6.6 Structural Measures

6.6.1 Comparison of Flood Control Measures

In this section, possible structural measures for flood control are proposed on the basis of discussions of the characteristics of each watershed. Possible structural measures were initially proposed considering topography, catchment area, storage volume and geology which are obtainable from the topographical map, geological map and aerial photo. The location and structural measures proposed are shown in Figure-6.14. After evaluation of suitability of each measure, feasible measures were determined and their effects were examined. Finally flood control measures were proposed for each watershed.

(1) Main Components of Flood Control Plan

1) Rewa River

For Rewa river, its downstream part has an almost constant flow capacity for a length of 35 km toward river mouth. Within this section of the river, there is almost no 'critical point' where river flow is hindered. The main stream of the river meanders all the way. At a place about 20 km from river mouth, the river channel is adjacent to some small rivers which flow directly to the sea. From the condition of the river channel and the topography in the watershed area, the following measures can be proposed as the main components of the flood control plan.

a) Diversion channel

b) Weir and retarding basin

c) Cut-off channel and retarding basin

d) Flood control dam

e) River improvement

- River channel widening
- River dike construction
- River bed excavation

2) Sigatoka River

Since the flow capacity of Sigatoka river is smaller at its downstream part, it is considered to be effective to discharge flood directly to the sea by a diversion channel. However, construction of the diversion channel seems to be difficult from the topographic conditions in the watershed. In addition, since the river flows through a narrow valley, it is difficult to find a suitable place to construct retarding basins with a significant storage volume. Therefore, only the following measures are considered to be suitable for the flood control plan.

a) Flood control dam

b) River improvement

- River channel widening
- River dike construction
- River bed excavation
- Dike construction surrounding urban area

3) Nadi River

Of the four rivers in the study area, Nadi river has the smallest flow capacity. In addition, there exists a 'critical point' at the downstream part 7.5-9.0 km from river mouth, where the flow capacity is relatively small. Under such a condition, construction of a diversion channel at the upstream side of the 'critical point' is considered to be effective. A route starting at a point of 14 km from river mouth and going through the side of Nadi airport may be the most favorable. Therefore, the flood control plan for Nadi river may consist of the following measures.

a) Diversion channel

b) Improvement of confluence point

c) Flood control dam

d) River improvement

- River channel widening
- River dike construction
- River bed excavation

4) Ba River

Of the four rivers in the study area, Ba river has the largest flow capacity. There are some points where flow capacity becomes smaller, but all of them are at the downstream part of the river. No potential site can be found for the construction of a diversion channel or retarding basin from the topographic conditions. Therefore, the following measures can be proposed for the flood control plan.

a) Flood control dam

b) River improvement

- River channel widening
- River dike construction
- River bed excavation

(2) Evaluation of Flood Control Measures

The flood control measures proposed above were compared and the suitability of each measure to watershed was evaluated. The results are shown in Table-6.24.

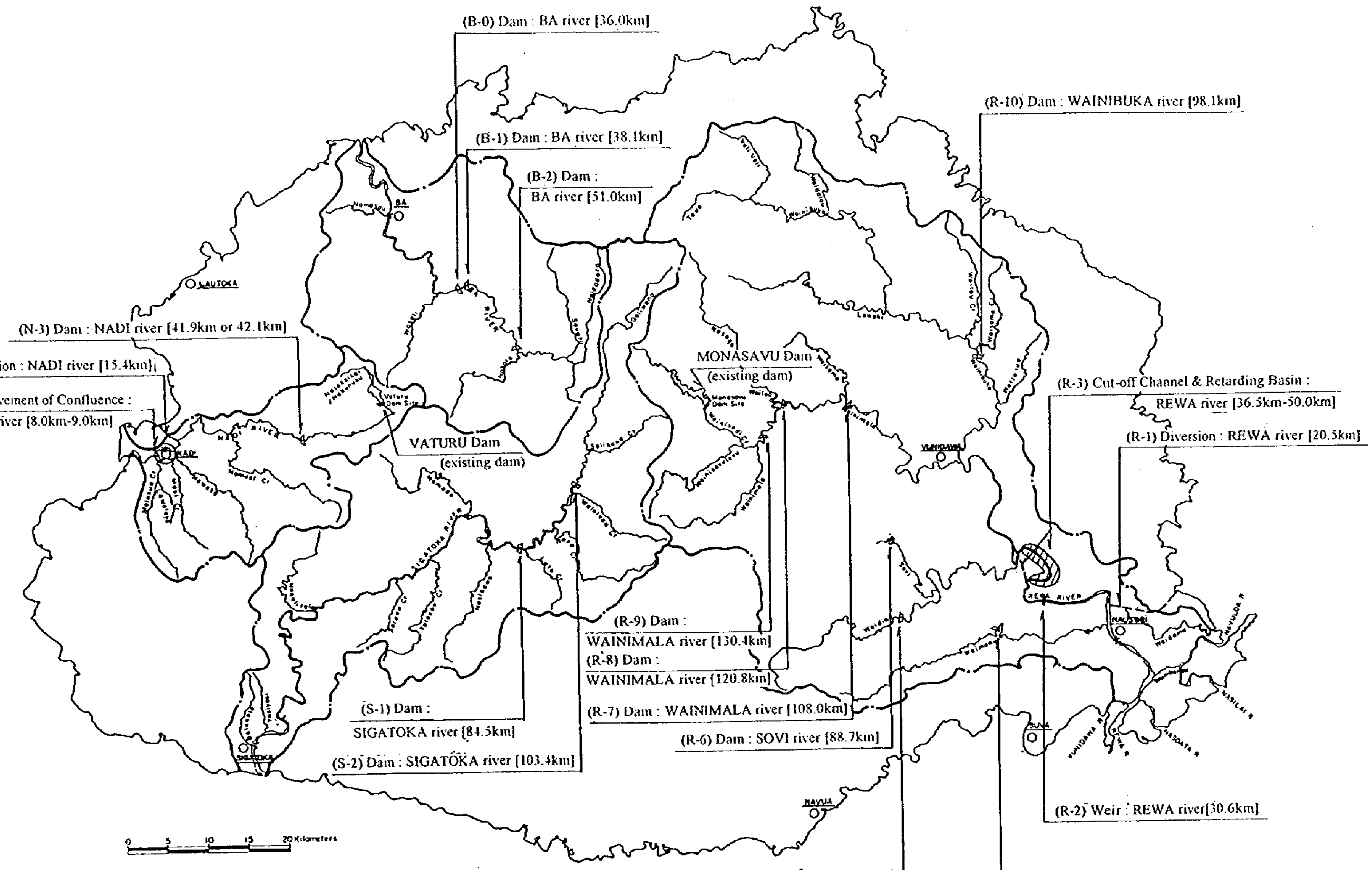

Figure-6.14 Proposed Sites for Flood Control Structural Measures

Table-6.24 (1/2) Comparison of Flood Control Measures

Flood control measures		Rewa River	Sigatoka River	Nadi River	Ba River
a. Diversion Channel	Merit	At 20 km from the river mouth, there is a river passing by and flowing directly to the sea. It is possible to construct a diversion channel by making use of this river.	Since the flow capacity of the river is small at its downstream part, construction of a diversion channel should be effective for flood control.	Since there exists a 'critical point' at the downstream of the river, construction of a diversion channel from its upstream side should be effective for flood control. A route from the point of 15.4 km through the side of Nadi airport is suitable.	Since the flow capacity of the river is small at its downstream part, construction of a diversion channel should be effective for flood control.
	Shortcoming	Land acquisition is needed	Topographically there is no potential candidate site for diversion channel construction.	Land acquisition is required.	Topographically there is no potential candidate site for diversion channel construction.
	Evaluation	O Very effective for flood control, although there may be a problem of land acquisition. If the sludge and soils excavated can be used for banking of the diversion channel, the efficiency will become higher.	× Impossible for topographic reason.	O Very effective for flood control, although there may be a problem of land acquisition. If the sludge and soils excavated can be used for banking of the diversion channel, the efficiency will become higher.	× Impossible for topographic reason.
b. Weir and retarding basin	Merit	By constructing a weir at about 30 km from the river mouth, its upstream area can be used as a retarding basin.	-	-	-
	Shortcoming	Provision of a large area as the retarding basin is required. The effectiveness of flood control depends on the retarding capacity; however there is a possibility that necessary storage capacity can not be obtained.	There is no area large enough as a retarding basin.	There is no area large enough as a retarding basin.	There is no area large enough as a retarding basin.
	Evaluation	Δ Possible measure for regulating flood.	× Impossible for topographic reason.	× Impossible for topographic reason.	× Impossible for topographic reason.
c. Short-cut channel and retarding basin	Merit	By a short-cut channel between 36 km to 50 km, flood can flow straight forward downstream and the old river course can be used as a retarding basin.	-	-	-
	Shortcoming	Land acquisition is required for short-cut channel construction. There is a possibility that necessary storage capacity can not be obtained.	-	-	-
	Evaluation	Δ Possible measure for regulating flood.	× Not suitable for this river from the condition of the river course.	× Not suitable for this river from the condition of the river course.	× Not suitable for this river from the condition of the river course.
d. Tributary improvement	Merit	-	-	The flow capacity of the river is the smallest near the confluence of the Nawaka creek to the Nadi river. Improvement of the Nawaka creek at this point is an effective measure.	-
	Shortcoming	-	-	Not only an improvement on the shape of the river course but also other works for increasing the flow capacity are required.	-
	Evaluation	× Not applicable from the condition of the tributaries.	× Not applicable from the condition of the tributaries.	O Effective for increasing the flow capacity of the Nadi river.	× Not applicable from the condition of the tributaries.
e. Flood control dam	Merit	Since the candidate site for dam construction lies in the devastate mountain area, there will be less problem in land acquisition. If the dam can be used for multi-purpose such as water supply and hydro power, the benefits will be high.	Since the candidate site for dam construction lies in the devastate mountain area, there will be no problem in land acquisition. If the dam can be used for multi-purpose such as water supply and hydro power, the benefits will be high.	Since the candidate site for dam construction lies in the devastate mountain area, there will be no problem in land acquisition. If the dam can be used for multi-purpose such as water supply and hydro power, the benefits will be high.	Since the candidate site for dam construction lies in the devastate mountain area, there will be no problem in land acquisition. If the dam can be used for multi-purpose such as water supply and hydro power, the benefits will be high.
	Shortcoming	Construction cost may be high. Since the current flow capacity is low, at least two dams are necessary for 50 year return period flood.	Construction cost may be high.	Construction cost may be high.	Construction cost may be high.
	Evaluation	Δ Considering the demand of electricity and water, it is a favorable measure when the dam is constructed for multi-purpose, which can decrease the cost for flood control.	× Water demand will not increase in future and there is no site of dam to have a large effect on flood control.	Δ Considering the demand of electricity and water in the Nadi area, it is a favorable measure when the dam is constructed for multi-purpose,. It is an advantage that the storage capacity required is small, unlike other rivers.	Δ A feasible measure combining flood control and water supply when water resources development is required due to increase in water demand.

