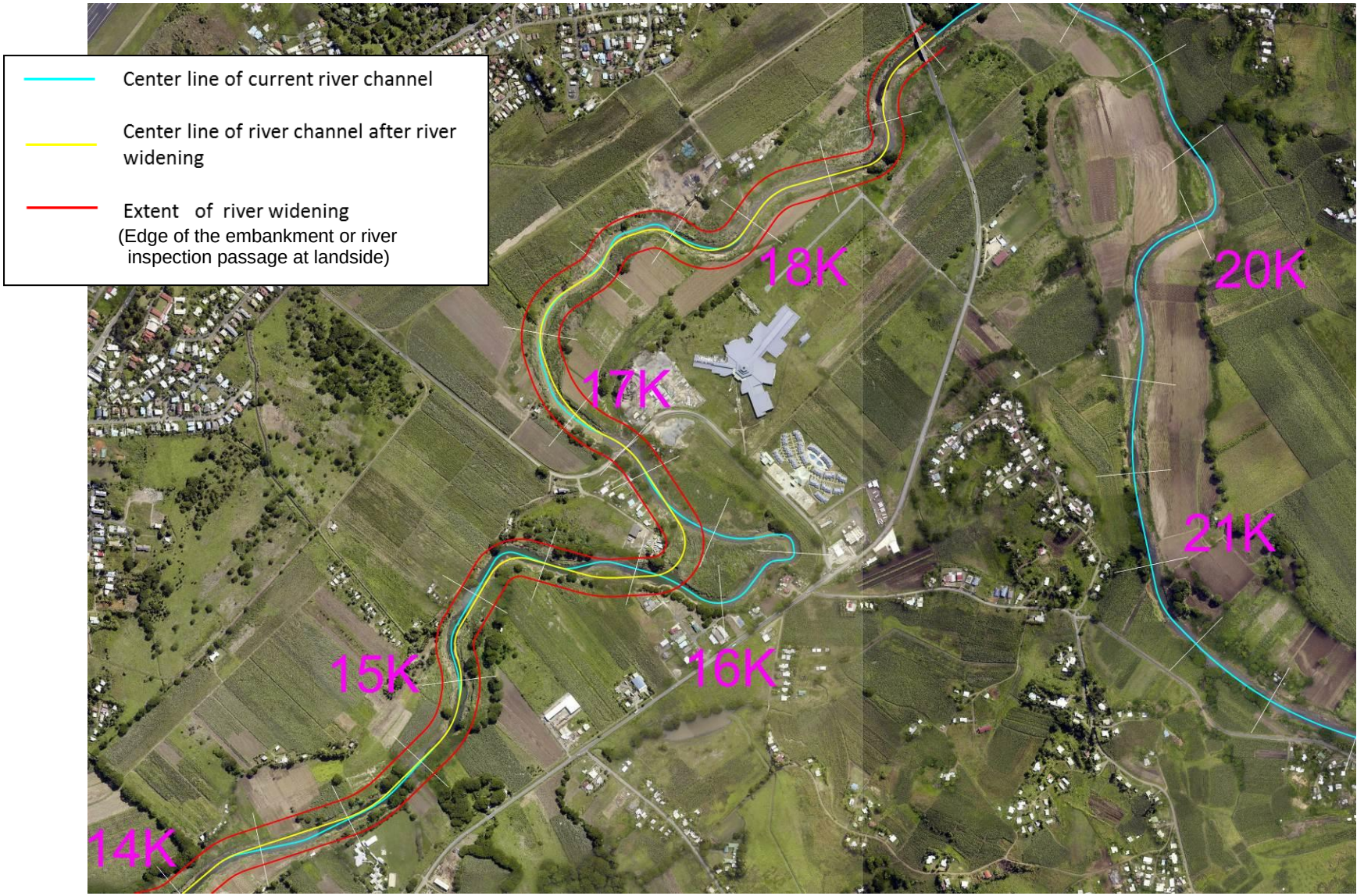


Figure 18-6 Plan of River Widening (3)

18.1.3 Longitudinal Plan

(1) Design High Water Level

The design high water level in a section from the lower reaches to the middle reaches is roughly set up to the inland ground level and which is set up based on the non-uniform flow calculation result at the time of design flow discharge, and the design high water level it is set up based on the overflow depth of the retarding basin and the non-uniform flow calculation result at the time of design flow discharge for a section in the upper reaches. (For more information see Draft Final Report, Main Report I: Master Plan Study, Chapter 8, 8.2.3 Longitudinal Plan). The High Water Level which is set based on the above is shown in Figure 18-8.

The High Water Level is set for Master Plan Level, however, after priority project before the completion of Master Plan, flood water level will exceed the High Water Level (but under designed dike crown elevation) by target design scales level flood (2012 flood).

Designed Discharge Distribution at the Priority Project is as shown in Figure 18-7.

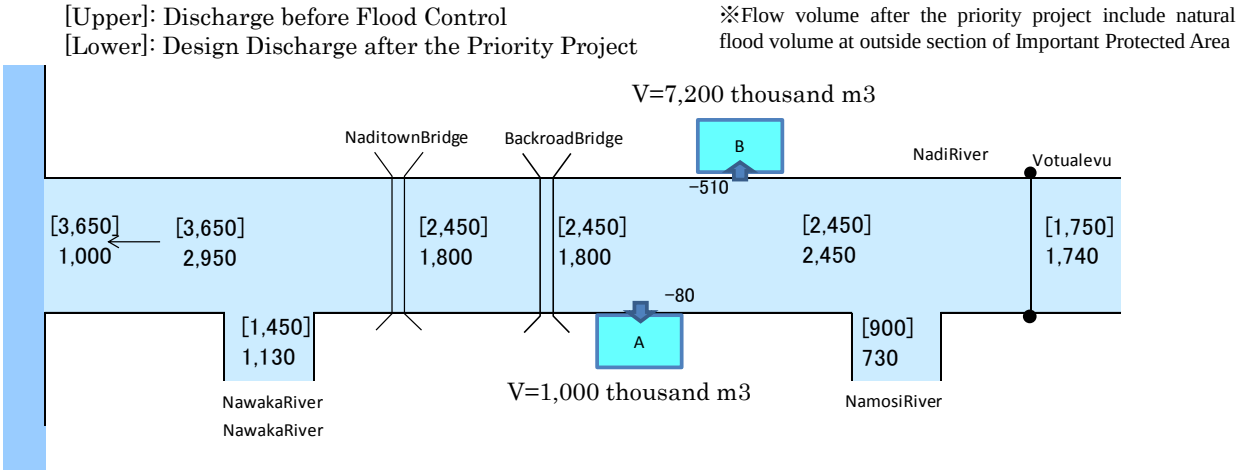


Figure 18-7 Designed Discharge Distribution at the Priority Project

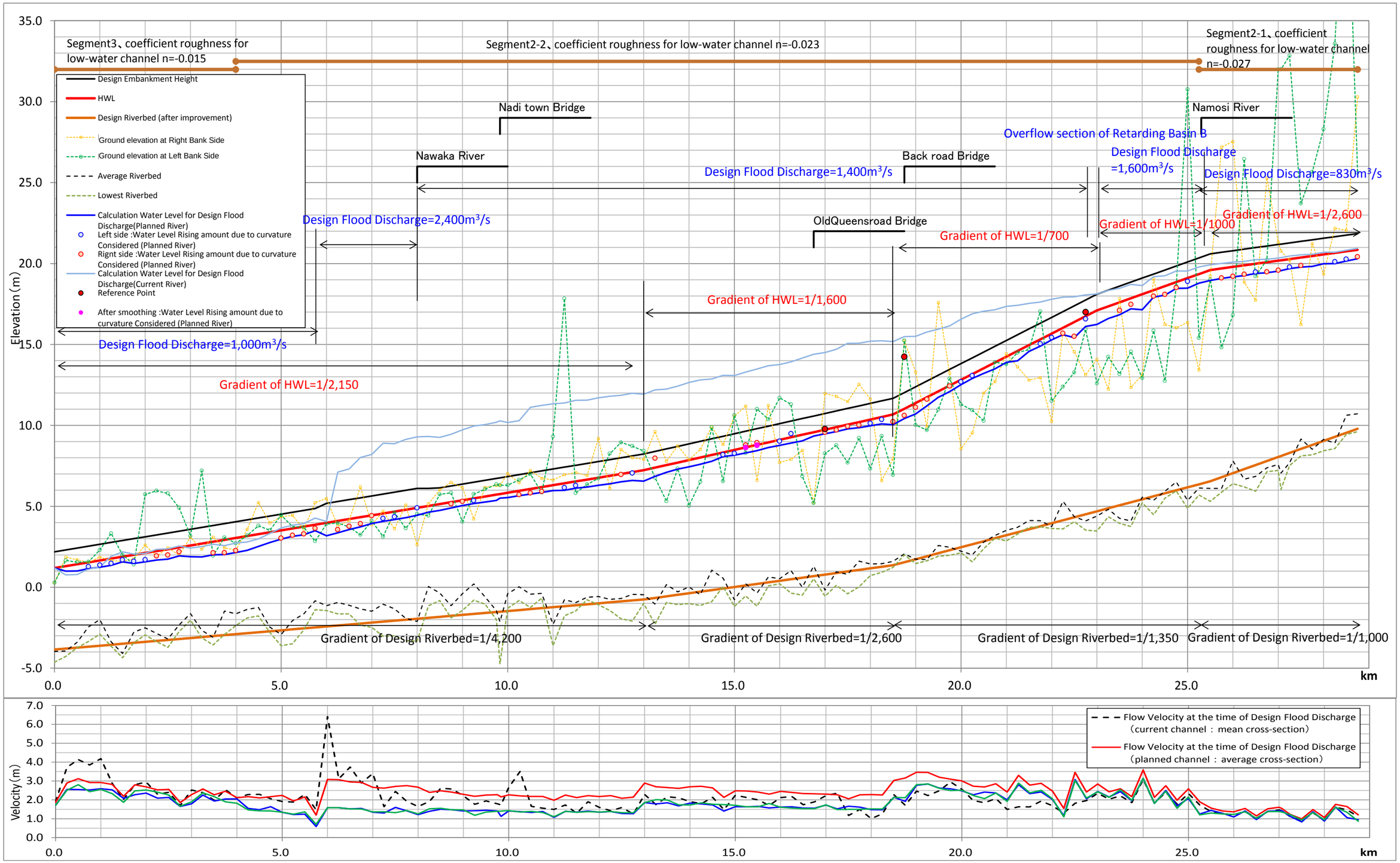


Figure 18-8 Designed Longitudinal Plan

Table 18-1 Longitudinal Feature (Nadi River)