Table-6.24 (2/2) Comparison of Flood Control Measures

Flood control measures		Rewa River	Sigatoka River	Nadi River	Ba River
f. River improvement - River course widening	Merit	When there exist only several 'critical points' where the flow capacity becomes low, river widening at these locations will be effective for flood control. River widening for the whole river will surely increase the river's capacity of flood discharge.	When there exist only several 'critical points' where the flow capacity becomes low, river widening at these locations will be effective for flood control. River widening for the whole river will surely increase the river's capacity of flood discharge.	When there exist only several 'critical points' where the flow capacity becomes low, river widening at these locations will be effective for flood control. River widening for the whole river will surely increase the river's capacity of flood discharge.	When there exist only several 'critical points' where the flow capacity becomes low, river widening at these locations will be effective for flood control. River widening for the whole river will surely increase the river's capacity of flood discharge.
	Shortcoming	Land acquisition is required especially when a long section of the river needs to be widened.	Land acquisition is required especially when a long section of the river needs to be widened.	Land acquisition is required especially when a long section of the river needs to be widened.	Land acquisition is required especially when a long section of the river needs to be widened.
	Evaluation	△ Possible measure for an improvement of the flow capacity of the river at the locations of 'critical points'.	△ Possible measure for an improvement of the flow capacity of the river at the locations of 'critical points'.	△ Possible measure for an improvement of the flow capacity of the river at the locations of 'critical points'.	△ Possible measure for an improvement of the flow capacity of the river at the locations of 'critical points'.
- Dike construction	Merit	The flow capacity of the river can be ensured by dike construction over a long distance.	The flow capacity of the river can be ensured by dike construction over a long distance.	The flow capacity of the river can be ensured by dike construction over a long distance.	The flow capacity of the river can be ensured by dike construction over a long distance.
	Shortcoming	Land acquisition is required, however it will encounter the difficulty due to the concentration of assets along the river. Therefore, the dike will be located within the river course, resulting in reduction of the current river width. Since the stage of river will become higher than the inland ground surface outside the dike, the potential of flood damage will still be high.	Land acquisition is required, however it will encounter the difficulty due to concentration of assets and Native Villages extending along the river. Therefore, the dike will be located within the river course, resulting in reduction of the current river width and higher flood stage of river than the current one. As a result, the potential of flood damage will be higher.	Land acquisition is required, however it will encounter the difficulty due to the concentration of assets along the river. Therefore, the dike will be located within the river course, resulting in reduction of the current river width and higher flood stage of river than the current one. As a result, the potential of flood damage will be higher.	Land acquisition is required. Since it is possible that the stage of river becomes higher than the inland ground surface outside the dike, the potential of flood damage will still be high.
	Evaluation	△ It may not be effective in Nausori and its vicinity, where assets are concentrated, due to the high potential of flood damage and problem to drain land side water during flood. It is effective in downstream from Nausori to increase the flow capacity of river.	× Dike construction is only applicable within the current river course reducing the river width and increasing the flood stage. As a result, the potential of flood damage will be higher. Therefore, its effect on flood control is not expected.	× Since the current flow capacity is too small compared to the design flood, the scale of dike would be very large. Besides, the dike within the current river course results in higher potential of flood damage and problem to drain land side water during flood. Therefore, it is not applicable.	○ Since there is no asset located along the river, except the sugar mill, the land acquisition is not difficult. Therefore, the dike can be located without reducing the river width. As long as its scale is not too large, the potential of flood damage will not increase. Therefore, it is a feasible measure.
- River bed dredging	Merit	The flow capacity of the river can be increased without any influence on the inland side.	The flow capacity of the river can be increased without any influence on the inland side.	The flow capacity of the river can be increased without any influence on the inland side.	The flow capacity of the river can be increased without any influence on the inland side.
	Shortcoming	The large volume of dredging is required to suppress the flood at the required level. Effectiveness can only expected as dredging is carried out over a long length of the river. Periodic dredging is necessary since sedimentation may happen continuously.	The large volume of dredging is required to suppress the flood at the required level. Effectiveness can only expected as dredging is carried out over a long length of the river. Periodic dredging is necessary since sedimentation may happen continuously.	The large volume of dredging is required to suppress the flood at the required level. Effectiveness can only expected as dredging is carried out over a long length of the river. Periodic dredging is necessary since sedimentation may happen continuously.	The large volume of dredging is required to suppress the flood at the required level. Effectiveness can only expected as dredging is carried out over a long length of the river. Periodic dredging is necessary since sedimentation may happen continuously.
	Evaluation	△ Since its effect on flood control is small, it is only effective to maintain the cross section of river.	△ For the Step 1 target, it is effective because flood discharge to be controlled is small; however, it is not effective for the Step 2 target.	× Since the scale of the river is too small to introduce a large dredger, it is not possible to conduct a large scale dredging which is required for the Step1 target.	△ Since its effect on flood control is small, it is only effective to maintain the cross section of river.
- Dike construction surrounding urban area	Merit		It is effective on suppression of flood in the urban area surrounding only the target area.		
	Shortcoming		Land acquisition is required. Since it is possible that the stage of river becomes higher than the inland ground surface surrounded by dike, the potential of flood damage will still be high. The difficulty of its application depends on topographic features.		
	Evaluation		△ A possible measure if topographic features are favorable and inland flood is allowed.		

Note: ○: Favorable △: Possible ×: Not Applicable

Based on the comparison and evaluation of flood control measures, the most effective and possible flood control measures for each watershed are as follows.

1) Rewa watershed: diversion channel and dike construction
2) Sigatoka watershed: river improvement (river bed excavation)
3) Nadi watershed: diversion channel and improvement of confluence
4) Ba watershed: river improvement (dike construction)

6.6.2 Structural Measures for Rewa Watershed

The diversion channel for the Rewa watershed drains the flood to the east coast after diverting flood at 20.5 km upstream from river mouth, approximately 3.0 km downstream from the bend. The dike on the left and right banks of Rewa river supplements to mitigate the flood damage.

(1) Design Discharge of Diversion Channel

If the design discharge of the diversion channel was determined to drain all objective flood, the dike construction of the Rewa would not be necessary; however, its scale would be too large to be realized. Therefore, the combination of the diversion channel and dike is proposed as the flood control plan for the Step 1 target, 1/20 probability flood.

The current flow capacity at Nausori, where the most of properties are located, would be maintained by the main stream and the excess flood (difference between 1/20 probability flood and current flow capacity at Nausori) which is 1,900 m^3/sec would be drained by the diversion channel. With this flood control plan, the discharge of the Rewa main stream would be reduced to 5,900 m^3/sec at river mouth, which is equivalent to the current flow capacity at Nausori.

(2) Route of Diversion Channel

There are two possible alignments of the diversion channel as shown in Table-6.25.

Table-6.25 Possible Alignment of Rewa Diversion Channel

No.	Alignment	Description
1	Rewa river at 20.5 km from river mouth → Namata river at 3.0 km from river mouth	to cross the hill in the western side of the Maumi village
2	Rewa river at 20.5 km from river mouth → Waidamu river mouth	to wider the cross section of Waidamu river

As a result of the hydraulic examination, the bed elevation at outlet was determined as EL. -5.0 m for both alignments. Therefore, bed widths of alignment No. 1 and No. 2 are 108 m and 149 m, respectively, to drain 1,900 m^3/sec. Rough cost estimate for two alignments was conducted and consequently alignment No. 1 has been selected because of its cheaper cost. Since objective of the cost estimate is comparison of two alignment, costs below are direct costs (main work + compensation work).

Alignment No. 1:	F$ 81 x 10^6 (total length: 8,900 m)
Alignment No. 2:	F$ 120 x 10^6 (total length: 16,600 m)

Excavated soil of the diversion channel is assumed to be used for dike construction and channel embankment whose width is large enough for the other uses, such as road, housing and so on, as shown in Figure-6.15.

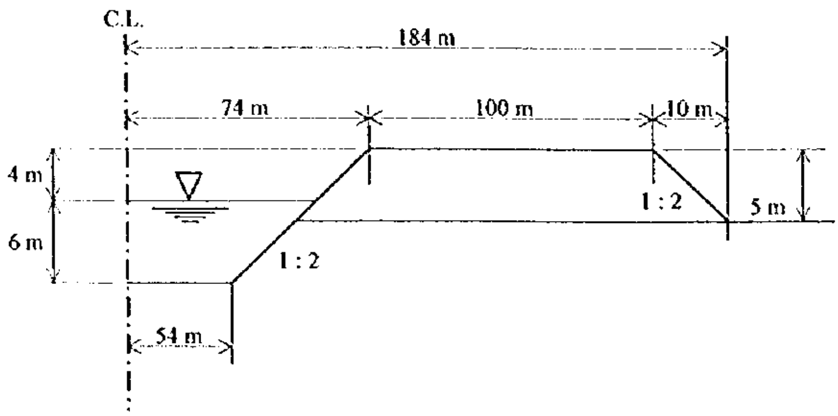

Figure-6.15 Standard Cross Section of Rewa Diversion Channel (3,000 m from River Mouth)

(3) Dike Construction

The dike construction is employed against the excess flood which is not covered by the diversion channel. Areas to be covered by dikes are as follows and there is over flow of approximately 1.5 m depth in those areas when discharge is 5,900 m^3/sec with the implementation of diversion channel only.

Left Bank of Rewa River

- between 12.0 km and 16.0 km from river mouth
- between 20.0 km and 20.5 km from river mouth

Right Bank of Rewa River

- between 12.0 km and 16.0 km from river mouth

To determine the scale of the dikes, the following Japanese standard were applied.

- Levee crown width: 6.0 m (5,000 m^3/sec $\leq$ discharge $<$ 10,000 m^3/sec)
- Levee free board: 1.5 m (5,000 m^3/sec $\leq$ discharge $<$ 10,000 m^3/sec)

The average height of dike is approximately 3.0 m to mitigate the flood damage by 20 year return period flood in combination with the diversion channel. The typical cross section of dike is shown in Figure-6.18.

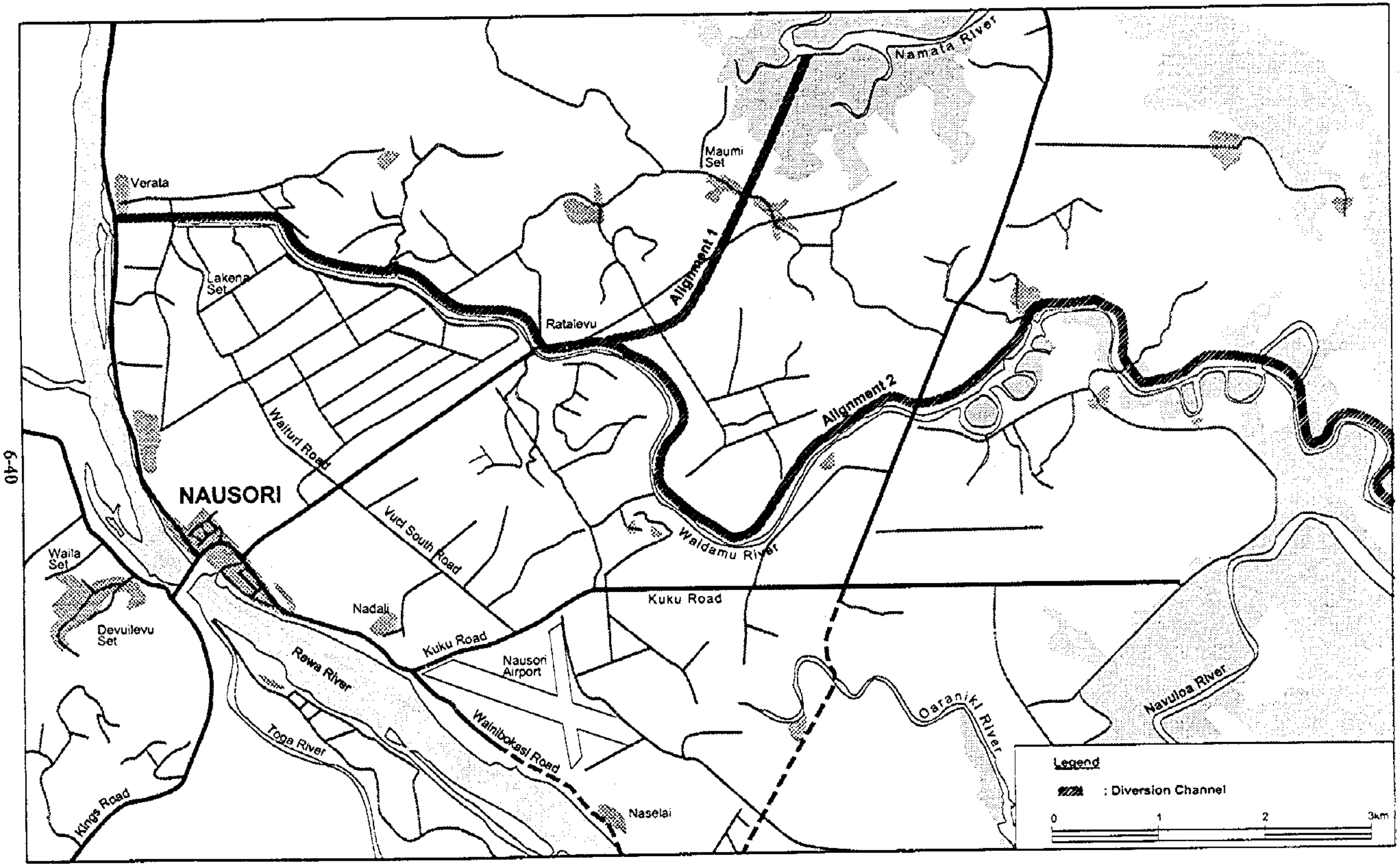

Figure-6.16 Possible Alignment of Diversion Channel (Rewa)

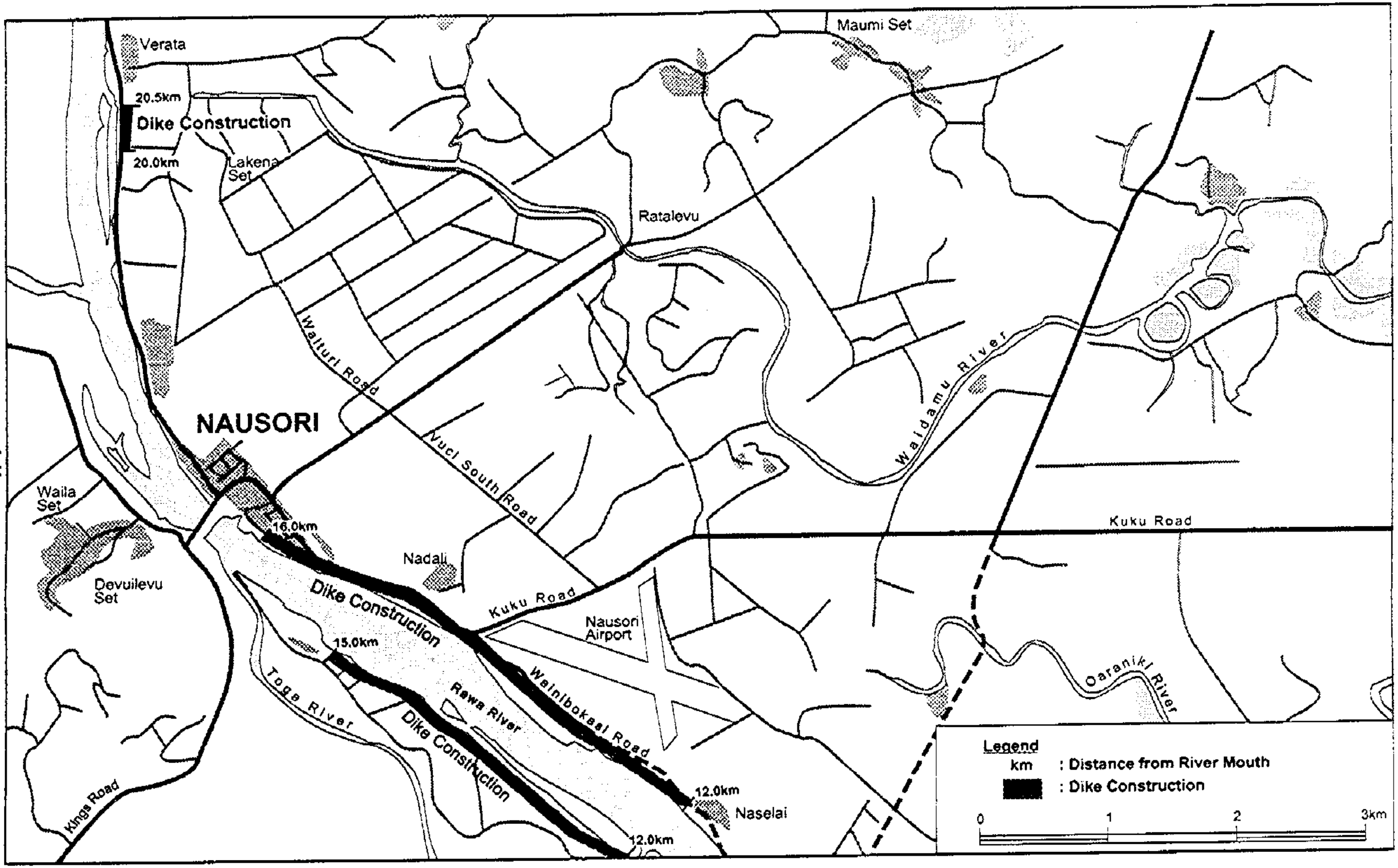

Figure-6.17 Proposed River Section for Dike (Rewa)