milepost	Current feature												Design feature														
	Structure	Interval	Left Bank	Right Bank	Lowest Riverbed	Average Riverbed	Headroom for bridge girder − free-board	Calculation water level of Design Flood	Water level rising amount due to	Water level after curvature	HWL − non-uniform flow calculation	Flow velocity	Allocation of Flow rate	Fee-board	HWL	Designed Embankment Height	Design Riverbed (after improvement)	Design water depth	Design river width	Gradient of HWL	Lowest Riverbed (after improvement)	Calculation Water Level for Design Flood Discharge	Water level rising amount due to curvature	Water level after consideration of curvature	HWL − non-uniform flow calculation	Flow velocity
0.000		0.000	0.280	0.270	-4.630	-3.963		1.19	0.00		0.00	1.91		1.0	1.19	2.19	-3.85	5.038	80			1.19	0.00		0.00	1.87
0.250		0.250	1.660	1.860	-4.270	-3.935		0.77	0.00		0.54	3.72		1.0	1.30	2.30	-3.79	5.095	80			0.99	0.00		0.31	2.89
0.500		0.250	1.550	1.700	-3.730	-3.395		0.79	0.00		0.63	4.13		1.0	1.42	2.42	-3.73	5.152	80			1.00	0.00		0.42	3.12
0.750		0.250	1.580	1.540	-3.350	-2.444		1.13	0.12	1.25	0.29	3.85		1.0	1.54	2.54	-3.67	5.208	80			1.16	0.12	1.28	0.26	2.92
1.000		0.250	2.300	1.860	-2.900	-1.994		1.24	0.12	1.37	0.29	4.18		1.0	1.65	2.65	-3.61	5.265	80			1.24	0.12	1.37	0.29	2.92
1.250		0.250	3.330	1.650	-3.642	-3.374		1.91	0.12	2.04	-0.27	2.87		1.0	1.77	2.77	-3.55	5.322	80			1.35	0.12	1.48	0.29	2.81
1.500		0.250	2.000	1.593	-4.356	-4.088		2.19	0.12	2.31	-0.42	2.03		1.0	1.89	2.89	-3.49	5.379	80			1.57	0.12	1.70	0.19	2.19
1.750		0.250	1.410	1.760	-3.420	-2.770		2.05	0.12	2.18	-0.17	2.80		1.0	2.00	3.00	-3.43	5.435	80			1.47	0.12	1.60	0.40	2.79
2.000		0.250	5.736	2.605	-2.950	-2.503		2.10	0.12	2.22	-0.10	2.94		1.0	2.12	3.12	-3.37	5.492	80			1.57	0.12	1.70	0.42	2.69
2.250		0.250	5.960	1.920	-3.354	-2.844		2.34	0.25	2.59	-0.36	2.30		1.0	2.23	3.23	-3.31	5.549	80			1.68	0.25	1.94	0.30	2.53
2.500		0.250	5.800	2.430	-3.710	-3.200		2.37	0.25	2.62	-0.27	2.40		1.0	2.35	3.35	-3.25	5.606	80			1.74	0.25	1.99	0.36	2.55
2.750		0.250	4.910	1.990	-2.730	-2.321		2.55	0.25	2.80	-0.33	1.70	1000	1.0	2.47	3.47	-3.20	5.662	80			1.94	0.25	2.19	0.28	1.86
3.000		0.250	3.170	3.083	-2.040	-1.631		2.42	0.00		0.16	2.52		1.0	2.58	3.58	-3.14	5.719	80			1.89	0.00		0.69	2.28
3.250		0.250	7.200	2.350	-3.126	-2.665		2.52	0.00		0.18	2.38		1.0	2.70	3.70	-3.08	5.776	80			1.87	0.00		0.83	2.58
3.500		0.250	1.950	3.097	-3.560	-3.099		2.65	0.12	2.77	0.04	1.97		1.0	2.82	3.82	-3.02	5.833	80			2.01	0.12	2.13	0.69	2.27
3.750		0.250	3.080	2.440	-2.910	-1.471		2.57	0.12	2.69	0.24	2.54		1.0	2.93	3.93	-2.96	5.889	80			2.02	0.12	2.14	0.80	2.46
4.000		0.250	2.714	2.286	-2.370	-1.636		2.73	0.12	2.85	0.20	2.10		1.0	3.05	4.05	-2.90	5.946	80			2.15	0.12	2.27	0.78	2.12
4.250		0.250	3.200	3.570	-1.900	-1.374		2.80	0.00		0.36	2.28		1.0	3.16	4.16	-2.84	6.003	80			2.28	0.00		0.89	2.17
4.500		0.250	3.800	5.230	-1.770	-1.244		2.99	0.00		0.30	2.29		1.0	3.28	4.28	-2.78	6.060	80			2.53	0.00		0.76	2.10
4.750		0.250	3.520	3.970	-2.800	-2.460		3.32	0.00		0.08	2.06		1.0	3.40	4.40	-2.72	6.116	80			2.76	0.00		0.63	2.17
5.000		0.250	4.460	4.360	-3.610	-2.923		3.66	0.06	3.72	-0.21	1.92		1.0	3.51	4.51	-2.66	6.173	80			2.97	0.06	3.03	0.48	2.23
5.250		0.250	3.750	4.440	-3.490	-2.061		3.83	0.06	3.89	-0.26	1.88		1.0	3.63	4.63	-2.60	6.230	80			3.15	0.06	3.21	0.42	1.94
5.500		0.250	3.714	3.587	-2.640	-1.645		3.93	0.06	3.99	-0.25	2.29		1.0	3.75	4.75	-2.54	6.287	80			3.24	0.06	3.30	0.45	2.15
5.750		0.250	2.850	5.230	-1.390	-0.836		4.28	0.15	4.42	-0.56	1.48		1.0	3.86	4.86	-2.48	6.343	150			3.50	0.15	3.64	0.22	1.19
6.000		0.250	3.910	5.480	-1.440	-1.141		4.06	0.00		-0.08	6.41		1.2	3.98	5.18	-2.42	6.400	150			3.18	0.00		0.80	3.08
6.250		0.250	3.970	3.780	-1.645	-0.936		7.12	0.20	7.31	-3.22	3.12		1.2	4.09	5.29	-2.36	6.457	150			3.37	0.20	3.56	0.53	3.07
6.500		0.250	3.720	4.115	-1.650	-1.116		7.31	0.20	7.51	-3.30	3.74		1.2	4.21	5.41	-2.30	6.514	150	1/2150	1/4200	3.57	0.20	3.77	0.45	2.95
6.750		0.250	3.240	6.200	-2.340	-1.339		8.02	0.20	8.21	-3.89	2.89		1.2	4.33	5.53	-2.24	6.570	150			3.73	0.20	3.93	0.40	2.93
7.000		0.250	4.090	3.867	-2.480	-1.479		8.20	0.47	8.68	-4.23	3.39	2400	1.2	4.44	5.64	-2.18	6.627	150			3.94	0.47	4.42	0.03	2.66
7.250		0.250	3.130	4.700	-3.027	-1.045		8.90	0.18	9.08	-4.51	1.64		1.2	4.56	5.76	-2.12	6.684	150			4.07	0.18	4.25	0.31	2.62
7.500		0.250	4.620	3.610	-3.000	-1.332		8.87	0.18	9.05	-4.37	2.44		1.2	4.68	5.88	-2.06	6.741	150			4.18	0.18	4.36	0.32	2.71
7.750		0.250	3.640	5.080	-3.300	-1.919		9.14	0.00		-4.34	1.92		1.2	4.79	5.99	-2.00	6.797	150			4.30	0.00		0.49	2.76
8.000	NavuBridge	0.250	4.525	2.624	-3.320	-2.117		9.29	0.45	9.75	-4.84	1.64		1.2	4.91	6.11	-1.95	6.854	150			4.45	0.45	4.90	0.01	2.67
8.250		0.250	4.424	5.156	-1.150	0.049		9.32	0.00		-4.29	1.92		1.0	5.03	6.11	-1.89	6.911	100			4.64	0.00		0.38	2.39
8.500		0.250	5.740	6.013	-0.820	-0.356		9.26	0.00		-4.12	2.62		1.0	5.14	6.14	-1.83	6.968	100			4.75	0.00		0.39	2.48
8.750		0.250	5.836	6.480	-1.890	-1.138		9.45	0.26	9.71	-4.45	2.57		1.0	5.26	6.26	-1.77	7.024	100			4.90	0.26	5.15	0.10	2.41
9.000		0.250	4.050	6.150	-1.430	-0.393		9.73	0.26	9.98	-4.61	2.21		1.0	5.37	6.37	-1.71	7.081	100			5.05	0.26	5.30	0.07	2.29
9.250		0.250	5.750	4.220	-0.800	0.202		9.96	0.18	10.14	-4.65	1.76		1.0	5.49	6.49	-1.65	7.138	100			5.17	0.18	5.35	0.14	2.19
9.500		0.250	6.060	6.170	-1.050	-0.600		10.05	0.00		-4.44	1.95		1.0	5.61	6.61	-1.59	7.195	100			5.26	0.00		0.34	2.25
9.750		0.250	6.360	6.290	-2.000	-1.450		10.20	0.00		-4.47	1.79		1.0	5.72	6.72	-1.53	7.251	100			5.36	0.00		0.36	2.27
9.830	NaditownBridge	0.080	6.300	6.300	-4.730	-2.131	5.300	10.29	0.00		-4.53	1.73		1.0	5.76	6.76	-1.51	7.270	100			5.51	0.00		0.25	2.16
10.000		0.170	6.310	7.020	-1.300	-0.398		10.18	0.00		-4.34	2.66		1.0	5.84	6.84	-1.47	7.308	100			5.54	0.00		0.30	2.26
10.250		0.250	6.630	6.460	-0.820	0.028		10.30	0.07	10.36	-4.41	3.51		1.0	5.96	6.96	-1.41	7.365	100			5.65	0.07	5.72	0.24	2.21
10.500		0.250	6.990	7.210	-1.250	-0.431		11.12	0.07	11.19	-5.12	1.66		1.0	6.07	7.07	-1.35	7.422	100			5.76	0.07	5.83	0.25	2.18
10.750		0.250	5.850	6.730	-0.670	-0.376		11.23	0.07	11.30	-5.11	1.56		1.0	6.19	7.19	-1.29	7.478	100			5.85	0.07	5.92	0.27	2.18
11.000		0.250	9.310	6.630	-3.610	-2.289		11.33	0.00		-5.03	1.49		1.0	6.30	7.30	-1.23	7.535	100			5.97	0.00		0.33	1.98
11.250		0.250	17.830	6.950	-1.760	-0.769		11.39	0.16	11.55	-5.13	1.73		1.0	6.42	7.42	-1.17	7.592	100			5.99	0.16	6.16	0.26	2.25
11.500		0.250	5.820	7.090	-1.460	-0.950		11.56	0.16	11.72	-5.18	1.29		1.0	6.54	7.54	-1.11	7.649	100			6.12	0.16	6.28	0.25	2.12
11.750		0.250	6.350	6.900	-0.770	-0.622		11.56	0.00		-4.90	1.90		1.0	6.65	7.65	-1.05	7.705	100			6.19	0.00		0.46	2.23
12.000		0.250	6.720	9.190	-1.080	-0.574		11.70	0.00		-4.93	1.60		1.0	6.77	7.77	-0.99	7.762	100			6.30	0.00		0.47	2.18
12.250		0.250	8.250	6.100	-1.440	-0.750		11.80	0.00		-4.92	1.43		1.0	6.89	7.89	-0.93	7.819	100			6.39	0.00		0.49	2.22
12.500		0.250	8.950	8.510	-1.950	-0.700		11.86	0.44	12.30	-5.30	1.60		1.0	7.00	8.00	-0.87	7.876	100			6.52	0.44	6.96	0.04	2.08
12.750		0.250	8.720	8.000	-2.090	-0.434		11.99	0.46	12.45	-5.33	1.25		1.0	7.12	8.12	-0.81	7.933	100			6.60	0.46	7.05	0.07	2.14
13.000		0.250	8.420	7.900	-1.000	-0.463		11.92	0.00		-4.69	2.28		1.0	7.23	8.23	-0.75	7.989	80			6.56	0.00		0.68	2.89
13.250		0.250	6.770	9.620	-2.290	-1.039		12.19	1.20	13.39	-6.00	1.75		1.0	7.39	8.39	-0.66	8.049	80			6.85	1.12	7.97	-0.58	2.69
13.500		0.250	5.320	7.780	-0.950	0.164		12.25	0.00		-4.70	2.16		1.0	7.55	8.55	-0.56	8.109	80			7.10	0.00		0.45	2.65
13.750		0.250	7.330	8.740	-1.070	-0.291		12.43	0.00		-4.72	2.11		1.0	7.70	8.70	-0.47	8.170	80			7.30	0.00		0.40	2.61
14.000		0.250	5.040	7.880	-1.010	0.022		12.65	0.00		-4.79	1.90		1.0	7.86	8.86	-0.37	8.230	80			7.44	0.00		0.42	2.69
14.250		0.250	6.510	8.510	-1.120	-0.464		12.81	0.00		-4.80	1.80		1.0	8.02	9.02	-0.27	8.290	80			7.60	0.00		0.42	2.72
14.500		0.250	9.880	9.920	-0.890	1.057		12.87	0.00		-4.70	2.13		1.0	8.17	9.17	-0.18	8.350	80			7.78	0.00		0.39	2.63
14.750		0.250	6.550	8.820	0.050	0.567		13.09	0.11	13.20	-4.87	1.48		1.0	8.33	9.33	-0.08	8.410	80			8.08	0.11	8.18	0.14	2.13
15.000		0.250	10.620	10.560	-1.190	-0.769		13.08	0.11	13.19	-4.70	2.24		1.0	8.48	9.48	0.01	8.470	80			8.16	0.11	8.27	0.22	2.48
15.250		0.250	8.290	11.190	-0.540	0.216		13.29	0.49	13.78	-5.14	2.13	1400	1.0	8.64	9.64	0.11	8.530	80			8.30	0.49	8.79	-0.15	2.47
15.500		0.250	11.010	6.600	-1.170	-0.354		13.49	0.49	13.98	-5.18	2.00		1.0	8.80	9.80	0.21	8.590	80	1/1600	1/2600	8.45	0.49	8.93	-0.13	2.42
15.750		0.250	10.380	11.230	0.090	0.637		13.69	0.00		-4.74	1.70		1.0	8.95	9.95	0.30	8.650	80			8.64	0.00		0.32	2.31
16.000		0.250	11.700	7.710	0.210	0.532		13.76	0.25	14.01	-4.90	2.12		1.0	9.11	10.11	0.40	8.710	80			8.77	0.25	9.02	0.09	2.45
16.250		0.250	11.300	7.910	-0.360	1.033		13.92	0.58	14.50	-5.24	2.18		1.0	9.27	10.27	0.50	8.771	80			8.91	0.58	9.49	-0.23	2.39
16.500		0.250	6.850	8.450	-0.490	0.008		14.16	0.00		-4.74	1.74		1.0	9.42	10.42	0.59	8.831	80			9.04	0.00		0.38	2.33
16.750		0.250	5.200	5.200	0.520	1.307		14.39	0.00		-4.81	1.89		1.0	9.58	10.58	0.69	8.891	80			9.34	0.00		0.24	2.32
17.000	OldQueensRoadBridg	0.250	8.260	11.980	-0.550	-0.182	9.780	14.50	0.09	14.59	-4.86	2.22		1.0	9.73	10.73	0.78	8.951	80			9.48	0.09	9.58	0.16	2.31
17.250		0.250	8.770	11.790	0.120	0.952		14.70	0.09	14.80	-4.91	2.36		1.0	9.89	10.89	0.88	9.011	80			9.62	0.09	9.71	0.18	2.27
17.500		0.250	7.700	11.470	-0.400	0.795		15.07	0.14	15.21	-5.17	1.18		1.0	10.05	11.05	0.98	9.071	80			9.79	0.15	9.94	0.11	2.05
17.750		0.250	9.220	12.540	0.030	1.613		15.08	0.15	15.23	-5.03	1.49		1.0	10.20	11.20	1.07	9.131	80			9.86	0.16	10.02	0.18	2.27
18.000		0.250	7.330	11.630	0.720	1.442		15.20	0.15	15.35	-4.99	1.01		1.0	10.36	11.36	1.17	9.191	80			9.97	0.16	10.13	0.23	2.28
18.250		0.250	9.340	6.590	0.920	1.459		15.23	0.30	15.52	-5.01	1.26		1.0	10.52	11.52	1.26	9.251	80			10.09	0.28	10.37	0.15	2.26
18.500		0.250	6.940	7.920	1.220	1.597		15.18	0.18	15.35	-4.68	2.27		1.0	10.67	11.67	1.36	9.311	70			10.04	0.19	10.23	0.44	3.03
18.750	BackroadBridge	0.250	15.240	15.240	2.000	2.061	14.240	15.49	0.18	15.66	-4.63	1.71		1.0	11.03	12.03	1.55	9.483	70			10.43	0.19	10.61	0.42	3.16
19.000		0.250	10.020	13.290	1.460	1.727		15.50	0.34	15.84	-4.45	2.46		1.0	11.39	12.39	1.73	9.655	70			10.71	0.40	11.11	0.27	3.46
19.250		0.250	9.710	9.900	1.640	1.713		15.77	0.34	16.11	-4.37	2.23		1.0	11.74	12.74	1.92	9.827	70			11.21	0.40	11.61	0.13	3.45
19.500		0.250	10.980	17.600	1.910	2.582		15.95	0.00		-3.85	2.48		1.0	12.10	13.10	2.10	9.999	70			11.74	0.00		0.36	3.20
19.750		0.250	12.890	13.240	1.970	2.471		16.15	0.32	16.46	-4.00	2.95		1.0	12.46	13.46	2.29	10.171	70			12.09	0.35	12.43	0.02	3.10
20.000		0.250	11.300	8.550	2.130	2.231		16.57	0.16	16.72	-3.91	2.56		1.0	12.81	13.81	2.47	10.343	70			12.52	0.17	12.69	0.12	3.00
20.250		0.250	10.940	9.530	1.570	2.008		16.89	0.16	17.05	-3.87	1.97		1.0	13.17	14.17	2.66	10.515	70			12.90	0.17	13.07	0.10	2.72
20.500		0.250	10.280	12.000	2.380	2.787		17.05	0.00		-3.52	1.85		1.0	13.53	14.53	2.84	10.687	70	1/700		13.21	0.00		0.32	2.68
20.750		0.250	13.910	12.710	3.030	3.198		17.15	0.00		-3.26	2.07		1.0	13.89	14.89	3.03	10.859	70			13.50	0.00		0.39	2.85
21.000		0.250	13.770	14.420	2.860	3.516		17.36	0.00		-3.11	1.49		1.0	14.24	15.24	3.21	11.031	65			13.89	0.00		0.35	2.41
21.250		0.250	14.500	13.610	3.290	3.708		17.42	0.00		-2.82	1.63		1.0	14.60	15.60	3.40	11.203	65			13.99	0.00		0.61	3.30
21.500		0.250	14.690	12.800	3.710	4.122		17.53	0.00		-2.58	1.63		1.0	14.96	15.96	3.58	11.375	65			14.57	0.00		0.39	2.78
21.750		0.250	17.040	12.950	3.730	4.116		17.62	0.15	17.77	-2.45	1.94		1.0	15.31	16.31	3.77	11.547	65		1/1350	14.89	0.15	15.05	0.27	2.88
22.000		0.250	11.510	10.250	3.630	3.745		17.80	0.15	17.95	-2.27	1.69		1.0	15.67	16.67	3.95	11.719	65			15.28	0.15	15.44	0.24	2.47
22.250		0.250	12.390	15.760	3.610	5.316		17.92	0.08	18.00	-1.97	1.29		1.0	16.03	17.03	4.14	11.891	65			15.61	0.08	15.69	0.34	1.55
22.500		0.250	13.270	14.550	4.060	4.353		17.94	0.08	18.02	-1.63	1.82		1.0	16.39	17.39	4.32	12.063	65			15.42	0.08	15.50	0.89	3.46
22.750		0.250	15.930	13.120	3.530	4.097	17.000	18.06	0.45	18.51	-1.77	1.96		1.0	16.74	17.74	4.51	12.235	65			16.11	0.46	16.57	0.17	2.41
23.000		0.250	12.600	14.080	3.470	4.401		18.12	0.00		-1.02	2.35		1.0	17.10	18.10	4.69	12.407				16.24	0.00		0.86	2.84
23.250		0.250	14.230	12.240	4.360	4.812		18.34	0.00		-0.99	2.03		1.0	17.35	18.35	4.88	12.471				16.61	0.00		0.74	2.43
23.500		0.250	13.170	17.840	3.950	4.254		18.47	0.27	18.74	-1.14	2.21		1.0	17.60	18.60	5.06	12.536				16.84	0.27	17.11	0.49	2.59
23.750		0.250	14.560	12.350	3.760	4.100		18.71	0.27	18.98	-1.13	1.85		1.0	17.85	18.85	5.25	12.601				17.21	0.27	17.48	0.38	2.17
24.000		0.250	12.920	13.110	5.220	5.562		18.64	0.00		-0.54	3.08	1600	1.0	18.10	19.10	5.43	12.666		1/1000		17.15	0.00		0.95	3.58
24.250		0.250	15.850	19.040	4.480	5.384		19.19	0.05	19.24	-0.89	1.83		1.0	18.35	19.35	5.62	12.731				17.93	0.05	17.98	0.37	2.13
24.500		0.250	12.750	16.240	5.510	5.928		19.25	0.05	19.30	-0.70	2.40		1.0	18.60	19.60	5.81	12.796				18.05	0.05	18.09	0.51	2.75
24.750		0.250	18.600	16.030	5.950	6.508		19.54	0.05	19.59	-0.74	1.77		1.0	18.85	19.85	5.99	12.860				18.46	0.05	18.51	0.34	1.98
25.000		0.250	30.760	16.360	4.870	5.363		19.54	0.41	19.96	-0.86	2.34		1.0	19.10	20.10	6.18	12.925				18.48	0.42	18.90	0.20	2.58
25.250		0.250	15.400	13.420	5.700	6.132		19.786	0.00		-0.44	1.73		1.0	19.35	20.35	6.36	12.990				18.789	0.00		0.56	1.90
25.500		0.250	19.000	19.210	5.310	6.107		19.919	0.00		-0.32	1.38		1.0	19.60	20.60	6.55	13.055				18.953	0.00		0.65	1.56
25.750		0.250	14.823	27.190	5.870	6.105		20.009	0.03	20.04	-0.34	1.28		1.0	19.70	20.70	6.80	12.901				19.08	0.03	19.11	0.59	1.41
26.000		0.250	16.820	27.540	6.400	7.812		20.085	0.03	20.11	-0.32	1.19		1.0	19.79	20.79	7.05	12.747				19.176	0.03	19.21	0.59	1.37
26.250		0.250	26.450	18.850	6.203	6.673		20.133	0.08	20.21	-0.32	1.40		1.0	19.89	20.89	7.30	12.593				19.254	0.08	19.34	0.55	1.55
26.500		0.250	19.220	17.730	5.930	6.847		20.241	0.08	20.32	-0.34	1.03		1.0	19.99	20.99	7.55	12.439				19.392	0.08	19.47	0.51	1.15
26.750		0.250	20.230	25.280	7.140	7.381		20.265	0.06	20.32	-0.24	1.37		1.0	20.08	21.08	7.80	12.286				19.429	0.06	19.49	0.59	1.53
27.000		0.250	31.990	21.330	7.220	7.586		20.339	0.06	20.40	-0.22	1.47		1.0	20.18	21.18	8.05	12.132				19.529	0.06	19.59	0.59	1.61
27.060		0.060	32.000	20.770	6.050	7.059		20.366	0.00		-0.17	1.42	830	1.0	20.20	21.20	8.11	12.095		1/2600	1/1000	19.565	0.00		0.64	1.55
27.250		0.190	32.840	20.220	7.512	7.687		20.466	0.09	20.56	-0.29	1.11		1.0	20.27	21.27	8.30	11.978				19.685	0.10	19.78	0.49	1.22
27.500		0.250	23.710	16.230	8.120	9.156		20.54	0.10	20.64	-0.27	0.89		1.0	20.37	21.37	8.55	11.824				19.776	0.10	19.87	0.50	0.99
27.750		0.250	25.660	21.220	8.180	8.522		20.575	0.00		-0.11	1.30		1.0	20.47	21.47	8.80	11.670				19.82	0.00		0.65	1.48
28.000		0.250	28.300	19.350	8.430	9.132		20.699	0.00		-0.14	0.96		1.0	20.56	21.56	9.05	11.516				19.987	0.00		0.58	1.06
28.250		0.250	33.570	22.178	8.566	8.908		20.699	0.11	20.81	-0.15	1.61		1.0	20.66	21.66	9.30	11.362				19.997	0.11	20.11	0.55	1.76
28.500		0.250	46.710	22.050	9.440	10.625		20.826	0.11	20.94	-0.18	1.47		1.0	20.75	21.75	9.55	11.209				20.154	0.11	20.26	0.49	1.64
28.750		0.250	25.620	30.300	9.611	10.714		20.937	0.12	21.05	-0.20	1.11		1.0	20.85	21.85	9.80	11.055				20.298	0.12	20.42	0.44	1.20

(2) Design Embankment Height (Free-Board)

In accordance with "Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 20", the design embankment height is provided with a freeboard 1.0m for a given flow rate as below.