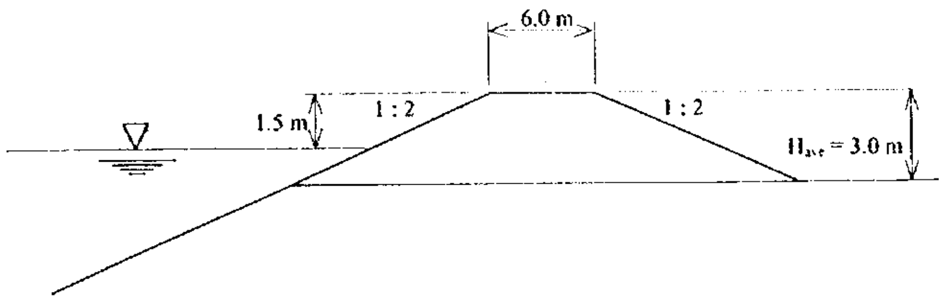

Figure-6.18 Standard Cross Section of Dike (Rewa)

6.6.3 Structural Measures for Sigatoka Watershed

Since the current flow capacity of Sigatoka river is 2,600 m^3/sec, 1/16 probability flood, the safety degree against flood is the highest among the objective 4 watersheds. It requires the flood control measures to drain only 300 m^3/sec to achieve the Step 1 target, (2,900 m^3/sec). Therefore, the large scale measures are not necessary and the river course widening by means of the river bed excavation (dredging) is considered as the most effective. Regarding the dike construction, land acquisition is difficult because the Native Villages are located along the river.

The scale of river bed excavation (dredging) based on the hydraulic examination is as follows:

- Length: 10 km, from river mouth to 10 km upstream
- Excavation width: 100 m
- Average excavation depth: 2.0 m
- Total volume to be excavated: 1,817,000 m^3

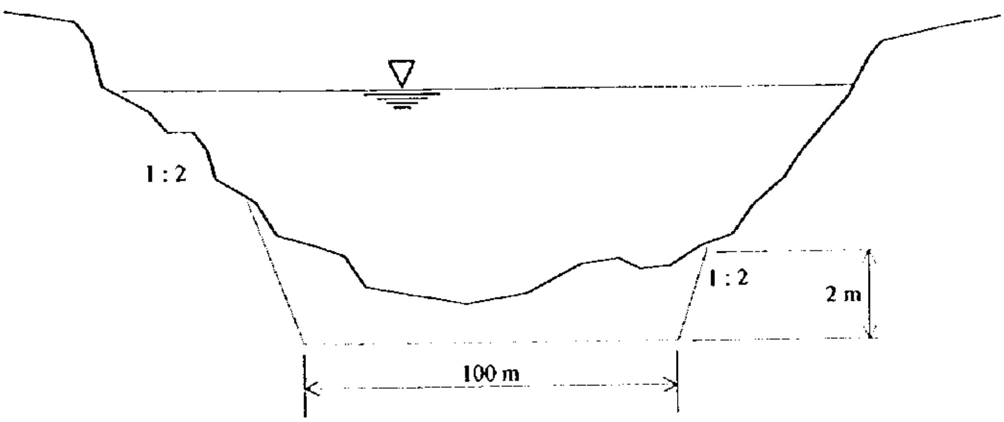

Figure-6.19 Standard Cross Section of Dredging (Sigatoka)

6.6.4 Structural Measures for Nadi Watershed

The current flow capacity of Nadi river is the smallest, 1/1 probability, among 4 watersheds. Therefore, the large scale measures are required to achieve the Step 1 target, 1/20 probability. Since the town extends along the river, the river course widening is difficult. Therefore, the flood control measure for the Nadi watershed is the diversion channel, in combination with the short cut channel around the confluence with Nawaka river (8.0 km upstream from Nadi river mouth) where there is a critical point in terms of the current flow capacity.

(1) Design Discharge of Diversion Channel

After implementation of the short cut channel, the flow capacity of Nadi river at Nadi town, between 9.0 km and 12.0 km from river mouth, would increase from 250 m^3/sec to 300 m^3/sec. Maintaining this flow capacity, the design discharge of the diversion channel was determined as 1,500 m^3/sec, the difference between the flow capacity improved and 1/20 probability flood at the diverting point.

(2) Alignment of Diversion Channel

There are 4 possible alignments of the diversion channel based on topographical features, current and future land use, land classification and so on.

Table-6.26 Possible Alignment of Nadi Diversion Channel

No.	Alignment	Description
1	Nadi river at 14 km upstream from river mouth → near the rubbish dump site	to use the existing canal which runs in the south of the airport
2	Nadi river at 14 km upstream from river mouth → the end of Enamanu road	to use the south part of the area for the airport extension plan
3	Nadi river at 19.5 km upstream from river mouth → the end of Nasoso road	to run along Nasoso road in the north of the airport
4	Nadi river at 19.5 km upstream from river mouth → the river mouth of Sabeto river	to use the existing canal which runs in the north of the airport

As a result of examination of the four possible alignments, the alignments in the north of Airport (No. 3 and 4) are considered as difficult to be implemented because the land acquisition is not feasible due to the resort hotels on the hill at the diverting point and no space available for detour to avoid the hill. For the alignment No. 1, there are two obstacles in terms of land use. One is the area of transmitters for the airport (approximately 45 ha) located in the south of the airport and another is the large development of the resort at the outlet of the diversion channel. Considering the above conditions, alignment No. 2 is the most feasible because of the less problems in the land acquisition.

- Alignment No. 1: Land acquisition is difficult. (total length = 3,700 m)
- Alignment No. 2: Land acquisition is relatively less problems. (total length = 3,000 m)
- Alignment No. 3: Land acquisition is difficult. (total length = 4,500 m)
- Alignment No. 4: Land acquisition is difficult. (total length = 6,500 m)

As a result of examinations of hydraulic specifications and land acquisition, alignment No. 2 was selected for the Nadi diversion channel. Since elevation of the sea bed at outlet of alignment No. 2 is approximately EL. -5.0 m, bed elevation at outlet was determined as EL. -5.0 m resulting in 52 m of bed width.

Assuming that excavated soil of the diversion channel is used for the embankment whose width is large enough for the other uses, such as road, housing and so on, the standard cross section of Nadi diversion channel is shown in Figure-6.20.

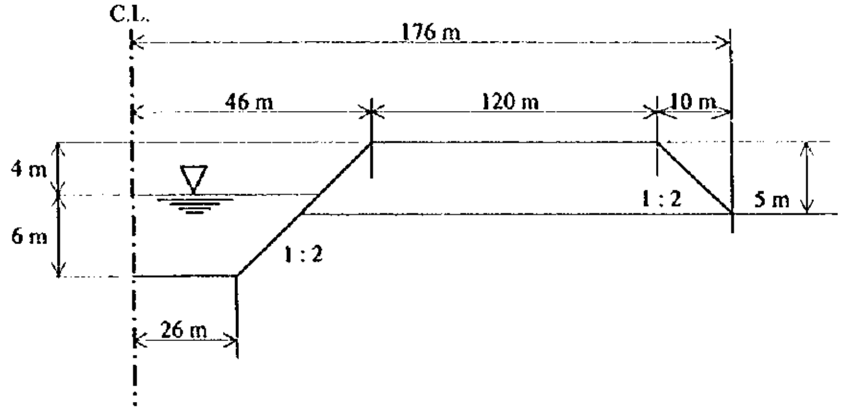

Figure-6.20 Standard Cross Section of Nadi Diversion Channel
(1,000 m from Outlet)