Table 18-2 Design Embankment Free-Board

Item	1	2	3	4	5	6
Flow Rate (m3/s)	Less than 200	More than 200 Less than 500	More than 500 Less than 2000	More than 2000 Less than 5000	More than 5000 Less than 1000	More than 10000
Free Board (m)	0.6	0.8	1	1.2	1.5	2

Source: "Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 20"

(3) Design Riverbed Height

The design riverbed height is set up nearly the present riverbed height. The design riverbed slope is set up nearly the present riverbed slope on due consideration of ensuring stability of the riverbed.

(4) Water Level Rise

The water level rise due to bridge pier, or due to the confluence point are considered but the water level rising amount due to curvature is corresponded by the correction of cross-shape or planar normal line if necessary, after checking the terrain situation behind the ground. In case that the water level is over HWL and there are no protection objects, the water level rising is confirmed within the free-board. This is considered a tentative situation in the step wise implementation so that the alignment is not revised. Water Level Rise is mentioned in Table 18-1.

18.1.4 Cross-Sectional Plan

(1) Slope Gradient

a) From 8.0k（Downstream beginning point of Dike）to 18.75k（Back Road Bridge）

Although in principle the slope gradient of embankment is set loosely than 1:3 of either river side or land side slope based on River Embankment Design Criteria in Japan, 2007, River Improvement and Management Division, Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Slope gradient either river side or land side for Nadi River is set as 1:2 because 1)Risk of dike breach due to riverbank erosion is low because cross-sectional shape of Nadi River after improvement is almost engraved to existing ground, 2)Height of embankment is from 0.5m to 3m if necessary and stability for structural and permeability is considered to be secured and 3) The present situation of the bank are considered to be stable with almost 1:2 through field investigation.

In addition, in this project, slope of land side is hardly formed because low land area besides embankment is filled with soil as mentioned later in "(4) Backfilling at Hinterland".

Typical Cross Section is as described in Figure 18-9.

On the other hand, slope gradient for other structures are set as below. Although details of each shape of structure are mentioned later in each clause, only outline is described for reference in this clause.

b) Surrounding Dike of Nadi Town

Either river or land side of slope gradient is set as 1:3 because conditions do not apply to those mentioned in above a).

c) Ring Dike

Either river or land side of slope gradient is set as 1:3 because conditions do not apply to those mentioned in above a).

d) Surrounding Dike for Retarding Basin A,B in upstream

Either river or land side of slope gradient is set as 1:3 because conditions do not apply to those mentioned in above a).

e) Dike along the river for Retarding Basin A, B in upstream

Either river or land side of slope gradient is set as 1:3 because conditions do not apply to those mentioned in above a).

(2) Top of Bank Width

In accordance with "Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 21", the embankment section is provided with a bank width for a given flow rate as mentioned in Table 18-3. Bank width is set as 4.0m

Table 18-3 Top of Bank Width

Design Discharge (m3/s)	Bank Width (m)
Less than 500	3
Moe than 500, Less than 2000	4
Moe than 2000, Less than 5000	5
Moe than 5000, Less than 10000	6
Moe than 10000	7

Source: "Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 21"

(3) Inspection passage

In accordance with "Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 27", the embankment is provided a inspection passage. Inspection passage width is set as 3.0m

Table 18-4 Inspection Passage (Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 27 and Rules Article 15)

(Inspection Passage)
Article 27: Inspection Passage shall be installed near Embankment.
Rules Article 15: Width od Inspection Passage of Embankment is more than 3m and less than width of crest of Embankment

Source: Edited by JICA Study Team from "Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 21"

Typical Cross Section

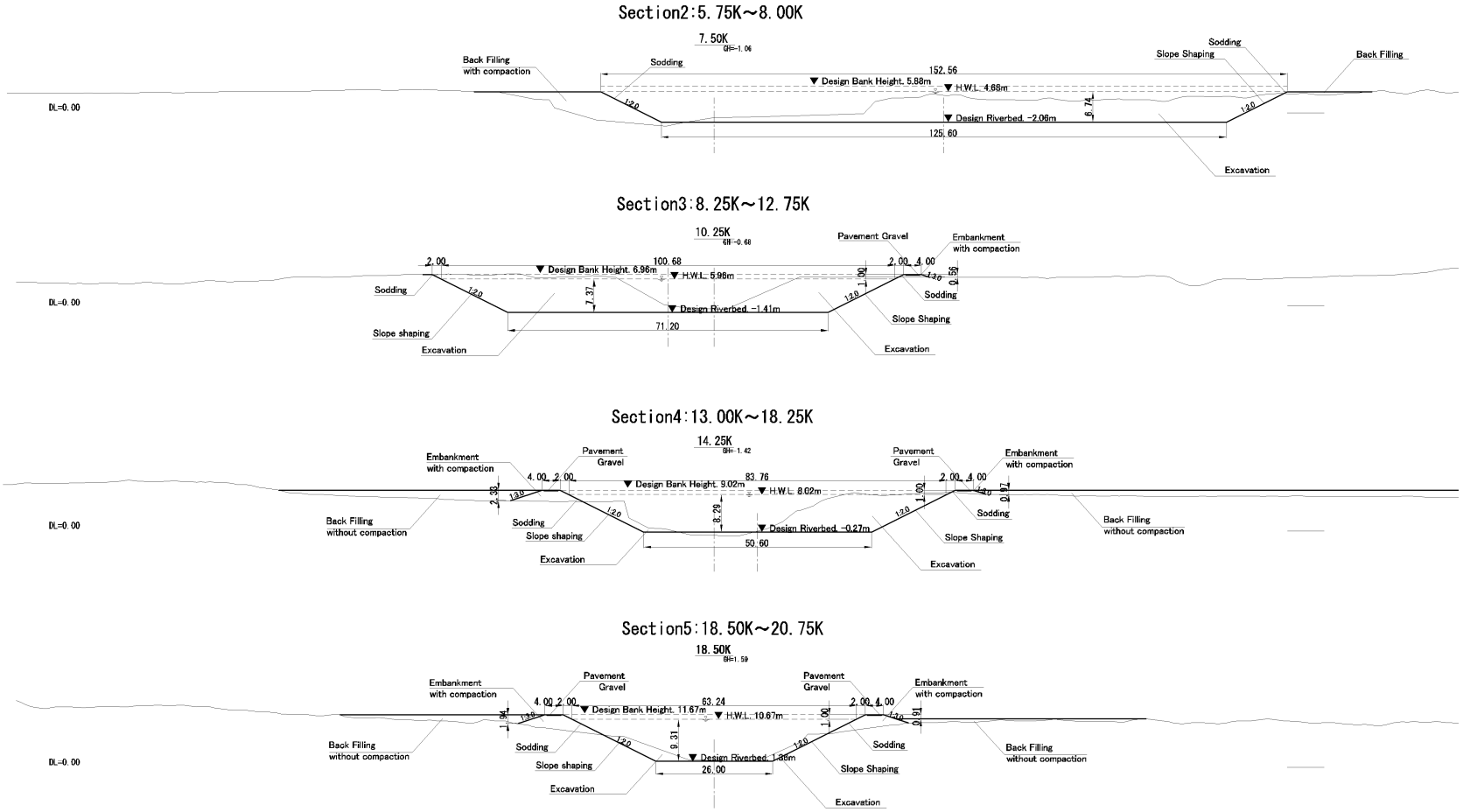


Figure 18-9 Typical Cross Section (Nadi River)

(4) Backfilling at Hinterland

Terrain of the project area is the shape of a river terrace and the ground elevation is generally higher as distance to land side from the river. Therefore, backfilling at hinterland is planned in order to the fill lower area between embankment and land side if any after installation of embankment, also aiming at 1) Improvement of safety degree for inundation (Land raising becomes hard to be inundated), 2) Cost reduction by reducing disposal cost for soil generated by construction by utilizing them to backfilling. This matter is already coordinated with the C/P of Fiji side.

In addition, for project costing, the backfilling cost is considered as project cost but land acquisition cost for hinter land is not considered because whether backfilling of hinterland is conducted or not actually is depending on intention of land owners. Land acquisition is conducted up to the land side end of embankment.

(5) Riverbank Protection

Riverbank Protection is basically installed when flood flow velocity is more than 2.0m/s in Japan. However, riverbank protection is not planned at the moment but considered adaptively although the flood flow velocity is more than 2.0m/s in some sections in Nadi River after the Priority Project. Adaptively, river bank protection is installed after extreme bank erosion occurs, and a margin in the cross section is left at outer side of river channel curve such as leave bank as a margin for erosion considering flow capacity or setting-back of embankment considering land acquisition cost.

<The reason for the adaptive management of riverbank protection>

1) During the past maximum flood, extreme riverbank erosion does not occur

2) River bank protection can be expected by vegetation because vegetation is flourished on the banks,

3) Installation of riverbank protection will cause riverbank erosion negatively near the installation area.

In addition, detailed planning of cross section mentioned above shall be done in Detailed Design Stage. At this moment, typical cross section is applied for the project costing because construction cost for typical cross section is supposed to be higher than that of cross-section mentioned in above.

Results of flood flow velocity with calculation conditions are mentioned in Table 18-5.

As the external force, the rainfall scale is same as that of design flood (1/50). The shape of river channel and roughness coefficient (composite roughness coefficient) is assumed in the river channel after improvement.