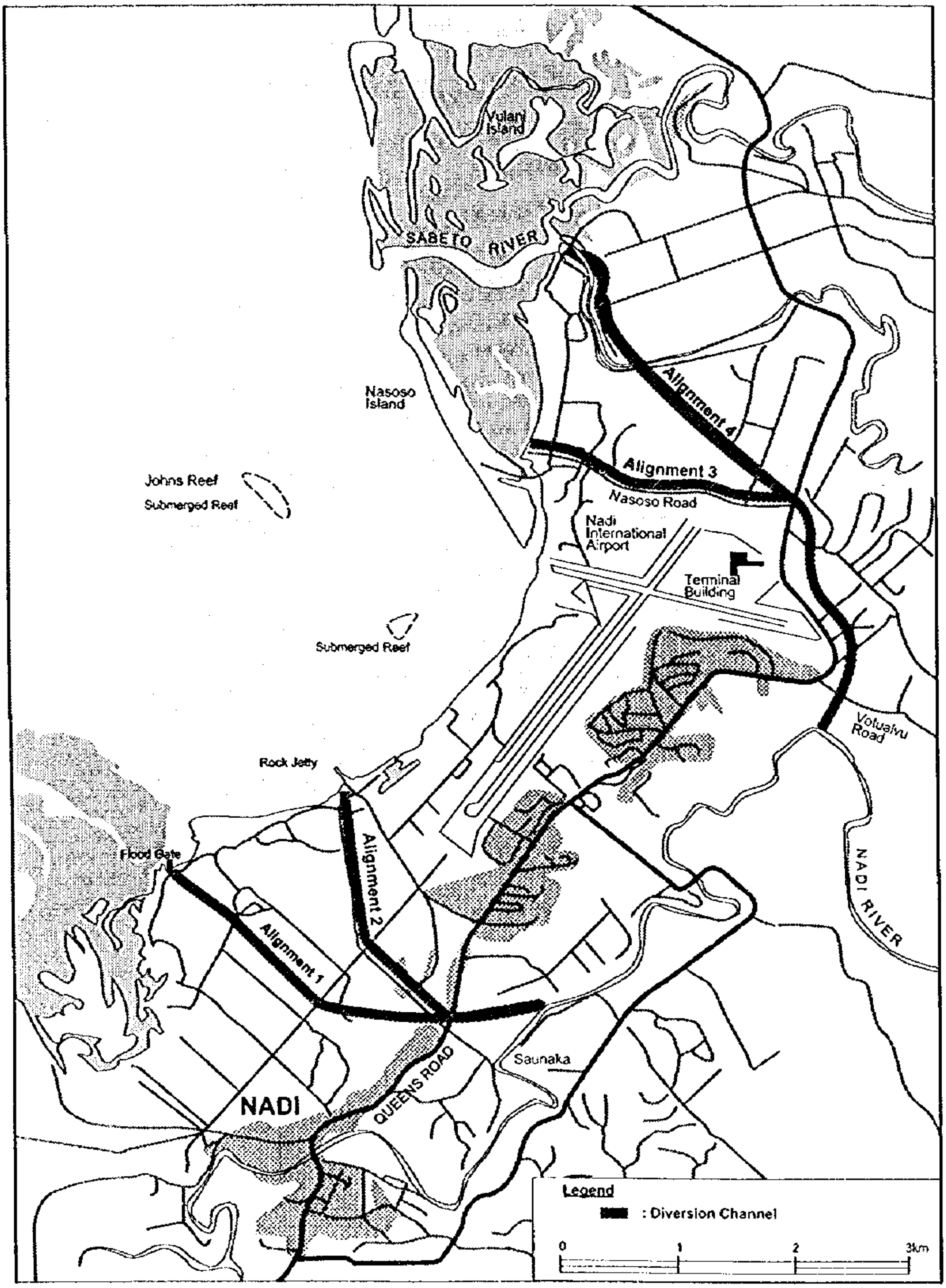

Figure-6.21 Possible Alignment of Diversion Channel (Nadi)

(3) Short Cut Channel

Nawaka river, a tributary of Nadi river in the left bank side, flows into Nadi river at about 8.0 km upstream from river mouth as shown in Figure-6.22. Around this confluence, Nadi river meander remarkably inducing the large bank erosion and sedimentation which reduce the cross section area of river. By implementation of the short cut channel connecting between 7.5 km and 9.0 km points from river mouth, the stable flow and bed slope would be maintained. The length of the short cut channel is approximately 250 m. The effect of the short cut channel on flood is to increase the flow capacity. Its increment is 0.3 m in terms of stage and 50 m^3/sec in terms of discharge.

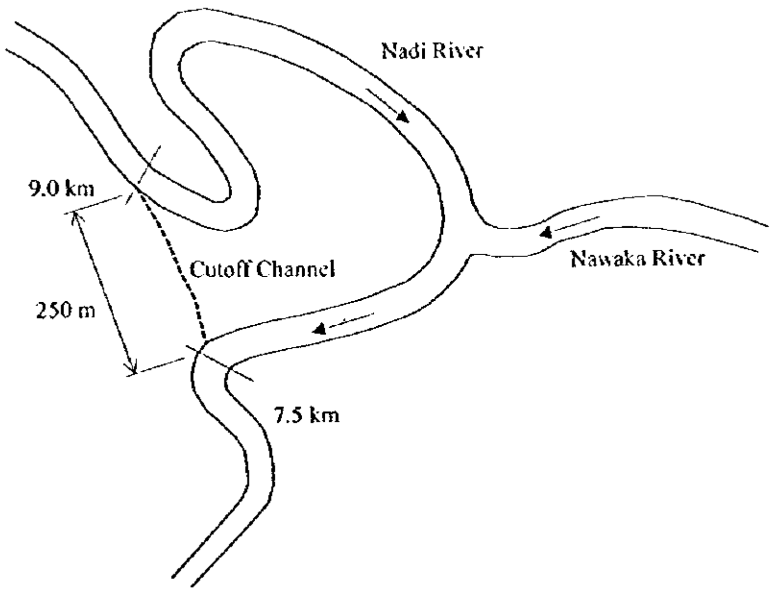

Figure-6.22 Confluence of Nadi River and Nawaka River

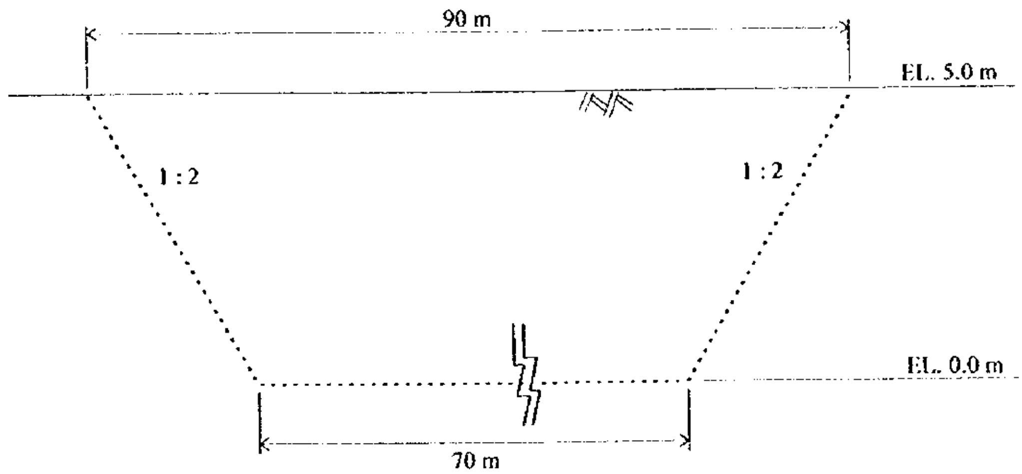

Figure-6.23 Standard Cross Section of Short Cut Channel (Nadi)

6.6.5 Structural Measures for Ba Watershed

According to the topographical features in the Ba watershed, the diversion channel is not applicable and river bed excavation is not effective on flood control because the design flood level is 2 ~ 4 m higher than the ground level. Since land use along the river in the Ba delta is mainly crop land and housing is not located close to the river, except a sugar mill, dike construction is considered as the most applicable measure.

(1) Dike Construction Area

- left bank side: 11.0 km - 16.0 km from river mouth
- right bank side: 10.0 km - 18.0 km from river mouth

(2) Scale of Dike

To determine the scale of the dike, following Japanese standard was applied.

- Levee crown width: 5.0 m (2,000 m^3/sec ≤ discharge < 5,000 m^3 /sec)
- Levee free board: 1.2 m (2,000 m^3/sec ≤ discharge < 5,000 m^3 /sec)

The average height of dike is 4.1 m to mitigate the flood damage by 1/20 probability flood. The typical cross section of dike is shown in Figreu-6.24 and proposed river section for dike construction is shown in Figure-6.25.

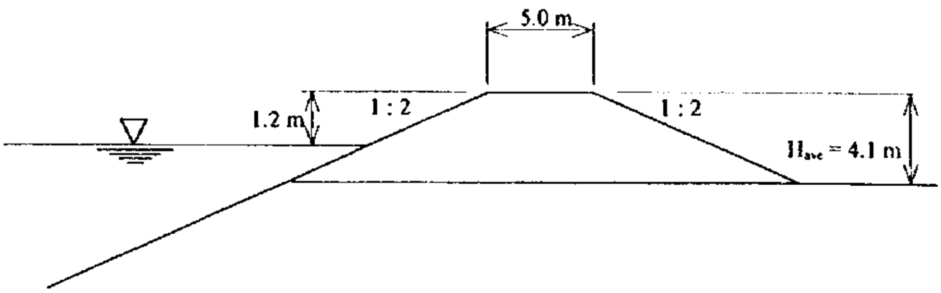

Figure-6.24 Standard Cross Section of Dike (Ba)

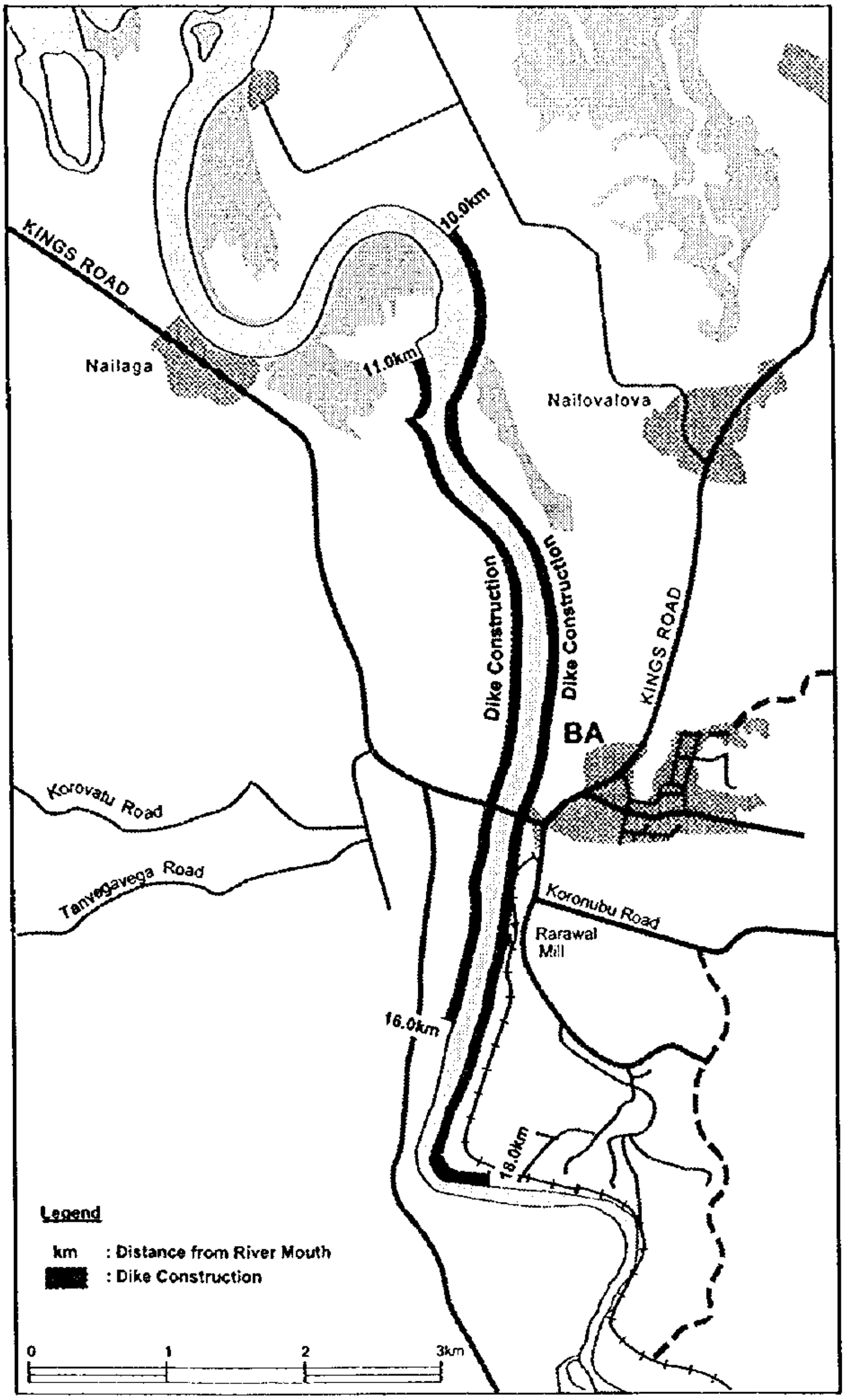

Figure-6.25 Proposed River Section for Dike (Ba)

6.6.6 Distribution of Design Flood Discharge

Design flood discharge with flood control measures described above would flow in the main stream and tributaries as shown in Figure-6.26. In the figure, the areas to be protected against 1/20 probability flood are also shown.

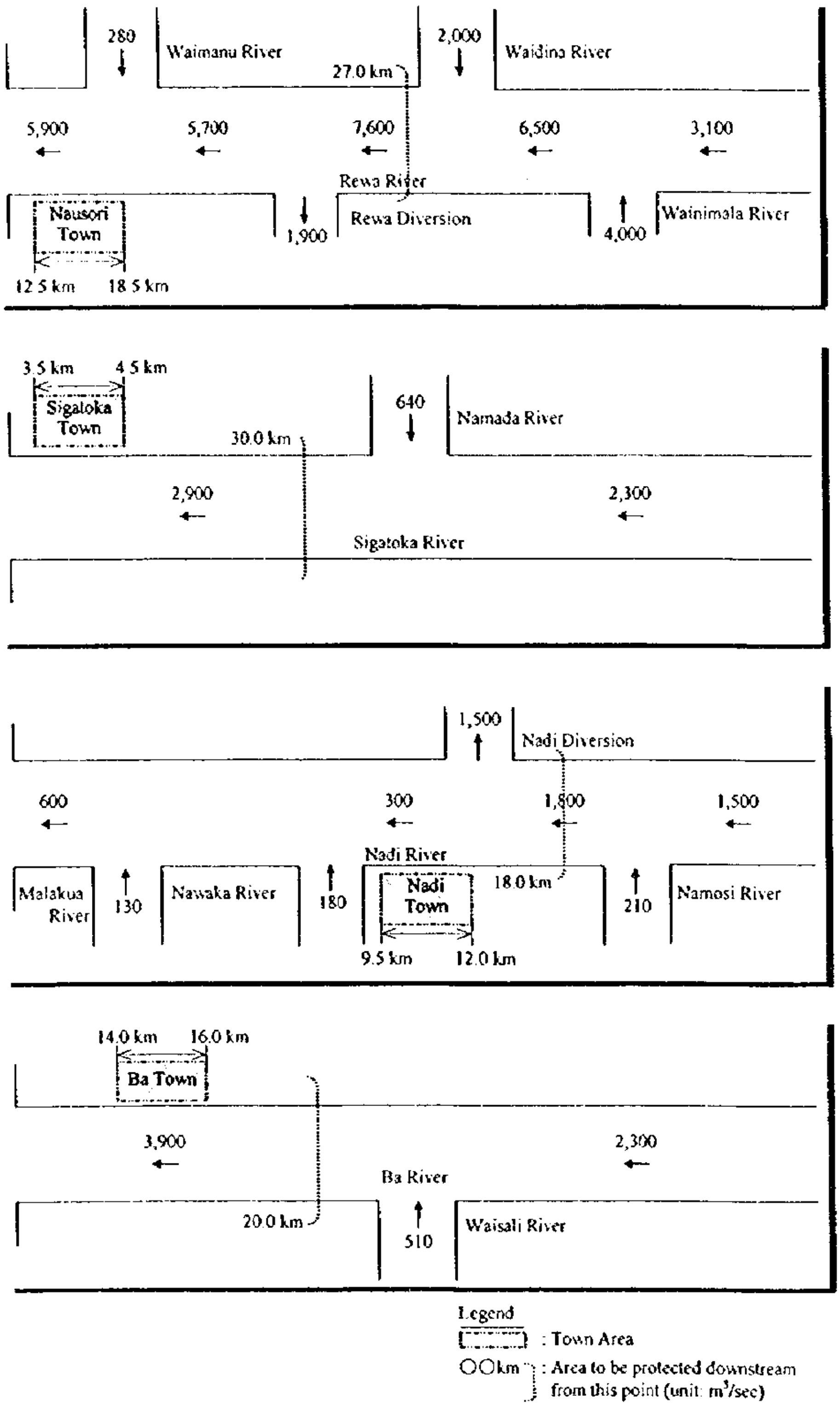

Figure-6.26 Distribution of Design Flood Discharge for 20 Year Return Period Flood

6.6.7 Cost Estimate

(1) Estimate of Quantities

The structural measures for cost estimate are shown below:

Rewa watershed	Diversion channel + Dike construction
Sigatoka watershed	Dredging
Nadi watershed	Diversion channel + Short cut channel
Ba watershed	Dike construction

By construction work of the diversion channels, the existing infrastructure, such as roads, wiring, piping etc. which is crossing the proposed sites will be cut in the Rewa and Nadi watershed. Therefore, the compensation work of the infrastructure with construction of bridges over the channels and road was added up in order to secure the traffic and the services. Near the outlet of the planned Nadi diversion channel, there is a flood gate at the end of the existing drainage to prevent the salt water intrusion. In this estimate, the flood gate was assumed to be installed at the outlet of the channel, although the necessity of the flood gate will be determined during the Feasibility Study based on the land use plan and so on.

The estimated quantities of the major construction works are shown below based on the above consideration.

Table-6.27 Quantities of Main Work and Compensation Work

Description		River	Rewa Diversion Channel + Dike Construction	Sigatoka Dredging	Nadi Diversion Channel + Short Cut Channel	Ba Dike Construction
Main Work	Excavation (m^3)	Sand and Soil	5,970,000	–	1,645,000[1)]	826,600
Main Work	Excavation (m^3)	Rock	450,000	–	–	–
Main Work	Excavation (m^3)	Sub Total	6,420,000	–	1,645,000[2)]	826,600
Main Work	Dike Construction (m^3)	loading & transportation	6,420,000[1)]	–	1,645,000[2)]	413,300
Main Work	Dike Construction (m^3)	Grading	6,420,000[1)]	–	1,645,000[2)]	826,600
Main Work	Dike Construction (m^3)	Compaction	6,420,000[1)]	–	1,645,000[2)]	826,600
Main Work	Dredging (m^3)		–	1,816,500	–	–
Compensation Work	Bridge (m)		960 (160 x 6)	–	300 (100 x 3)	–
Compensation Work	Road (m)		2,000		1,000	
Compensation Work	Flood Gate (m)		–	–	76 (x 1)	–

1): including 330,000 m^3 of dike construction
2): including 100,000 m^3 of the short cut channel construction

(2) Composition of Project Cost

The composition of the project cost is shown below. The ratios of the administration cost, the engineering cost and the contingency are estimated based on comparison of the similar projects in the world.