Table 18-5 Flood Flow velocity

Location	Flood Flow Velocity[1]												Conditions near river channel			Riverbank Protection	
	Master Plan						Priority Project										
	Water Depth	Degree of roughness	Energy Gradient	Velocity (Average)	Velocity (left bank side)	Velocity (right bank side)	Water Depth	Degree of roughness	Energy Gradient	Velocity (Average)	Velocity (left bank side)	Velocity (right bank side)	a) Past damage, bank erosion	b) Outer bending and asset existing	c) Bridge Protection		
0.000	1.19	0.015	0.000138590	1.87	1.71	1.71	1.18	0.015	0.0002002	2.11	1.92	1.91					
0.250	0.99	0.015	0.000251510	2.89	2.55	2.51	0.76	0.015	0.0008487	4.26	4.15	3.94					
0.500	1.00	0.015	0.000331090	3.12	2.55	2.80	0.78	0.015	0.0013184	4.83	4.69	4.44					
0.750	1.16	0.015	0.000287200	2.92	2.52	2.43	1.12	0.015	0.0008716	3.98	3.73	3.68					
1.000	1.24	0.015	0.000291770	2.92	2.59	2.56	1.24	0.015	0.0011985	4.31	3.95	3.97					
1.250	1.35	0.015	0.000257390	2.81	2.53	2.33	1.91	0.015	0.0003348	2.87	2.78	2.81					
1.500	1.57	0.015	0.000145340	2.19	2.08	1.87	2.19	0.015	0.0001361	2.03	1.98	2.00					
1.750	1.47	0.015	0.000245450	2.79	2.27	2.47	2.05	0.015	0.0002684	2.80	2.37	2.59					
2.000	1.57	0.015	0.000239590	2.69	2.36	2.52	2.10	0.015	0.0003398	2.94	2.65	2.79					
2.250	1.68	0.015	0.000221760	2.53	2.09	2.41	2.34	0.015	0.0001839	2.30	1.95	2.24					
2.500	1.74	0.015	0.000186870	2.55	2.12	2.26	2.37	0.015	0.0001650	2.40	2.18	2.22					
2.750	1.94	0.015	0.000122790	1.86	1.65	1.66	2.55	0.015	0.0000982	1.70	1.54	1.56					
3.000	1.89	0.015	0.000177670	2.28	1.79	1.89	2.42	0.015	0.0002533	2.53	2.07	2.21					
3.250	1.87	0.015	0.000224980	2.58	2.25	2.37	2.52	0.015	0.0002073	2.39	2.23	2.20					
3.500	2.01	0.015	0.000170180	2.27	1.94	2.17	2.61	0.015	0.0001576	2.20	2.05	2.14					
3.750	2.02	0.015	0.000214170	2.46	2.05	1.89	2.41	0.015	0.0004063	3.19	2.48	2.49					
4.000	2.15	0.015	0.000163340	2.12	2.05	1.82	2.62	0.015	0.0003415	2.83	2.65	2.50					
4.250	2.28	0.027	0.000521430	2.17	1.55	1.46	2.70	0.025	0.0011568	3.30	1.63	1.64					
4.500	2.53	0.027	0.000449240	2.10	1.48	1.42	3.06	0.025	0.0010959	3.37	1.80	1.93					
4.750	2.76	0.028	0.000537290	2.17	1.64	1.41	3.75	0.034	0.0014862	2.93	2.50	2.35					
5.000	2.97	0.024	0.000301630	2.23	1.34	1.35	4.21	0.029	0.0006503	3.07	1.89	1.95					
5.250	3.15	0.026	0.000280950	1.94	1.22	1.24	4.53	0.026	0.0005348	2.74	2.04	1.95					
5.500	3.24	0.026	0.000353420	2.15	1.24	1.36	4.68	0.030	0.0012565	3.10	2.20	2.35					
5.750	3.50	0.024	0.000082020	1.19	0.59	0.70	5.08	0.027	0.0003608	2.49	1.36	1.55	○				
6.000	3.18	0.024	0.000575440	3.08	1.59	1.59	5.35	0.027	0.0012760	1.89	1.05	1.00					
6.250	3.37	0.024	0.000555110	3.07	1.58	1.58	5.37	0.027	0.0007355	2.03	1.12	1.12				Adaptive management of riverbank protection[2]	
6.500	3.57	0.024	0.000497220	2.95	1.52	1.52	5.41	0.027	0.0010149	2.10	1.17	1.15					
6.750	3.73	0.024	0.000478540	2.93	1.55	1.51	5.45	0.031	0.0007864	2.22	1.25	1.12	○				
7.000	3.94	0.024	0.000381880	2.66	1.35	1.36	5.53	0.030	0.0008455	2.17	1.17	1.18	○				
7.250	4.07	0.024	0.000365560	2.62	1.30	1.37	5.58	0.038	0.0003464	2.24	1.20	1.23					
7.500	4.18	0.024	0.000391170	2.71	1.60	1.32	5.62	0.027	0.0004204	2.41	1.50	1.31					
7.750	4.30	0.024	0.000390020	2.76	1.42	1.44	5.66	0.031	0.0003199	2.60	1.42	1.37					
8.000	4.45	0.024	0.000360710	2.67	1.22	1.25	5.74	0.036	0.0002884	2.65	1.41	1.51					
8.250	4.64	0.024	0.000310630	2.39	1.40	1.53	5.87	0.025	0.0002767	2.56	1.68	1.74					
8.500	4.75	0.024	0.000334810	2.48	1.51	1.55	5.96	0.024	0.0004644	2.66	1.81	1.75					
8.750	4.90	0.024	0.000314510	2.41	1.47	1.47	6.10	0.027	0.0005329	2.60	1.75	1.78	○	○			
9.000	5.05	0.024	0.000269650	2.29	1.41	1.47	6.23	0.027	0.0003936	2.51	1.72	1.74				Adaptive management of riverbank protection	
9.250	5.17	0.024	0.000251270	2.19	1.43	1.18	6.36	0.033	0.0003575	2.36	1.58	1.49	○				
9.500	5.26	0.024	0.000259360	2.25	1.45	1.35	6.45	0.027	0.0002866	2.41	1.74	1.33		○			
9.750	5.36	0.024	0.000260990	2.27	1.41	1.39	6.57	0.027	0.0002083	2.44	1.93	1.56		○	○	Riverbank Protection	
9.830	5.51	0.024	0.000218160	2.16	1.13		6.72	0.026	0.0001664	2.35	1.54	0.72					
10.000	5.54	0.024	0.000251240	2.26	1.41	1.43	6.74	0.026	0.0004769	2.48	1.71	1.65					
10.250	5.65	0.024	0.000246870	2.21	1.37	1.36	6.86	0.028	0.0011888	2.41	1.60	1.62	○	○			
10.500	5.76	0.024	0.000233430	2.18	1.33	1.39	6.96	0.027	0.0001672	2.39	1.60	1.63		○			
10.750	5.85	0.024	0.000230050	2.18	1.38	1.33	7.04	0.029	0.0001803	2.40	1.67	1.60				Adaptive management of riverbank protection	
11.000	5.97	0.024	0.000158780	1.98	1.07	1.11	7.17	0.027	0.0001161	2.21	1.45	1.49					
11.250	5.99	0.025	0.000254200	2.25	1.40	1.40	7.18	0.028	0.0002095	2.46	1.70	1.67	○	○			
11.500	6.12	0.024	0.000210810	2.12	1.35	1.34	7.30	0.032	0.0001539	2.35	1.64	1.60					
11.750	6.19	0.025	0.000245230	2.23	1.40	1.38	7.37	0.029	0.0002385	2.45	1.71	1.67					
12.000	6.30	0.025	0.000231890	2.18	1.35	1.36	7.47	0.026	0.0001226	2.39	1.64	1.65					
12.250	6.39	0.025	0.000241600	2.22	1.38	1.38	7.55	0.030	0.0001504	2.45	1.67	1.70					
12.500	6.52	0.025	0.000194970	2.08	1.28	1.32	7.67	0.027	0.0001419	2.32	1.56	1.62					
12.750	6.60	0.025	0.000225310	2.14	1.27	1.32	7.76	0.029	0.0001052	2.34	1.48	1.59	○				
13.000	6.56	0.025	0.000451550	2.89	1.86	1.86	7.67	0.027	0.0003192	3.18	2.23	2.23	○			Adaptive management of riverbank protection	
13.250	6.85	0.025	0.000370880	2.69	1.78	2.01	7.95	0.032	0.0002586	2.94	2.19	2.34	○	○			
13.500	7.10	0.025	0.000377600	2.65	1.85	1.99	8.16	0.027	0.0002751	2.93	2.24	2.35					
13.750	7.30	0.025	0.000333760	2.61	1.68	1.74	8.33	0.029	0.0003270	2.95	2.09	2.13					
14.000	7.44	0.025	0.000354970	2.69	1.83	1.73	8.46	0.031	0.0003051	3.05	2.24	2.14					
14.250	7.60	0.025	0.000338180	2.72	1.78	1.84	8.61	0.030	0.0002225	3.12	2.23	2.27					
14.500	7.78	0.025	0.000333640	2.63	1.73	1.77	8.80	0.027	0.0002785	2.99	2.13	2.18					
14.750	8.08	0.027	0.000286400	2.13	1.40	1.75	9.15	0.031	0.0001422	2.33	1.71	2.03					
15.000	8.16	0.026	0.000284940	2.48	1.64	1.71	9.16	0.032	0.0004092	2.86	2.06	2.12					
15.250	8.30	0.025	0.000273310	2.47	1.63	1.63	9.31	0.029	0.0002953	2.82	2.03	2.02		○		Adaptive management of riverbank protection	
15.500	8.45	0.026	0.000276110	2.42	1.66	1.63	9.45	0.031	0.0003191	2.77	2.04	2.03					
15.750	8.64	0.026	0.000290330	2.31	1.57	1.81	9.66	0.034	0.0002585	2.55	1.93	2.12		○			
16.000	8.77	0.025	0.000278160	2.45	1.62	1.61	9.75	0.033	0.0003857	2.80	2.00	2.02					
16.250	8.91	0.025	0.000251170	2.39	1.63	1.56	9.89	0.027	0.0002621	2.76	2.02	1.97					
16.500	9.04	0.025	0.000237910	2.33	1.57	1.54	10.03	0.032	0.0002635	2.69	1.96	1.93					
16.750	9.34	0.026	0.000245740	2.32	1.56	1.53	10.40	0.029	0.0002078	2.64	2.13	2.09			○	Riverbank Protection	
17.000	9.48	0.026	0.000241060	2.31	1.72	1.74	10.54	0.032	0.0003910	2.62	2.10	2.09					
17.250	9.62	0.025	0.000218610	2.27	1.52	1.48	10.67	0.029	0.0003734	2.59	1.90	1.84					
17.500	9.79	0.027	0.000221150	2.05	1.66	1.50	10.86	0.034	0.0001059	2.33	1.98	1.84					
17.750	9.86	0.026	0.000231610	2.27	1.61	1.50	10.90	0.028	0.0001189	2.60	1.98	1.85					
18.000	9.97	0.026	0.000233340	2.28	1.48	1.52	11.02	0.037	0.0001030	2.60	1.85	1.90					
18.250	10.09	0.025	0.000205930	2.26	1.48	1.52	11.13	0.036	0.0001517	2.61	1.85	1.89					
18.500	10.04	0.026	0.000441550	3.03	2.14	2.13	11.01	0.031	0.0003711	3.51	2.66	2.65					
18.750	10.43	0.025	0.000526450	3.16	1.92	2.11	11.50	0.031	0.0001821	3.51	2.66	2.81					
19.000	10.71	0.028	0.000704840	2.74	2.29	2.29	11.72	0.030	0.0004255	3.08	2.69	2.69					
19.250	11.21	0.028	0.000678190	2.66	2.23	2.23	12.13	0.031	0.0003281	3.01	2.63	2.63					
19.500	11.74	0.028	0.000585680	2.59	2.17	2.17	12.67	0.034	0.0005938	2.95	2.58	2.58					
19.750	12.09	0.028	0.000496610	2.70	2.24	2.27	13.06	0.031	0.0006562	3.10	2.68	2.72					
20.000	12.52	0.028	0.000468760	2.47	2.09	2.09	13.42	0.031	0.0004566	2.84	2.49	2.49					
20.250	12.90	0.028	0.000378190	2.44	2.06	2.06	13.83	0.031	0.0002452	2.81	2.47	2.47					
20.500	13.21	0.029	0.000442940	2.39	2.02	2.02	14.11	0.035	0.0003203	2.88	2.53	2.53					
20.750	13.50	0.029	0.000438930	2.37	2.01	2.01	14.36	0.030	0.0002652	2.86	2.51	2.51					
21.000	13.89	0.028	0.000312890	2.57	2.24	2.24	14.84	0.028	0.0001203	3.10	2.78	2.78					
21.250	13.99	0.030	0.000682360	2.51	2.19	2.19	14.80	0.029	0.0001786	3.02	2.72	2.72					
21.500	14.57	0.030	0.000455850	2.46	2.14	2.14	15.49	0.031	0.0002128	2.96	2.66	2.66				Adaptive management of riverbank protection	
21.750	14.89	0.030	0.000484000	2.41	2.11	2.11	15.79	0.028	0.0002408	2.90	2.62	2.62					
22.000	15.28	0.028	0.000269290	2.37	2.08	2.08	16.19	0.031	0.0002098	3.00	2.71	2.71					
22.250	15.61	0.027	0.000105960	2.34	2.05	2.05	16.68	0.026	0.0000832	2.95	2.66	2.66					
22.500	15.42	0.031	0.000767510	2.31	2.03	2.03	16.18	0.034	0.0003624	2.90	2.62	2.62					
22.750	16.11	0.031	0.000323530	2.63	2.31	2.31	17.27	0.031	0.0002048	2.86	2.59	2.59					
23.000	16.24	0.030	0.000425690	2.57	2.26	2.26	17.32	0.030	0.0002858	2.82	2.55	2.55					
23.250	16.61	0.033	0.000368010	2.52	2.22	2.22	17.67	0.032	0.0002463	2.79	2.53	2.53					
23.500	16.84	0.043	0.000743410	2.47	2.18	2.18	17.83	0.039	0.0004763	2.76	2.50	2.50					
23.750	17.21	0.035	0.000339860	2.44	2.15	2.15	18.06	0.034	0.0003705	3.43	3.11	3.11					
24.000	17.15	0.031	0.000754130	2.39	2.10	2.10	17.67	0.030	0.0009251	3.31	3.00	3.00					
24.250	17.93	0.031	0.000259490	2.13	1.81	1.82	19.16	0.031	0.0002862	2.81	2.53	2.46					
24.500	18.05	0.035	0.000567050	2.75	2.50	2.46	19.17	0.033	0.0006263	3.71	3.46	3.41					
24.750	18.46	0.028	0.000160740	1.98	1.68	1.56	19.79	0.028	0.0001944	2.65	2.33	2.22					
25.000	18.48	0.028	0.000254140	2.58	2.07	2.15	19.72	0.028	0.0003298	3.52	2.94	3.07					
25.250	18.789	0.029	0.000141620	1.90	1.25	1.20	20.22	0.029	0.0001745	2.55	2.24	2.21					
25.500	18.953	0.035	0.000190190	1.56	1.44	1.30	20.39	0.037	0.0004362	2.73	2.55	2.34					
25.750	19.08	0.038	0.000159340	1.41	1.29	1.26	20.73	0.039	0.0003746	2.50	2.32	2.24					
26.000	19.176	0.034	0.000154170	1.37	1.10	1.23	21.02	0.036	0.0002938	2.21	1.88	1.99					
26.250	19.254	0.037	0.000199370	1.55	1.42	1.37	21.16	0.038	0.0004327	2.63	2.39	2.40					
26.500	19.392	0.036	0.000100130	1.15	0.96	1.02	21.53	0.037	0.0001997	1.88	1.63	1.71					
26.750	19.429	0.039	0.000233720	1.53	1.40	1.38	21.59	0.041	0.0004495	2.48	2.32	2.26					
27.000	19.529	0.035	0.000188490	1.61	1.42	1.38	21.79	0.036	0.0003845	2.66	2.40	2.33					
27.060	19.565	0.039	0.000209760	1.55	1.43	1.36	21.87	0.039	0.0004413	2.60	2.43	2.32					
27.250	19.685	0.049	0.000242170	1.22	1.12	1.21	22.20	0.050	0.0004446	1.86	1.81	1.82					
27.500	19.776	0.040	0.000107270	0.99	0.83	0.93	22.40	0.041	0.0001772	1.49	1.28	1.46					
27.750	19.82	0.040	0.000311820	1.48	1.37	1.33	22.51	0.043	0.0004541	1.91	1.86	1.70					
28.000	19.987	0.036	0.000104720	1.06	0.87	0.95	22.76	0.038	0.0001604	1.57	1.37	1.41					
28.250	19.997	0.040	0.000341880	1.76	1.62	1.61	22.73	0.040	0.0006072	2.64	2.53	2.41					
28.500	20.154	0.029	0.000165340	1.64	1.06	1.34	23.10	0.031	0.0002372	2.21	1.72	1.66					
28.750	20.298	0.030	0.000085830	1.20	0.95	0.87	23.35	0.031	0.0001313	1.71	1.26	1.36					

Current River Channel section

Transition section

River Widening Section

Retarding basin Section

Current River Channel section

1)At hatching section in above table, the flow rate exceeds 2.0 m/s
2) Riverbank protection is considered adaptively, if necessary in the future, river bank protection shall be installed

18.2 Retarding Basin A, B

Retarding Basin A and B temporarily storage 80 m3/s in Retarding Basin A and 510 m3/s in Retarding Basin B of flood discharge volume 2,450 m3/s before flood control, and flow 1,800m3/s at Back Road Bridge with full in order to prevent inundation in Important Protected Area in Nadi River Basin.

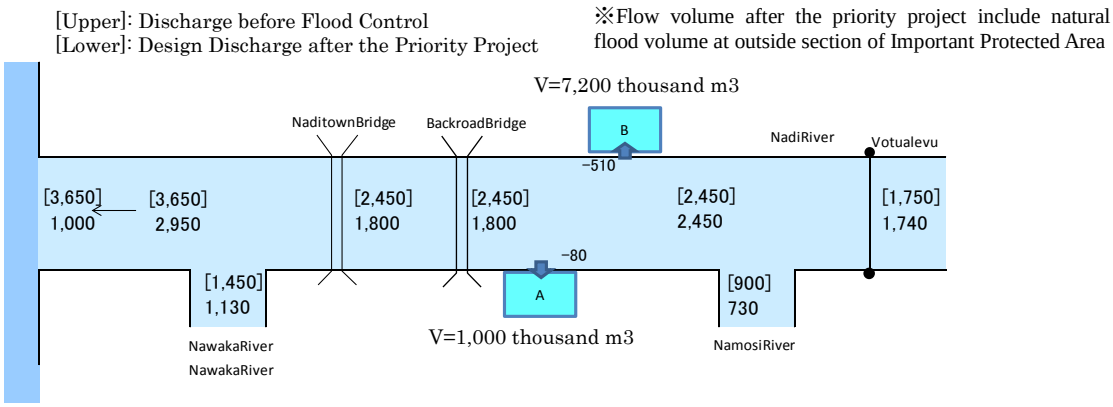


Figure 18-10 Designed Discharge Distribution at the Priority Project

Although these basins are filled with flood water when large scale flood (more than 1/10 design return period) occurs, flood water is drained to the river after flood and after clearing, basins become like normal condition and it also becomes possible to cultivate. In addition, the river dike (surrounding dike of retarding basins) is constructed together with the retarding basins so that the inundation damages by small scale flood are reduced.

18.2.1 Retarding Basin A

(1) Layout and Facilities Design

Layout and Facilities Design is conducted considering ensuring of flood control discharge at the Priority Project and smooth intake of peak cut discharge 80m3/s to the basin. In order to secure flood control discharge, location of overflow dike is set at 20.5km of Nadi River.

Specifications of the basin are set in order to secure peak cut discharge through hydrological analysis. Peak cut discharge, flood control discharge and outflow rate is set as mentioned in Table 18-6. Specifications of drainage sluice gate (the number of gates, outflow rate) are set as a scale that flood water in the basin can be drained within 24 hours[2].

[2] The reason is that the second peak of rainfall occurred 24 hours later and the durable inundated hours of sugar cane is approximately 72 hours.

Table 18-6 Specifications for Retarding Basin A at the Priority Project

	Retarding Basin A
Location	Leftbank Side: 18.75 k ～21.0k
Flood Control Discharge （1000m3）	996
Peak Cut Discharge （m3/s）	80
Peak water level in the basin by calculation （EL.m）	14.50
Length and Location of Overflow Dike	60m 20.455～20.5k
Elevation of the top of Overflow Dike （EL.m）	13.53 （20.5k HWL）
Peak water level at overflow dike by calculation （EL.m）	14.51
Overflow Depth (m)	0.98
Design Elevation of Height of Embankment surrounding the basin （EL.m）	14.53 （20.5k Design Embannkment Height）
Specifications of dicharge.	B1.5×H1.5×1Gate Elevation of the bottom of drainage waterway EL. 9.59 m Outflow Rate Q=10.9m3/s Drainage Time t=17.0 hrs

In addition, ground elevation in the basin is high in some part (high terrace). Therefore, high-level terrace in the basin is excavated 1.5m to the bottom such as stripping topsoil and leveling in order to secure flood control discharge in the basin[4]Layout of Retarding Basin A is as shown in Figure 18-11.

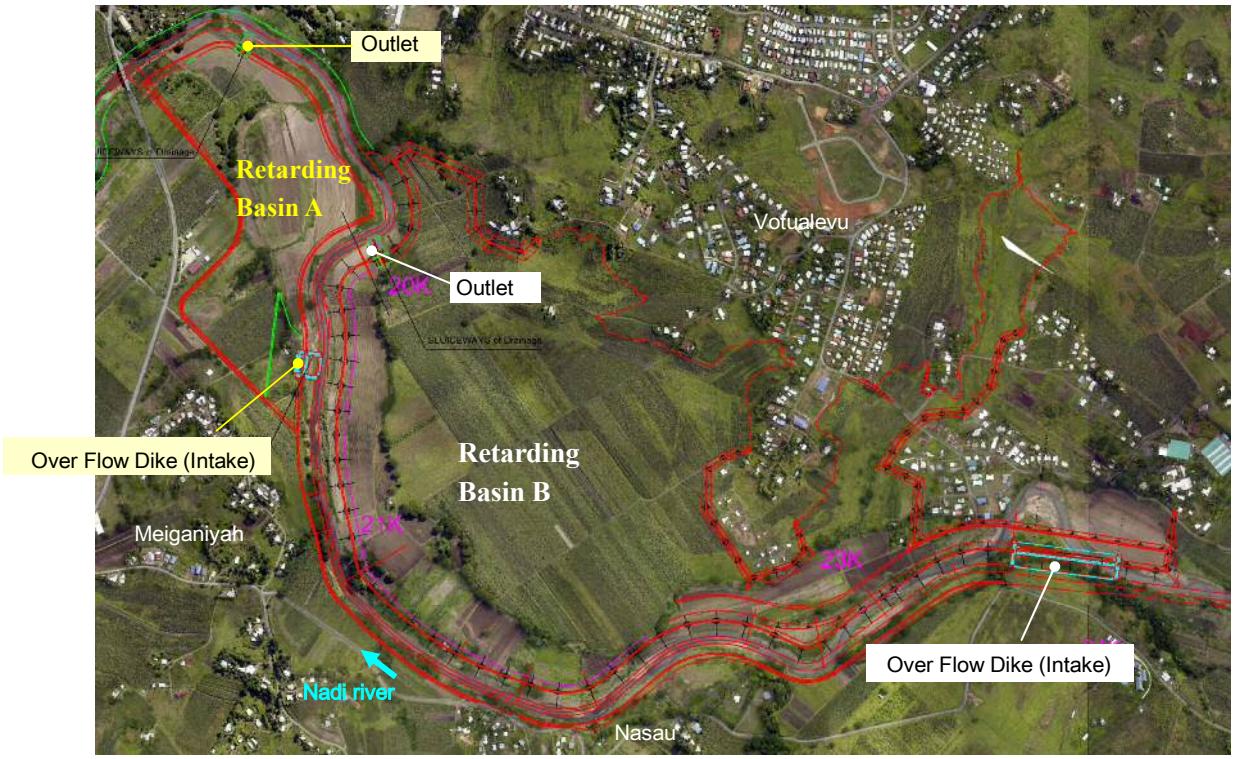


Figure 18-11 Layout of Retarding Basin A

[4] In the time of this study the area inside the retarding basin is to be done an acquisition by the intension of Ministry of Land, Fiji so that the compensation for crops is not required. In the detail design stage in future , in case that the easement is set instead of land acquisition, the compensation for crops will be necessary (same as the retarding B).

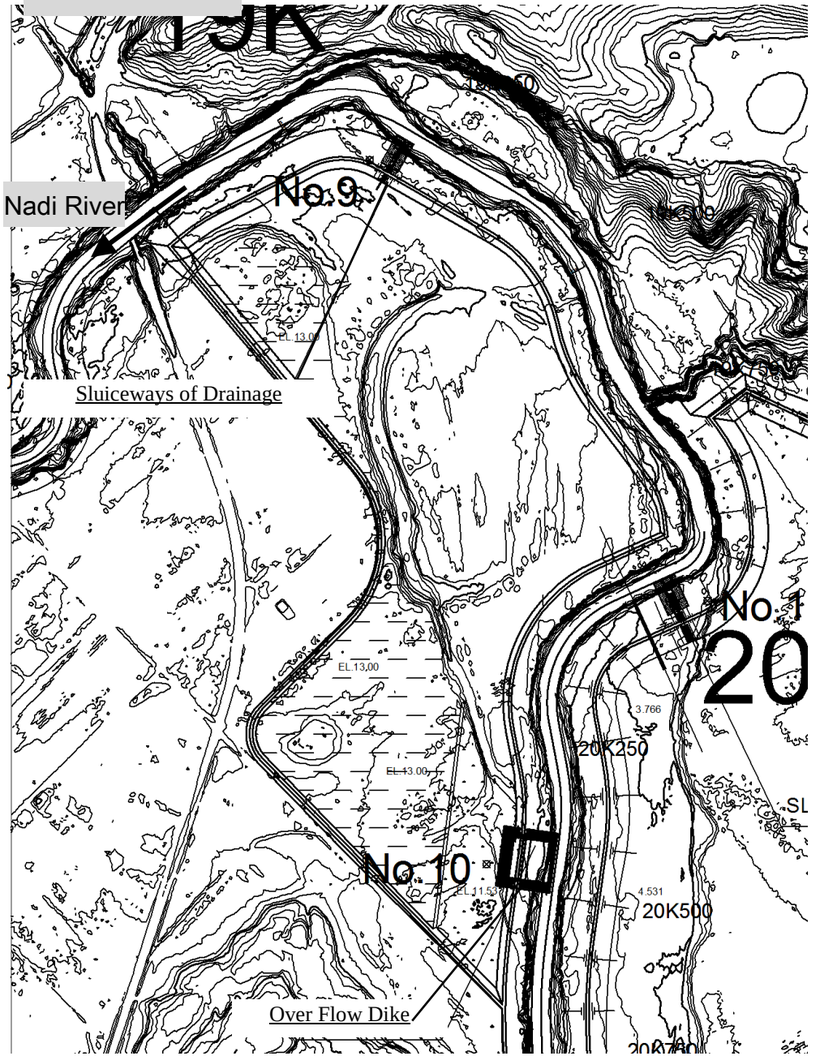
(2) Cross-Sectional Plan

Either river or land side of slope gradient or surrounding dike and dike along the river are set as 1:3 based on River Embankment Design Criteria in Japan, 2007, River Improvement and Management Division, Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism. (see 18.1.4(1)a)

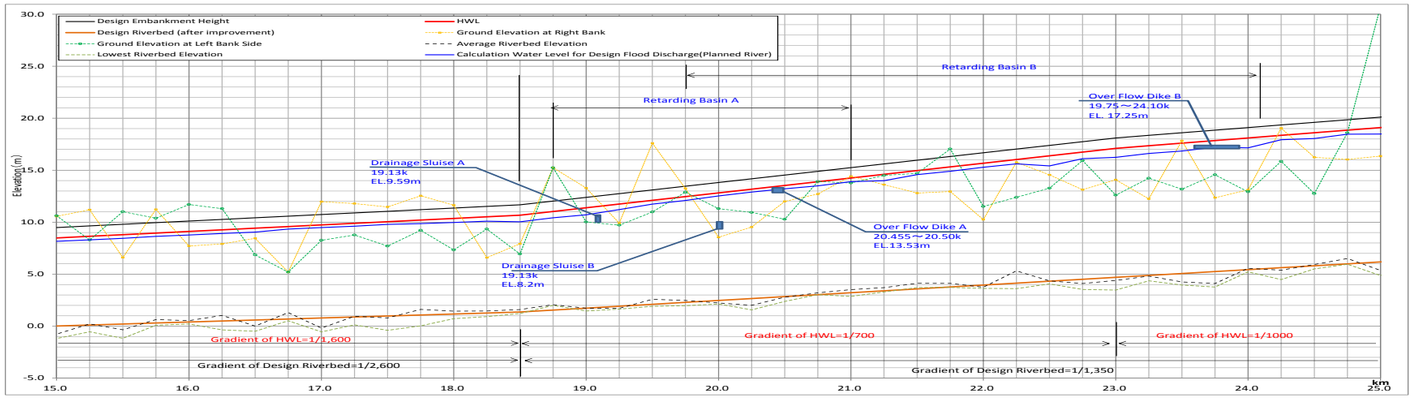
Bank width is set as 4.0m based on "Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 21" . (see 18.1.4 (2))

Typical Cross Section is mentioned in Figure 18-12.

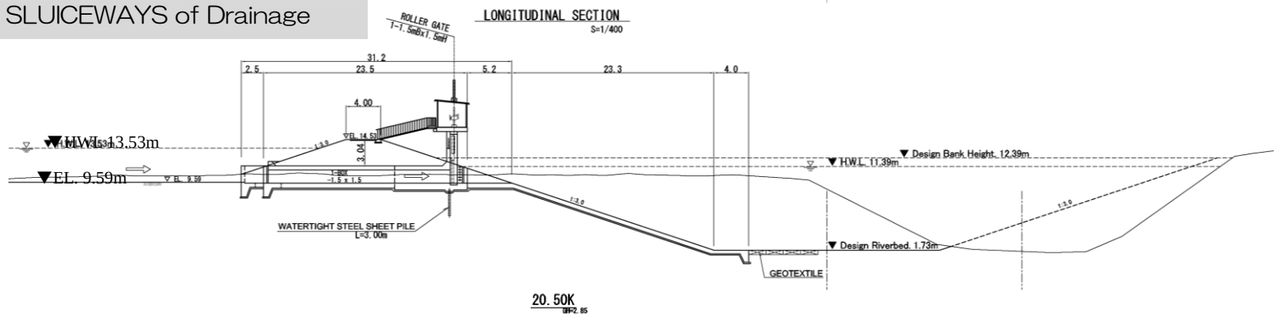
Plan View



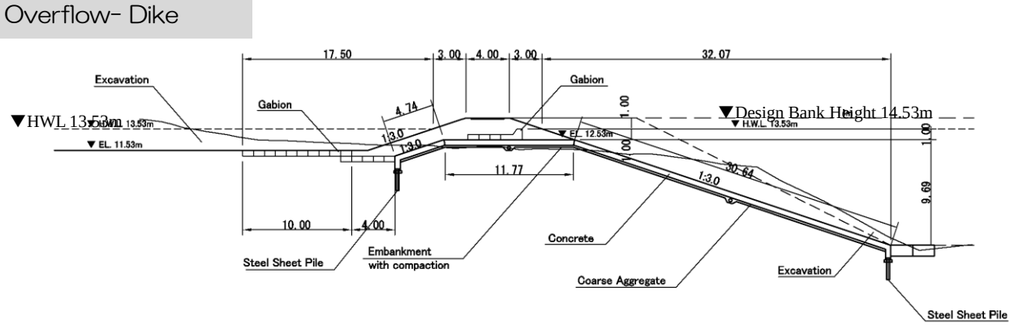
Longitudinal Plan



SLUICEWAYS of Drainage



Overflow- Dike



Typical cross section

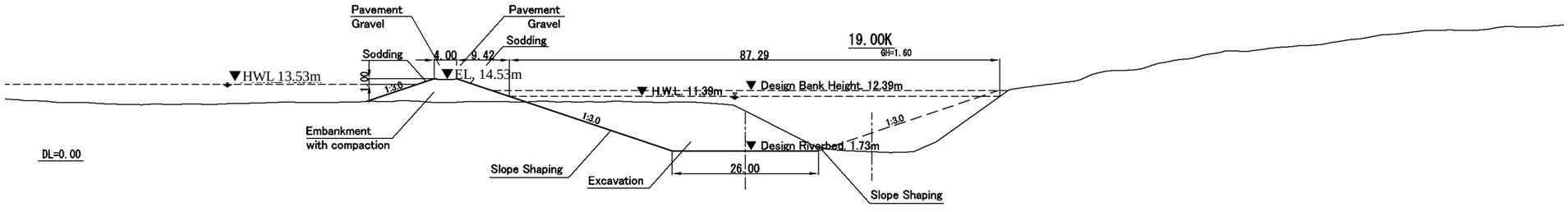


Figure 18-12 General Plan of Retarding Basin A

Typical Cross Section of Retarding Basin

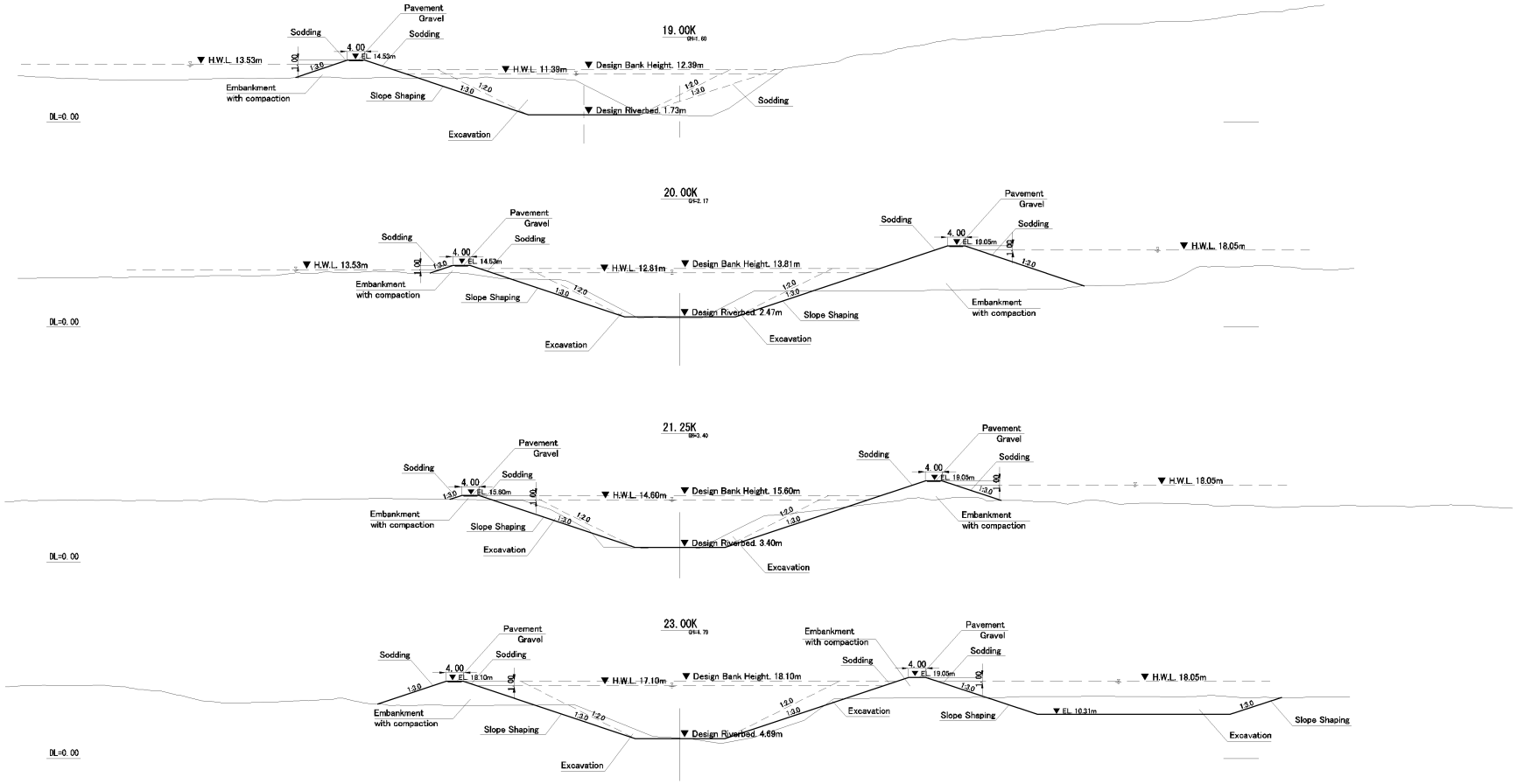


Figure 18-13 Typical Cross Section (Retarding Basin A,B)

(3) Overflow Dike

Specifications of overflow dike are set in order to secure peak cut discharge.

Concrete facing structure is applied for basic structure of overflow dike because it can respond to relatively severe hydraulic conditions and have strong durability, however there are some kinds of structures type such as asphalt facing, concrete block facing and gabion facing.

In addition, the crest elevation of overflow dike is different between the Priority Project and Master Plan because flood control discharge is different between them. Actually, flood control discharge at Master Plan is lower than that at the Priority Project. Therefore, the crest elevation of overflow dike at Master Plan is lower than that at the Priority Project and it is required to lower the crest elevation of overflow dike from the Priority Project to Master Plan. In such a situation, it is planned that basic specifications of overflow dike follows the those at Master Plan and L-shaped retaining wall is installed on the top of overflow dike in order to secure the crest elevation at the Priority Project and can be removed at Master Plan. Details are verified in detailed design stage.

Typical Cross Section of overflow dike is mentioned in Figure 18-13. The basic design of the over flow dike is as shown in Figure 18-16 in case of larger scale retarding basin B.