1) Construction cost
2) Land acquisition
3) Administration: 5 % of 1)
4) Engineering: 15 % of 1)
5) Physical contingency of construction quantities: 10 % of the sum of 1) ~ 4)
6) Price contingency: based on annual inflation rate of 5% for local cost and 3% for foreign cost, and construction period of 4 years
7) Taxes and duties: 10 % of the sum of 1) ~ 6)

(3) Estimate of Construction Cost

1) Condition of Unit Cost

a) In Fiji, the standard price per unit work is not available for the cost estimate. Therefore, the unit price of each work item was estimated based on the costs of previous works similar to the projects in the Master Plan, except for dredging. The unit price for the earth work in Fiji is approximately 80 % of that in Japan.

b) The unit price of the previous works available in D&I was adopted for dredging and the flood gate construction work.

c) The unit price of the construction work for the bridges and roads in compensation work was estimated based on data collection and interview study to the contractors in Fiji.

2) Estimate of Construction Cost

The construction cost in each watershed was estimated as shown in Table-6.28 to 6.31, using the above unit cost.

Table-6.28 Construction Cost of Rewa Diversion Channel and Dike Construction

Description			Unit Price	Quantity	Amount (F$)	Remarks
Main Work	Excavation	Sand and Soil	2.1 F$/m³	5,970,000 m³	12,537,000	Transportation Distance 20 m
		Rock	5.6 F$/m³	450,000 m³	2,520,000	
	Dike Construction[1]	loading & transportation	4.0 F$/m³	6,420,000 m³	25,680,000	Transportation Distance 500 m
		Grading	2.5 F$/m³	6,420,000 m³	16,050,000	
		Compaction	0.9 F$/m³	6,420,000 m³	5,778,000	
	Sub-Total				62,565,000	
Compensation Work	Bridge		32,500.0 F$/m	960 m	31,200,000	6 bridges x 160 m
	Road		F$/m	2,000 m	2,000,000	
	Sub-Total				33,200,000	
Construction Cost = Main Work + Compensation Work					95,765,000	

1): including 330,000 m³ of dike construction

Table-6.29 Sigatoka Dredging Cost

Description	Unit Price	Quantity	Amount (F$)	Remarks
Dredging	4.4 F$/m³	1,816,500 m³	7,992,600	

Table-6.30 Construction Cost of Nadi Diversion Channel and Short Cut Channel

Description			Unit Price	Quantity	Amount (F$)	Remarks
Main Work	Excavation	Sand and Soil	2.1 F$/m³	1,645,000 m³	3,454,500	Transportation Distance 20 m
		Rock	5.6 F$/m³	0 m³	0	
	Dike Construction[1]	loading & transportation	5.2 F$/m³	1,645,000 m³	8,554,000	Transportation Distance 1,500 m
		Grading	2.5 F$/m³	1,645,000 m³	4,112,500	
		Compaction	0.9 F$/m³	1,645,000 m³	1,480,500	
	Sub-Total				17,601,500	
Compensation Work	Bridge		32,500.0 F$/m	300 m	9,750,000	3 bridges x 100 m
	Road		1,000.0 F$/m	1,000 m	1,000,000	
	Flood Gate		70,000.0 F$/Unit	19 Units	1,330,000	1 gate = 4 m
	Sub-Total				12,080,000	
Construction Cost = Main Work + Compensation Work					29,681,500	

1): including 100,000 m³ of the short cut channel construction

Table-6.31 Construction Cost of Ba Dike

Description			Unit Price	Quantity	Amount (F$)	Remarks
Main Work	Excavation	Sand and Soil	3.3 F$/$m^3$	826,600 m^3	2,727,780	Transportation Distance 50 m
		Rock	5.6 F$/$m^3$	0 m^3	0	
	Dike Construction	loading & transportation[1]	5.2 F$/$m^3$	413,300 m^3	2,149,160	Transportation Distance 1,500 m
		Grading	2.5 F$/$m^3$	826,600 m^3	2,066,500	
		Compaction	0.9 F$/$m^3$	826,600 m^3	743,940	
	Sub-Total				7,687,380	

1): The half of the material for the dike will be obtained from the area near the project site. The other half will be transported in the average distance of 1.5 km.

(4) Estimate of Land Acquisition and Compensation

Among the land tenure system of Native Land, State Land and Free-hold Land in Fiji, land acquisition cost was counted for Free-hold Land and 99-year lease cost was counted for Native Land. State Land does not require either acquisition or lease but requires only compensation for the present land use.

The area by land tenure and the number of houses within the project site was estimated overlapping the project plan to the aerial photography (1994) and the cadastral map available from the Department of Land and Survey. The unit price of the land, 99-year lease and the unit compensation cost by preset land use, such as houses, sugarcane field, grazing, public facilities, etc. was set through discussion with the Department of Land and Survey. The dredging project for Sigatoka watershed does not require land acquisition and compensation cost.

(5) Estimate of Project Cost

The project cost (1996 price base) was estimated based on the conditions below.

- The ratio between local cost and foreign cost was set as shown in Table-6.32 based on the construction works in Fiji.
- The ratio of material and equipment cost to labor cost is set as 7:3.
- Taxes and duties are included in the cost except the price contingency.
- The price contingency was taken into consideration with annual inflation rate of 5 % for the local currency portion and 3 % for the foreign currency portion.

Table-6.32 Ratio of Local Currency and Foreign Currency

Item	Local Currency	Foreign Currency
1. Construction Cost		
1) Material & Equipment	20 %	80 %
2) Labor	80 %	20 %
2. Land Acquisition	100 %	0 %
3. Administration	100 %	0 %
4. Engineering	20 %	80 %
5. Physical Contingency	40 %	60 %

The result of project cost estimate is shown in Table-6.33.

Table-6.33 Project Cost

Unit: F$ 1,000

Project	Item	Project Cost	Local Currency	Foreign Currency
Rewa Diversion Channel and Dike Construction	1. Construction Cost	95,800	36,400	59,400
	1) Material & Equipment	67,100	13,400	53,700
	2) Labor	28,700	23,000	5,700
	2. Land Acquisition	5,000	5,000	-
	3. Administration	4,800	4,800	-
	4. Engineering	14,400	2,900	11,500
	5. Physical Contingency	12,000	4,800	7,200
	Sub Total	132,000	54,000	78,000
	6. Price Contingency	7,800	4,200	3,600
	7. Tax	14,000	14,000	0
	Grand Total	153,800	72,200	81,600
Sigatoka Dredging	1. Construction Cost	8,000	3,040	4,960
	1) Material & Equipment	5,600	1,120	4,480
	2) Labor	2,400	1,920	480
	2. Land Acquisition	-	-	-
	3. Administration	400	400	-
	4. Engineering	1,200	240	960
	5. Physical Contingency	1,000	400	600
	Sub Total	10,600	4,080	6,520
	6. Price Contingency	620	320	300
	7. Tax	1,120	1,120	0
	Grand Total	12,340	5,520	6,820
Nadi Diversion Channel and Short Cut Channel	1. Construction Cost	29,700	11,280	18,420
	1) Material & Equipment	20,800	4,160	16,640
	2) Labor	8,900	7,120	1,780
	2. Land Acquisition	4,000	4,000	-
	3. Administration	1,500	1,500	-
	4. Engineering	4,500	900	3,600
	5. Physical Contingency	4,000	1,600	2,400
	Sub Total	43,700	19,280	24,420
	6. Price Contingency	2,620	1,500	1,120
	7. Tax	4,630	4,630	0
	Grand Total	50,950	25,410	25,540
Ba Dike Construction	1. Construction Cost	7,700	2,920	4,780
	1) Material & Equipment	5,400	1,080	4,320
	2) Labor	2,300	1,840	460
	2. Land Acquisition	1,000	1,000	-
	3. Administration	400	400	-
	4. Engineering	1,200	240	960
	5. Physical Contingency	1,000	400	600
	Sub Total	11,300	4,960	6,340
	6. Price Contingency	670	380	290
	7. Tax	1,200	1,200	0
	Grand Total	13,170	6,540	6,630

Note: 1) Tax: Value Added Tax (VAT)
2) Material & Equipment = Construction Cost x 70 %
3) Labor = Construction Cost x 30 %

6.6.8 Economic Evaluation

(1) Conditions of Economic Evaluation

The economic evaluation of the flood control projects (structural measures proposed in the section 6.6 and afforestation in the Sigatoka watershed proposed in the section 6.10) was made by comparing the two present values, economic benefit and cost of the project. The major economic benefit of the flood control project is presented as an expected reduction in flood damage by implementing the project, that is an economic difference between "with-project" and "without-project" situations. The comparison on economic benefit and cost was carried out using Economic Internal Rate of Return (EIRR), together with Benefit-Cost Ratio (B/C) and Net Present Value (NPV).