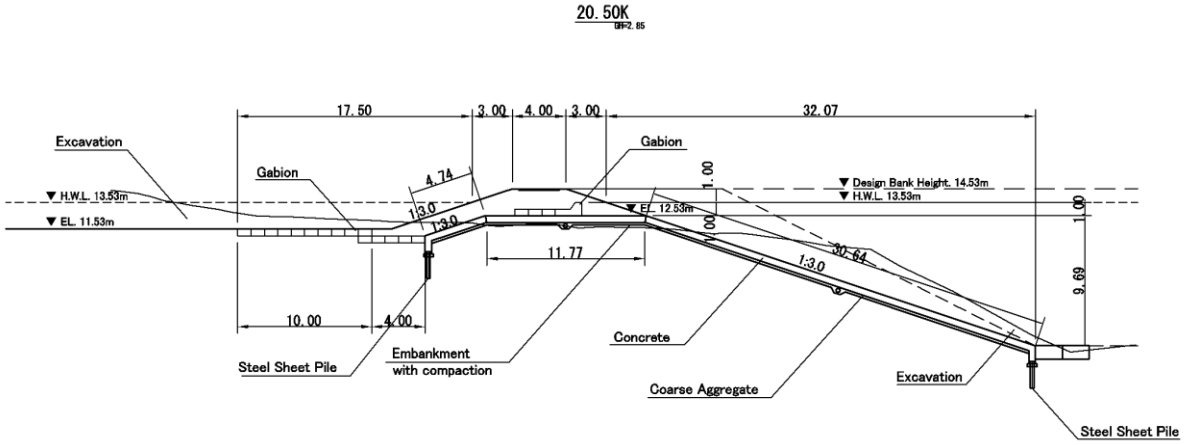


Figure 18-14 Typical Cross Section of Overflow Dike for Retarding Basin A

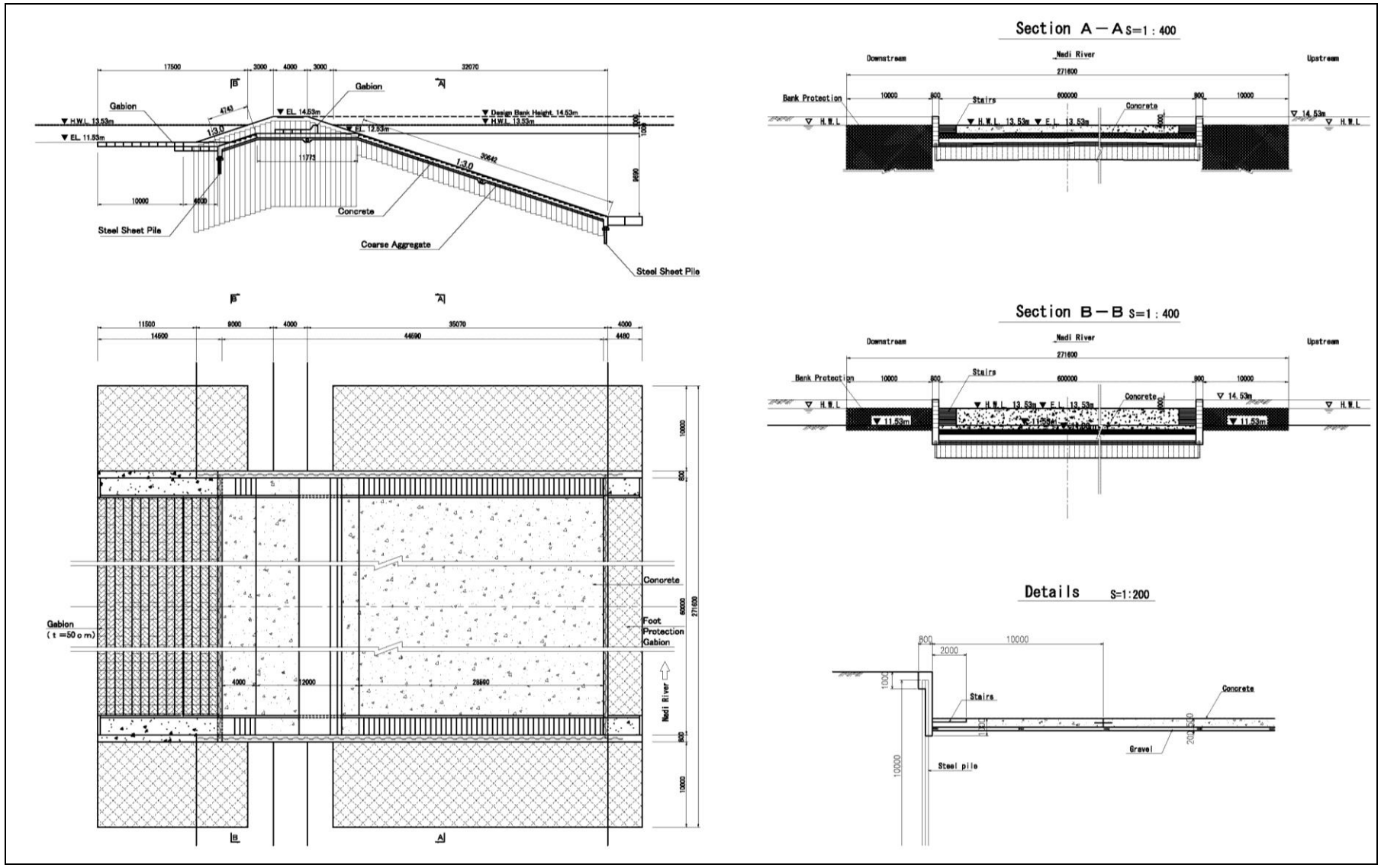


Figure 18-15 General Plan of Overflow Dike for Retarding Basin A

18.2.2 Retarding Basin B

(1) Layout and Facilities Design

Layout and Facilities Design is conducted considering ensuring of flood control discharge at the Priority Project and smooth intake of peak cut discharge 510m3/s to the basin. In order to secure flood control discharge, location of overflow dike is set at 24.0km of Nadi River.

Specifications of the basin are set in order to secure peak cut discharge through hydrological analysis. Peak cut discharge, flood control discharge and outflow rate is set as mentioned in Table 18-7. Specifications of drainage sluice gate (the number of gates, outflow rate) are set as a scale that flood water in the basin can be drained within 24 hours[3].

[3] The reason is that the second peak of rainfall occurred 24 hours later and the durable inundated hours of sugar cane is approximately 72 hours.

Table 18-7 Specifications for Retarding Basin B at the Priority Project

	Retarding Basin B
Location	Rightbank Side: 19.75k～24.10k
Flood Control Discharge （1000m3）	7,157
Peak Cut Discharge （m3/s）	510
Peak water level in the basin by calculation （EL.m）	18.50
Length and Location of Overflow Dike	300m 23.65k～23.95k
Elevation of the top of Overflow Dike （EL.m）	17.25 (23.75k HWL-0.4m)
Peak water level at overflow dike by calculation （EL.m）	18.89
Overflow Depth (m)	1.64
Design Elevation of Height of Embankment surrounding the basin （EL.m）	19.05 （23.95k Design Embannkment Height）
Specifications of dicharge.	B2.5×H2.5×2Gates Elevation of the bottom of drainage waterway EL. 8.20 m Outflow Rate Q=93.1m3/s Drainage Time t=16.4 hrs

In addition, ground elevation in the basin is high in some part (high terrace). Therefore, high-level terrace in the basin is excavated 1.0m to the bottom such as stripping topsoil and leveling in order to secure flood control discharge in the basin.

Layout of Retarding Basin B is as shown in Figure 18-16.

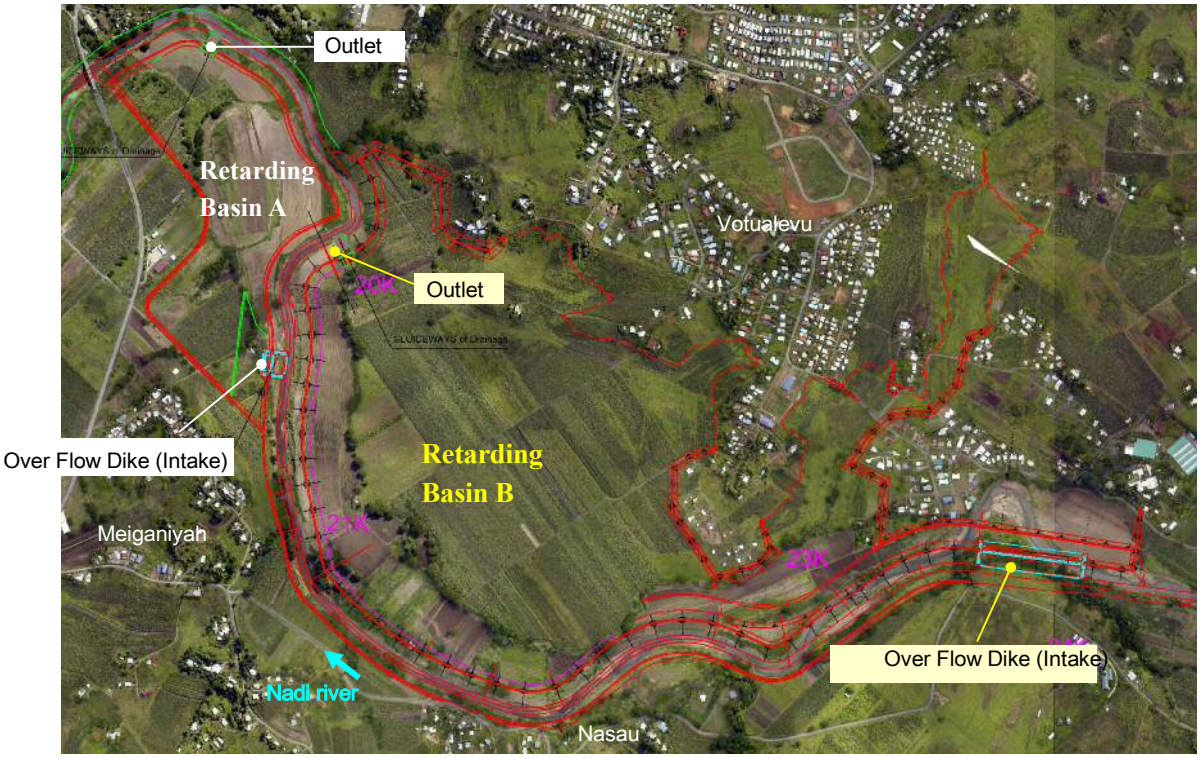


Figure 18-16 Layout of Retarding Basin B

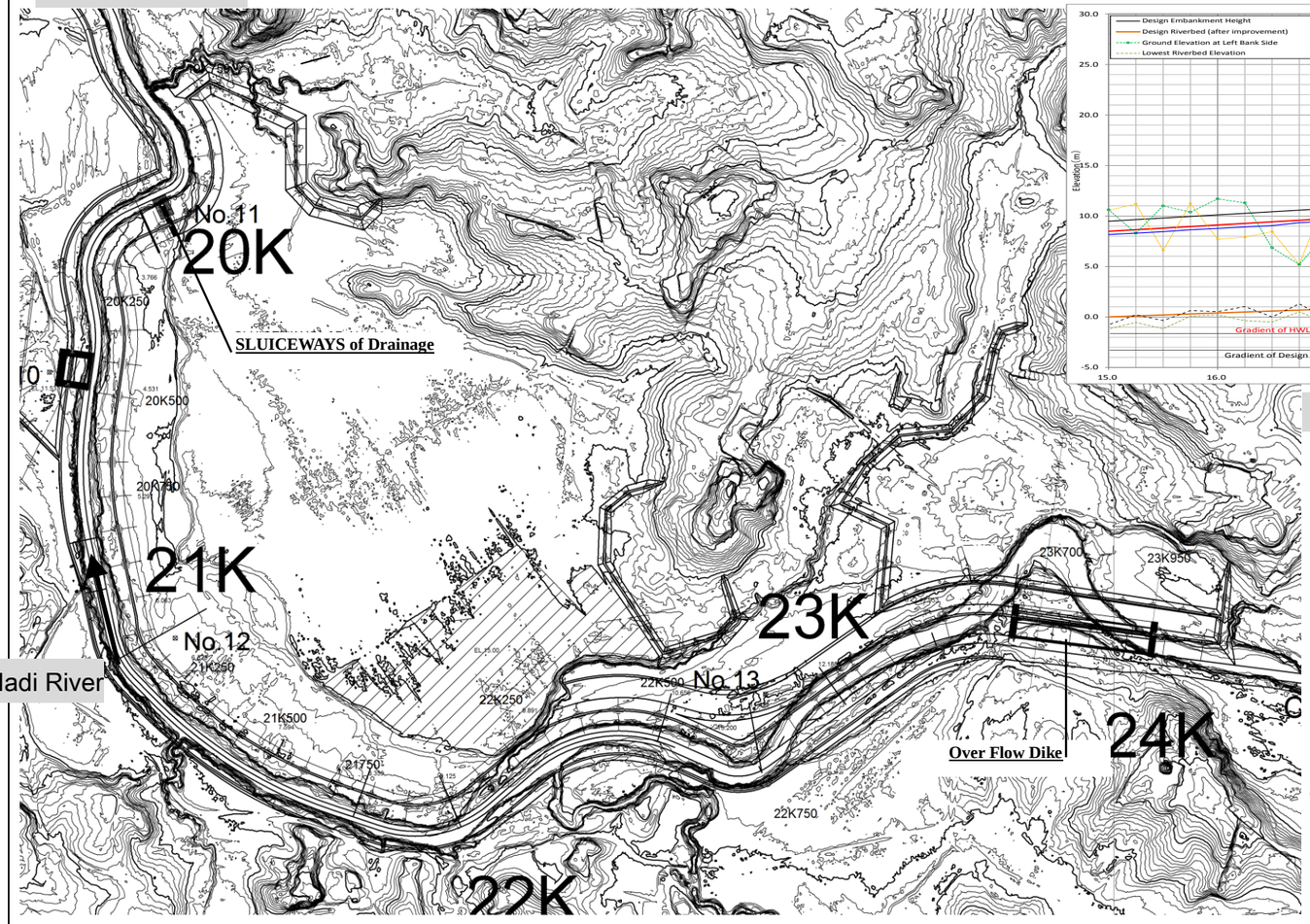
(2) Cross-Sectional Plan

Either river or land side of slope gradient or surrounding dike and dike along the river are set as 1:3 based on River Embankment Design Criteria in Japan, 2007, River Improvement and Management Division, Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism. (see 18.1.4(1)a)

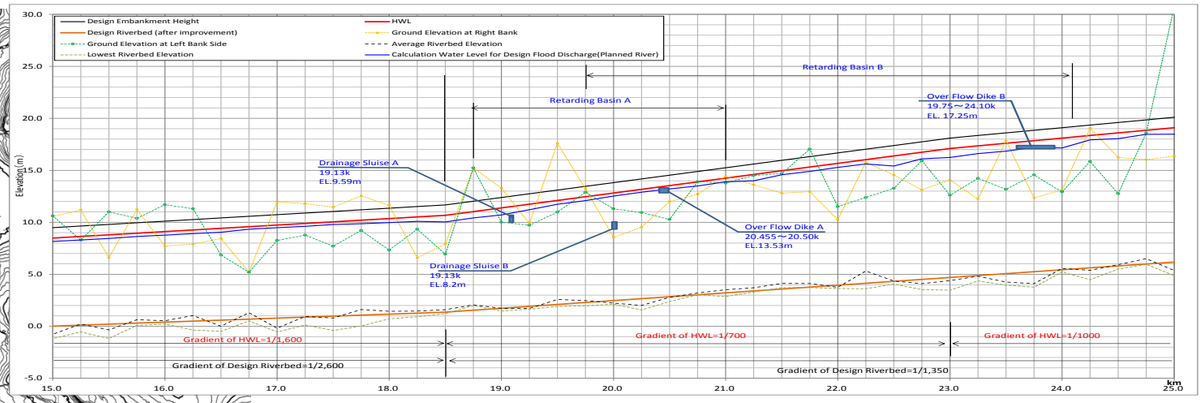
Bank width is set as 4.0m based on "Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 21" . (see 18.1.4 (2))

Typical Cross Section is mentioned before in Figure 18-12.

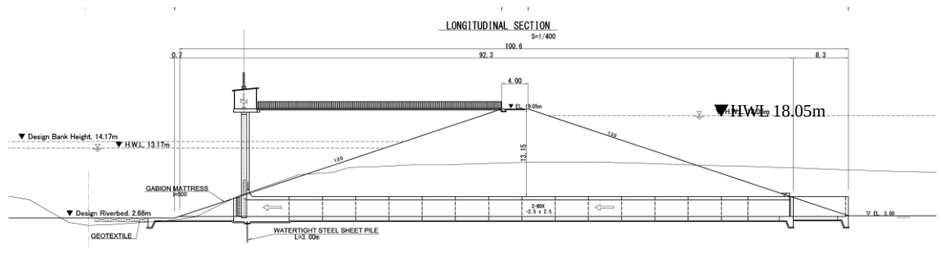
Plan View



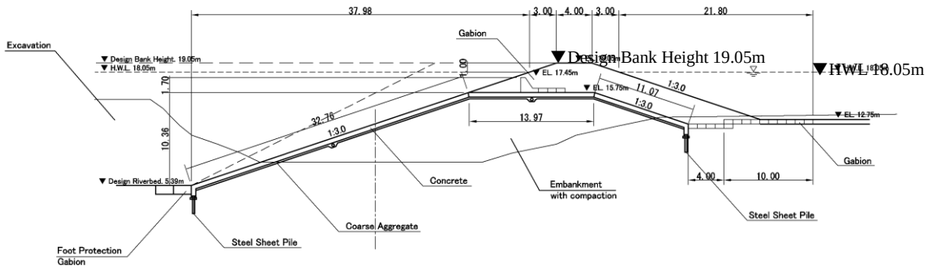
Longitudinal Plan



SLUICEWAYS of Drainage



Overflow- Dike



Typical cross section

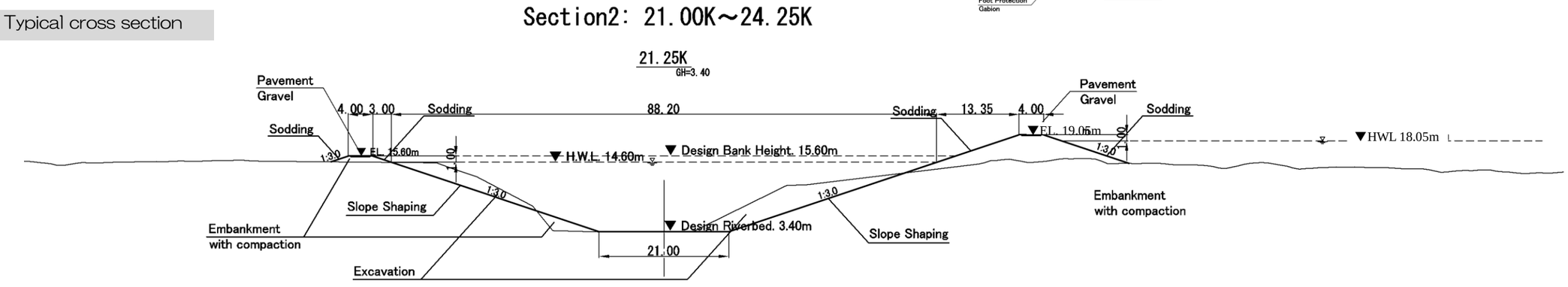


Figure 18-17 General Plan of Retarding Basin B

(3) Overflow Dike

Specifications of overflow dike are set in order to secure peak cut discharge.

Concrete facing structure is applied for basic structure of overflow dike because it can respond to relatively severe hydraulic conditions and have strong durability, however there are some kinds of structures type such as asphalt facing, concrete block facing and gabion facing.

In addition, the crest elevation of overflow dike is different between the Priority Project and Master Plan because flood control discharge is different between them. Actually, flood control discharge at Master Plan is lower than that at the Priority Project. Therefore, the crest elevation of overflow dike at Master Plan is lower than that at the Priority Project and it is required to lower the crest elevation of overflow dike from the Priority Project to Master Plan. In such a situation, it is planned that basic specifications of overflow dike follows the those at Master Plan and L-shaped retaining wall is installed on the top of overflow dike in order to secure the crest elevation at the Priority Project and can be removed at Master Plan. Details are verified in detailed design stage.

Typical Cross Section of overflow dike is mentioned in Figure 18-15. The basic design of the over flow dike is as shown in Figure 18-16.

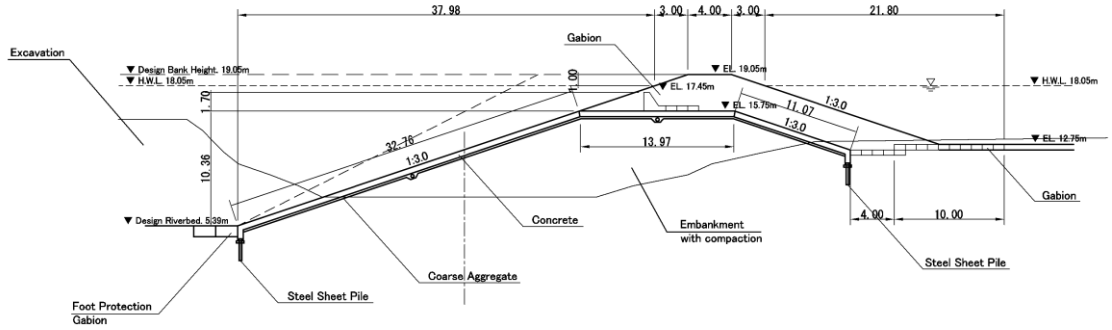


Figure 18-18 Typical Cross Section of Overflow Dike for Retarding Basin B

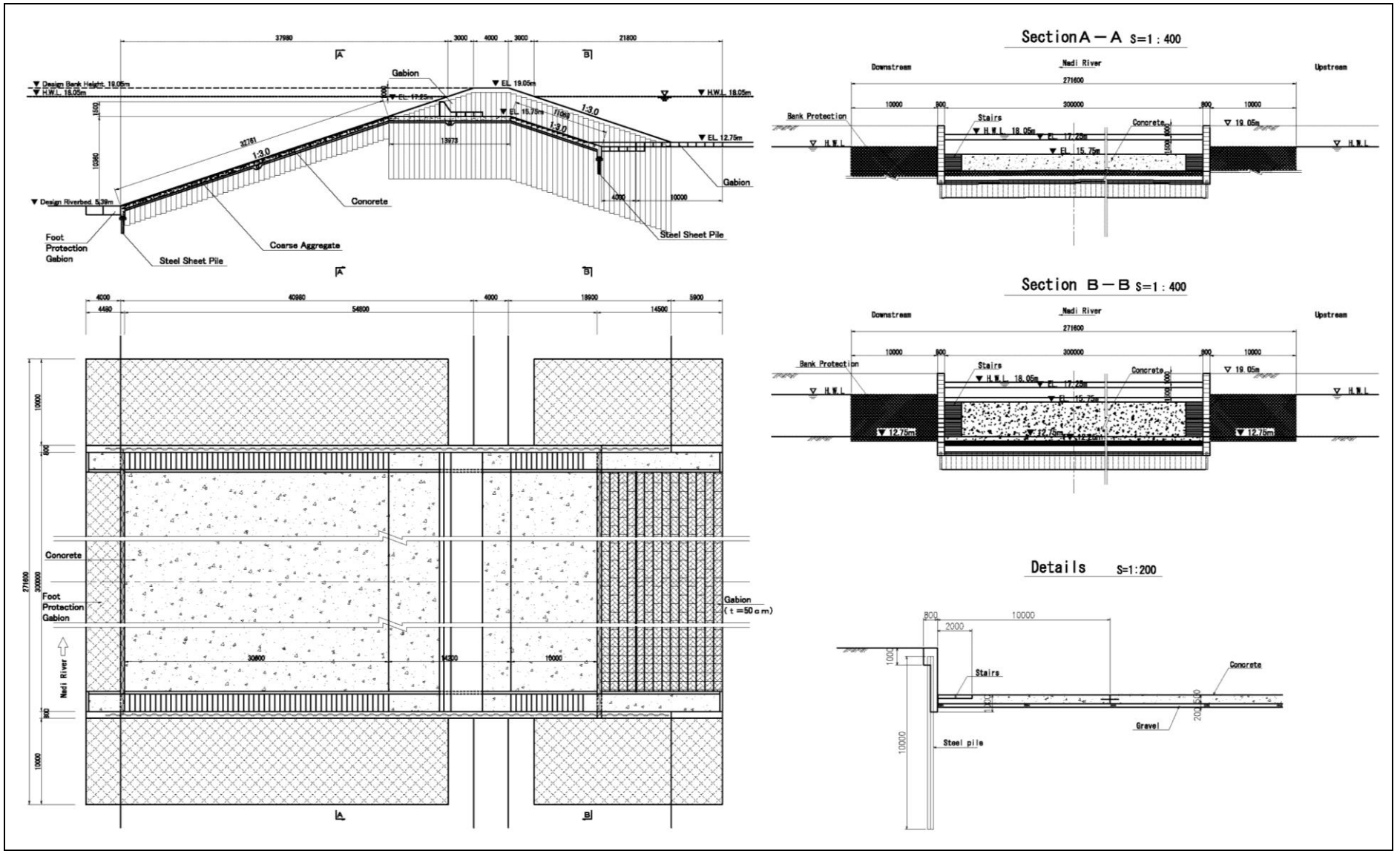


Figure 18-19　General Plan of Overflow Dike for Retarding Basin B

18.3 Surrounding Dike of Nadi Town

Surrounding Dike of Nadi Town is installed mainly in order to prevent flood water of Nawaka River from flowing into Important Protected Area where central of Nadi Town is located.

18.3.1 Plan

Surrounding Dike of Nadi Town are embankments which are installed as a priority project ahead of other dikes in other sections at left bank side of Nadi River and at right bank side of Nawaka River in order to prevent flood water of Nawaka River from flowing into Important Protected Area.

The location of dike is determined based on the inundation analysis, the alignment is set along the present river avoiding housing relocation.

In the area of proposed right dike of Nawaka River, Nawaka River around Queens Road meanders complexly and the old river channel is also left. The area has a function of natural retarding basin at present so that retarding effect is expected in flooding time and also the review of alignments will be examined in the Master Plan in future, and it is not effective for the new dikes to meander complexly along the present river channel (from view point of construction). Therefore the alignment of new dike is determined separately from the present river channel in smooth shape avoiding the relocation of housing

Plan of Surrounding Dike is as described in Figure 18-20.

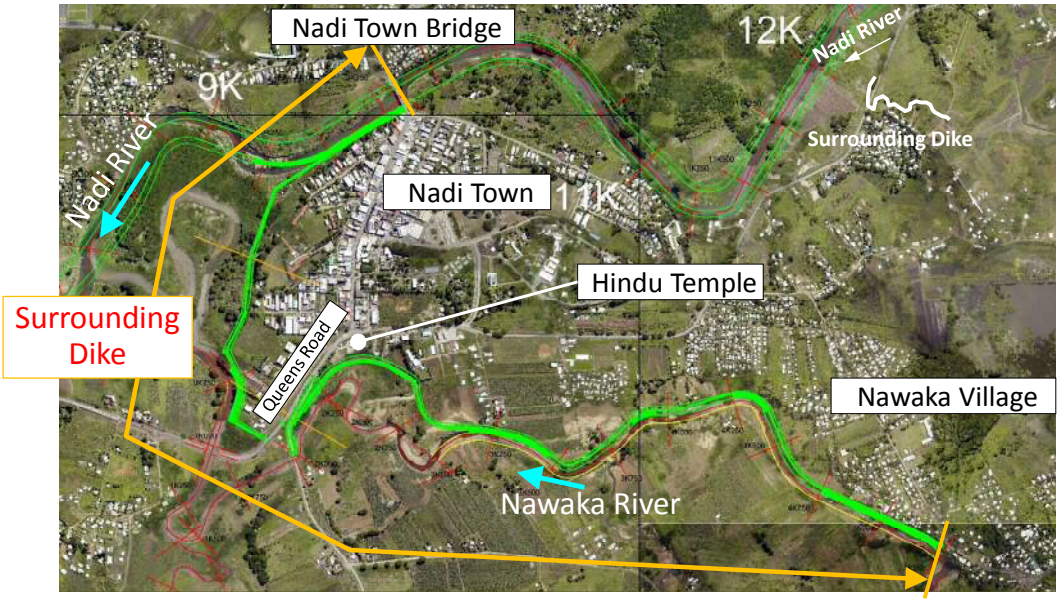


Figure 18-20 Plan of Surrounding Dike

18.3.2 Longitudinal Plan

The Height of surrounding dike of Nadi Town is basically set as the same height as that of Master Plan.

However, inundation depth after the Priority Project when historical maximum flood occurs will exceed the height of embankment of Nawaka River. This is why retarding basins in tributaries area which are proposed in Master Plan are not installed as the Priority Project and flood discharge of target design scale exceeds the level of embankment of Master Plan of Nawaka River just only after the Priority Project. Therefore, the height of surrounding dike along Nawaka River is set as the same height of inundation depth after the Priority Project.

The longitudinal plan is as shown in Table 18-8.

Table 18-8 Longitudinal Plan of Surrounding Dike of Nadi Town

No.	Cross Section	Existing Ground Level	HWL	Inundation Depth by calculation when 1/50 flood occurs		Proposed height of Surrounding Dike	Setting Basis
				River	Landside		
1	Cross 1	6.36	5.76	–	–	6.76	Following the elevation of the crest of embankment of the Nadi River
2	Nadi 9.75K	6.36	5.72	6.28	–	6.72	
3	Nadi 9.50K	5.96	5.61	6.16	–	6.61	
4	Cross 2	5.43	–	–	5.73	6.67	
5	Cross 3	3.31	–	–	5.73	6.70	
6	Cross 4	5.19	–	–	5.73	6.74	
7	Cross 5	5.28	–	–	6.68	8.00	
8	Nawaka 0.75K	5.44	5.79	6.72	6.68	8.00	
9	Cross 6	6.14	–	–	7.79	8.00	
10	Nawaka 2.00K	6.20	7.26	–	8.68	9.00	Following the inundation depth of landside when 1/50 flood occurs
11	Cross 7	6.24	–	–	8.58	9.00	
12	Nawaka 2.50K	6.50	–	8.78	8.67	9.00	
13	Nawaka 2.25K	6.50	7.56	8.73	8.67	9.00	
14	Cross 8	6.56	–	–	8.76	9.00	
15	Cross 9	6.62	–	–	8.76	9.00	
16	Nawaka 2.75K	6.80	8.15	8.79	8.77	9.15	Following the elevation of the crest of embankment of the Nawaka River
17	Nawaka 3.25K	7.04	8.73	8.95	8.91	9.73	
18	Nawaka 3.50K	6.23	9.03	9.09	9.02	10.03	
19	Nawaka 3.75K	7.26	9.32	9.24	9.03	10.32	
20	Nawaka 4.00K	6.93	9.62	9.84	9.40	10.62	
21	Nawaka 4.25K	10.07	9.91	10.05	9.29	10.91	
22	Nawaka 4.50K	8.25	10.20	10.85	9.73	11.20	
23	Nawaka 4.75K	9.58	10.50	11.21	11.21	11.50	
24	Nawaka 5.00K	10.94	10.79	11.60	11.23	11.79	
25	Nawaka 5.25K	11.00	11.09	12.11	–	12.09	

← Location of Queens Road

18.3.3 Cross-Sectional Plan

Either river or land side of slope gradient of surrounding dike and dike along the river are set as 1:3 based on River Embankment Design Criteria in Japan, 2007, River Improvement and Management Division, Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism. (see 18.1.4(1)a)

Bank width is set as 4.0m based on "Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 21" (see Table 18-3).

Typical Cross Section is mentioned before in Figure 18-18.

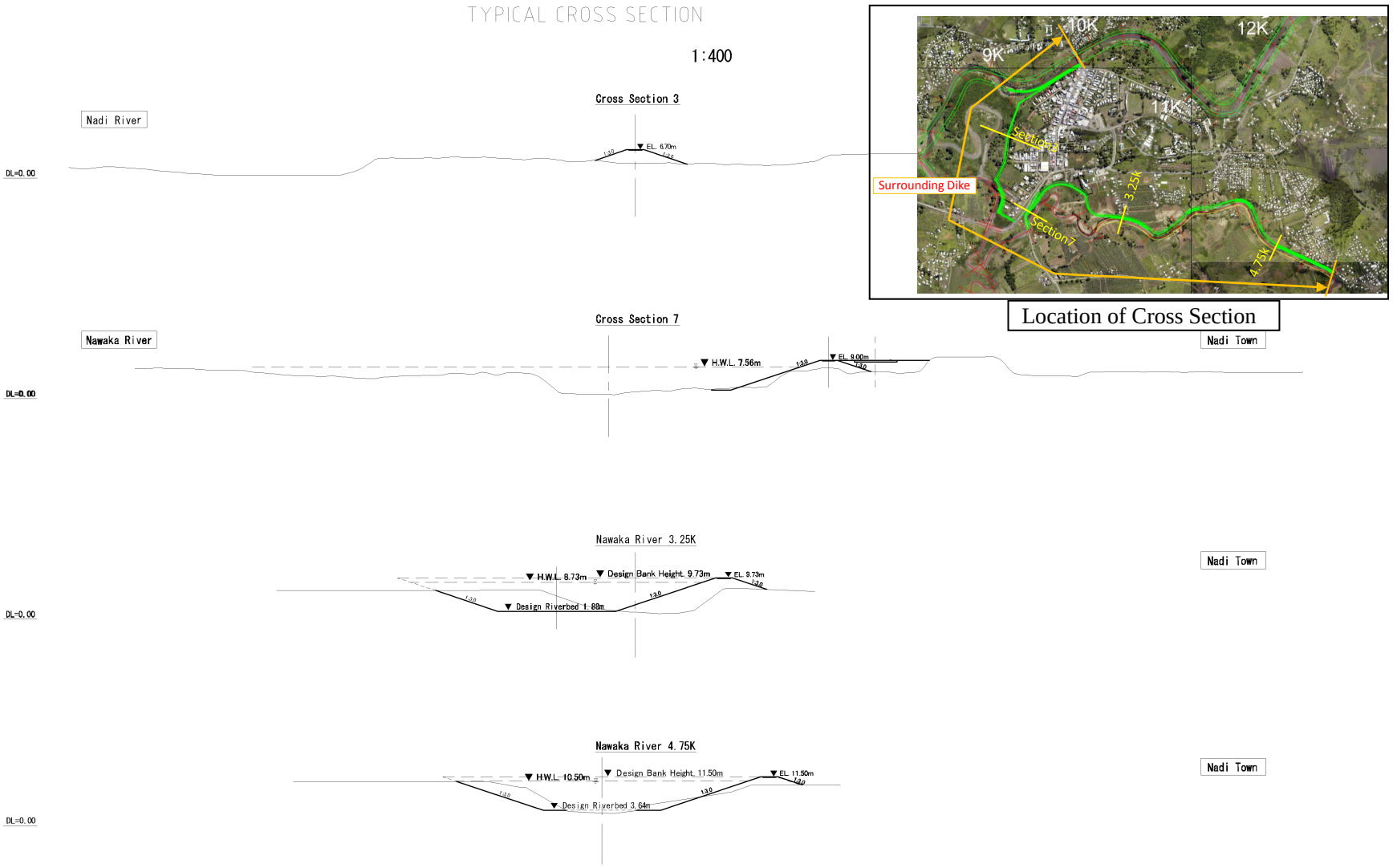


Figure 18-21　Typical Cross Section (Surrounding Dike of Nadi Town)

18.4 Ring Dike

Ring Dike is installed in order to prevent flood water from flowing into community which is located in downstream natural inundation area.

18.4.1 Plan

Ring Dike is arranged in a way that surrounds the outer edge of the community to be protected. Access slope road from outer side of ring dike to inner side, drainage system and outlet is also installed.

Plan of Ring Dike is as shown in Figure 18-19.

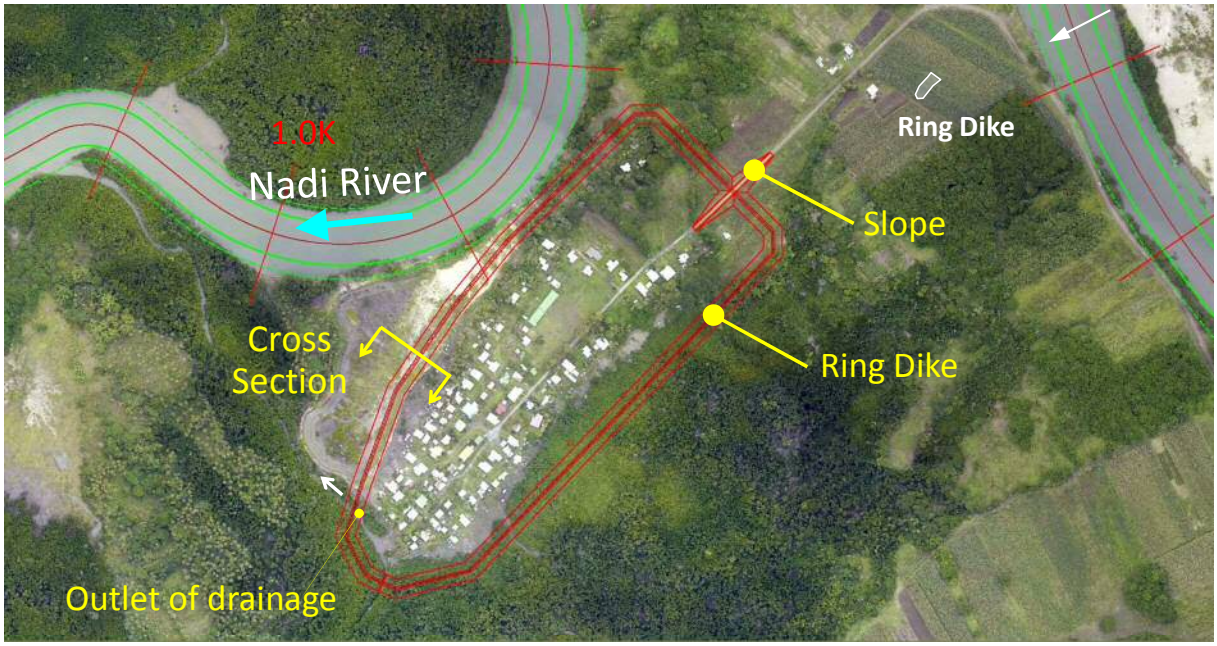


Figure 18-22 Plan of Ring Dike

18.4.2 Longitudinal Plan

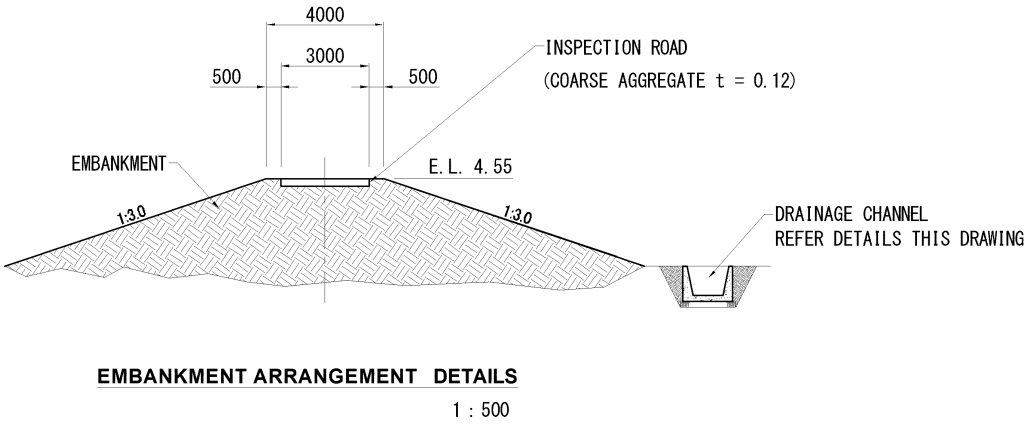
The elevation of inundation in downstream retarding basin is higher than water level in the Nadi River. Therefore, the elevation of the crest of Ring Dike is set considering on the elevation of inundation. The elevation of the crest of Ring Dike is set as E.L. 4.55m in entire section.

18.4.3 Cross-Sectional Plan

Either river or land side of slope gradient of Ring Dike are set as 1:3 based on River Embankment Design Criteria in Japan, 2007, River Improvement and Management Division, Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism. (see 18.1.4(1)a)

Bank width is set as 4.0m based on "Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 21" . (see 18.1.4 (2))

Typical Cross Section is mentioned in Figure 18-23.



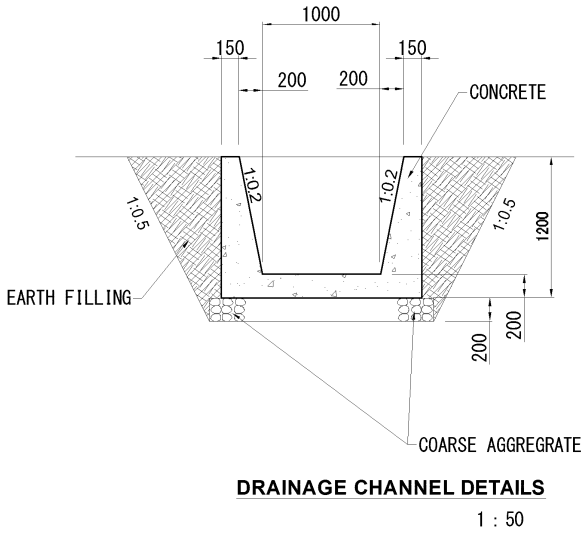


Figure 18-23 Typical Cross Section (Ring Dike)

18.5 Shortcuts of tributaries

Surrounding Dike of Nadi Town mentioned before in Chapter 18.3 cause negative impact (Increasing of Inundation Depth) around the confluence points of Nawaka River and the Malakua River. Shortcuts of tributaries is planned in order to mitigate the negative impact and flood flow can be drained smoothly to downstream by them.

The specifications (Length, Width) of shortcuts are set through hydrological analysis. Details of election of counter measures and flood analysis result are mentioned in "*Final Report: Volume Ⅱ, Main Report, Part Ⅰ:Master Plan Sturdy, 7.7.3(3) Counter Measures for Negative Impact caused by the Priority Project*".".

Plan and typical cross section of shortcuts are described in Figure 18-24 and Figure 18-25.

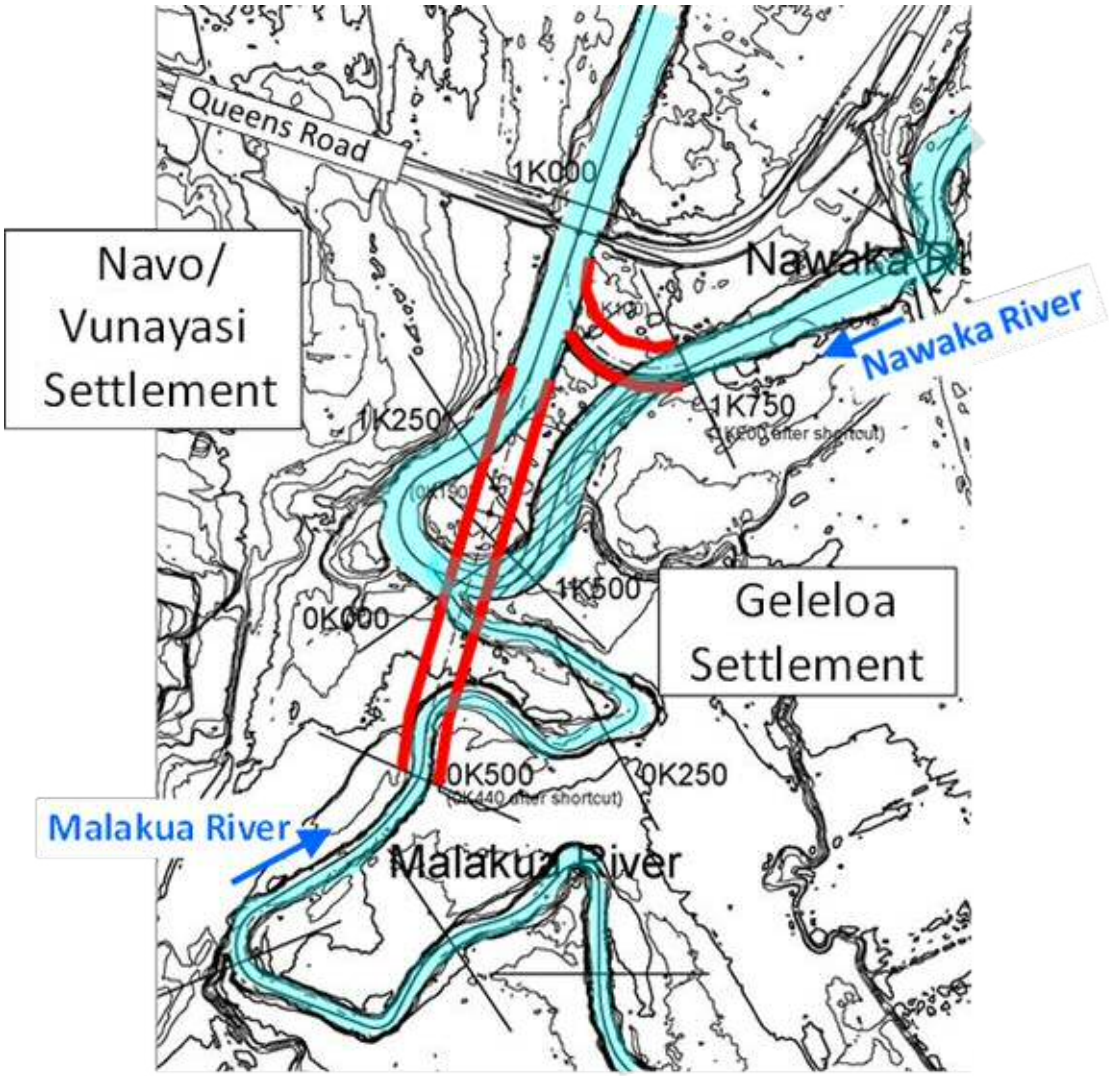


Figure 18-24 Plan of Shortcuts of Tributaries

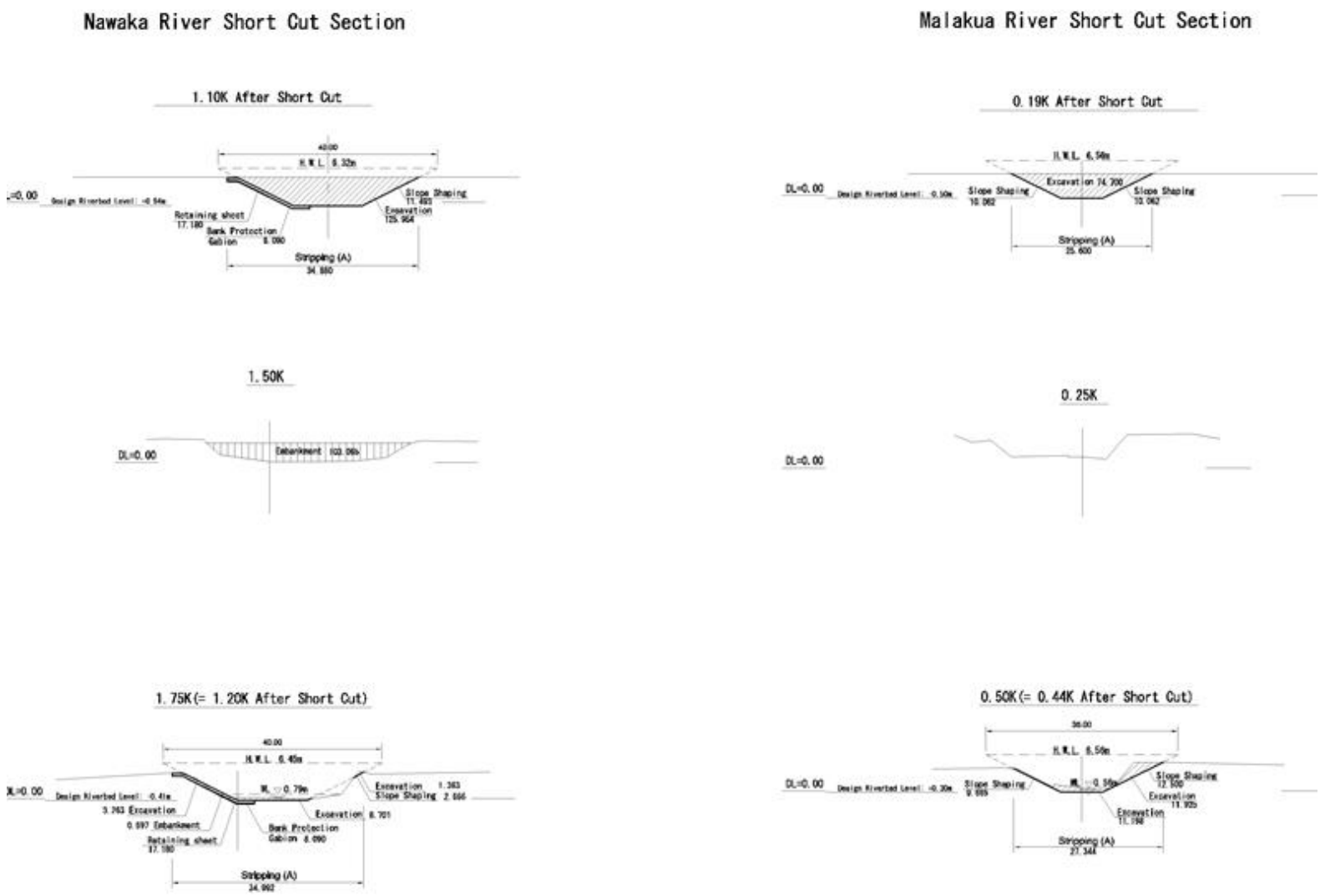


Figure 18-25 Typical Cross Section (Shortcuts of Tributaries)