The economic cost and benefit were estimated using the economic prices under the conditions and assumptions as shown below;

- Transfer payments such as value added tax of 10 % are not included in the economic cost and benefit.
- Standard conversion rate (SCR) applied to equipment and materials procured locally is assumed to be 94.0 %, taking the export and import situations of Fiji in recent years into consideration.
- Opportunity cost of wages for laborers is assumed to be 94 % of existing cost, taking unemployment situations in recent years into consideration.
- Opportunity cost of land to be acquired for the project is assumed to be 90 % of the financial cost.
- Inflation factor is not taken into account in economic evaluation.
- Economic life of the project (hereinafter referred to as the "project life") is taken as 50 years after the completion of construction works for structural measures and 100 years for afforestation.
- Construction period is assumed to be 4 years.
- The benefit and the OM cost (operating and maintenance cost) for the project are expected to accrue every year during the period of the project life after completion of the construction works.
- Opportunity cost of capital is assumed to be 10 % and used as the discount rate, as indicated by the Capital Planning Office.

(2) Annual Average Damage Reduction

The expected annual average damage reduction is described in the section 6.4 and the result is summarized in Table-6.34.

Table-6.34 Annual Damage Reduction

Unit: F$ 1,000

Flood Control Measures	Rewa	Sigatoka	Nadi	Ba
Structural Measures	1,966	381	8,278	1,446
Afforestation	–	186	–	–

The annual average damage reduction is equivalent to an expected Annual Average Benefit. This benefit is expected to accrue every year during the project life (50 years for structural measures and 100 years for afforestation).

(3) Economic Cost

- The economic cost is a converted value from the project costs under the conditions and assumptions described in (1). As a result of the conversion, the economic costs and OM cost per annum were estimated. Meanwhile, the land lease charge of F$ 1.0 /year was included in OM cost for afforestation. The result is shown in Table-6.35.

Table-6.35 Economic Cost of Project

Unit: F$ 1,000

Flood Control Measures	Economic Cost	Rewa	Sigatoka	Nadi	Ba
Structural Measures	Project Cost	134,467	10,854	43,794	11,358
	Annual OM Cost	98	8	31	8
Afforestation	Project Cost	–	17,551	–	–
	Annual OM Cost	–	34	–	–

(4) Economic Evaluation

The economic evaluation of projects was conducted using the annual average economic benefit and cost in Table-6.34 and Table-6.35. The results of the evaluation are summarized in Table-6.36.

Table-6.36 Economic Evaluation of Project

Flood Control Measures	Item	Rewa	Sigatoka	Nadi	Ba
Structural Measures	Economic Benefit (F$ 1,000/year)	1,966	381	8,278	1,416
	Economic Project Cost (F$ 1,000)	134,467	10,854	43,794	11,358
	Economic Annual Maintenance Cost (F$ 1,000/year)	98	8	31	8
	EIRR (%)	negative	2.00	15.06	10.73
	B/C (Ratio)	0.12	0.30	1.61	1.08
	NPV (F$ 1,000)	-93,911	-6,075	21,143	737
Afforestation	Economic Benefit (F$ 1,000/year)	–	186	–	–
	Economic Project Cost (F$ 1,000)	–	17,551	–	–
	Economic Annual Maintenance Cost (F$ 1,000/year)	–	39	–	–
	EIRR (%)	–	negative	–	–
	B/C (Ratio)	–	0.09	–	–
	NPV (F$ 1,000)	–	-10,593	–	–

Discount Rate: 10 %

As a result, the EIRR of the structural measures indicates "negative" for the Rewa, 2.00 % for the Sigatoka, 15.06 % for the Nadi, 10.73 % for the Ba. Those percentages indicate that the structural measures for the Nadi is the most feasible, in view of the opportunity cost of capital (10 %) in Fiji. In addition, B/C of 1.61 at discount rate of 10 % supports the feasibility of the structural measures in the Nadi. EIRR of the Ba shows 10.73 % which is slightly higher than the opportunity cost of capital and B/C is 1.08 at discount rate of 10 %. This means that the structural measures in the Ba are at the threshold for implementation. Meanwhile, the negative results and low percentage of EIRR for the Rewa and Sigatoka indicate that the projects (structural measures and afforestation) are not economically feasible. In addition, B/C of 0.12 and 0.30 for structural measures, and 0.09 for afforestation at discount rate of 10 % show low economic viability.

In conclusion, it is expected that the flood control project (structural measures) in the Nadi watershed would make the high contribution to not only the flood mitigation, but also the promotion of economic development in the region.

6.7 Non Structural Measures

Flood control plans consist of structural measures, such as improvement of river (dike, river course widening, dredging) and storage facilities (dam, retarding basin), and non structural measures without any involvement of construction. Structural measures for each watershed were examined and proposed in the previous sections. In the following section, non structural measures are discussed.

The following items are considered as non structural measures for flood control.

- Mitigation of flood discharge from watershed
- Reduction of flood damage potential
- Reinforcement of flood management

6.7.1 Mitigation of Flood Discharge from Watershed

In Fiji, population and assets are located in the lower reach of river and the flood damage in those areas is caused by overspill from a river channel. To suppress the overspill without structural measures, both water retention function and water storage function of watershed have to be improved in order to mitigate flood discharge into a river channel.

Water retention and storage functions of watershed is improved by the following non structural measures.

(1) To increase the area of forest

The area of forest varies with watershed. It covers 40 ~ 50 % of watershed in the Sigatoka, Nadi and Ba watershed, which are located in the western Viti Levu, while it covers 70 % of the Rewa watershed in the eastern Viti Levu. According to the case study in the Sigatoka watershed described in the section 6.10, 10 % of the peak discharge is reduced by afforestation. Therefore, afforestation should be promoted.

(2) To regulate the land use so as not to damage the water retention function of watershed

There has been no large scale development in Fiji so far; however, tourist developments and housing developments have been planned in the Nadi watershed and some of them are already under the construction. The development is expected to expand to other watersheds in future. Without regulation, the land which has a water retention function, such as agricultural land, bushes, forest and so on, would be reduced. Therefore, it is necessary to regulate the land use in order to keep the areas for water retention. For example, regulation ponds and parks which retain and store the water, should be promoted in the large scale development by enforcement of law.

(3) To promote the land use which has a retarding function of flow

The land which has a retarding function of flow, such as swamp, should be maintained and promoted as natural reserves.

(4) To maintain the flow capacity of river

At least, current flow capacity of river should be maintained by suppressing inflow of soil into river channel because sedimentation reduces the cross section area of flow. The inflow of soil can be controlled at the source and at the river. The former is the soil conservation, such as terracing and afforestation, while a green belt on river banks is effective for the latter.

6.7.2 Reduction of Flood Damage Potential

The flood prone area should be designated based on the past records of flood and be publicized. To reduce the current flood damage potential, housing in the flood prone area should be limited by law; however, if it is not avoidable, a raised house which is proof against flood should be promoted.

6.7.3 Reinforcement of Flood Management

Mitigation of flood discharge from watershed and reduction of flood damage potential are non structural measures before a flood occurs. When a flood is expected, communication system, evacuation system and flood prevention are essential. In Fiji, National Disaster Management Plan has been formulated. When any disaster is expected or occurred, National Disaster Management Council will be formed by relative government authorities to conduct alarming, relief assistance, rehabilitation and so on. However, it still need reinforcement.

The flood management mainly consists of the followings and is conducted by interactive cooperation among the relative government authorities.

- Analysis of flood conditions
- Flood forecasting
- Communication system of flood (flood alarming)
- Evacuation system
- Flood prevention activities

Fiji Meteorological Service provides the flood information, such as route of cyclone and area of rainfall, based on the satellite and radar analysis, while Public Works Department conducts the hydrological analysis, such as rainfall and discharge. Based on those information and data, scale and route of cyclone can be related to rainfall and discharge. Once the relation was determined, it would be possible to forecast a flood and successively flood alarming, evacuation and flood prevention would be conducted effectively.

To establish the flood management, the followings are necessary to be employed in Fiji.

1) Reinforcement of Hydrological Observation

The hydrological data is a base of the flood management. Considering the current conditions, the following improvement of raingauge and gauging stations is necessary.

- Since there is a large spatial variation of rainfall in Fiji, raingauge stations should be located with at least 20 km interval referring to the raingauge network in Japan.
- The rating curve should be revised by observation during flood and non-uniform flow calculation.

To cover the lack of raingauge and gauging stations, new stations should be located as shown in Table-6.37.

Table-6.37 Necessary Number of New Hydrological Station

Hydrological Station	River	Necessary Total Number	Number of New Station	Remarks
Raingauge Station	Rewa	12	5	middle to low reach
	Sigatoka	7	2	middle and low reach
	Nadi	3	–	
	Ba	3	1	middle reach
	Total	25	8	
Gauging Station	Rewa	9	1	along the Rewa river downstream from the confluence with the Wailoa river
	Sigatoka	4	1	at Nakuilau
	Nadi	4	–	
	Ba	4	–	
	Total	21	2	

2) Publicity of Flood Information and Establishment of Flood Forecasting System

- Publicity of hydrological data
- Analysis of relation between cyclone and rainfall/discharge during flood
- Establishment of flood forecasting system in each watershed

3) Establishment of Communication System (Flood Alarming System)

- Establishment of flood management system
- Establishment of communication system which provides accurate information immediately to relative authorities

- Establishment of evacuation system
- Establishment of refuge places
- Formulation of flood management manual

The conceptual diagram of flood management system is shown in Figure-6.27 and that of flood forecasting and alarming system is shown in Figure-6.28.

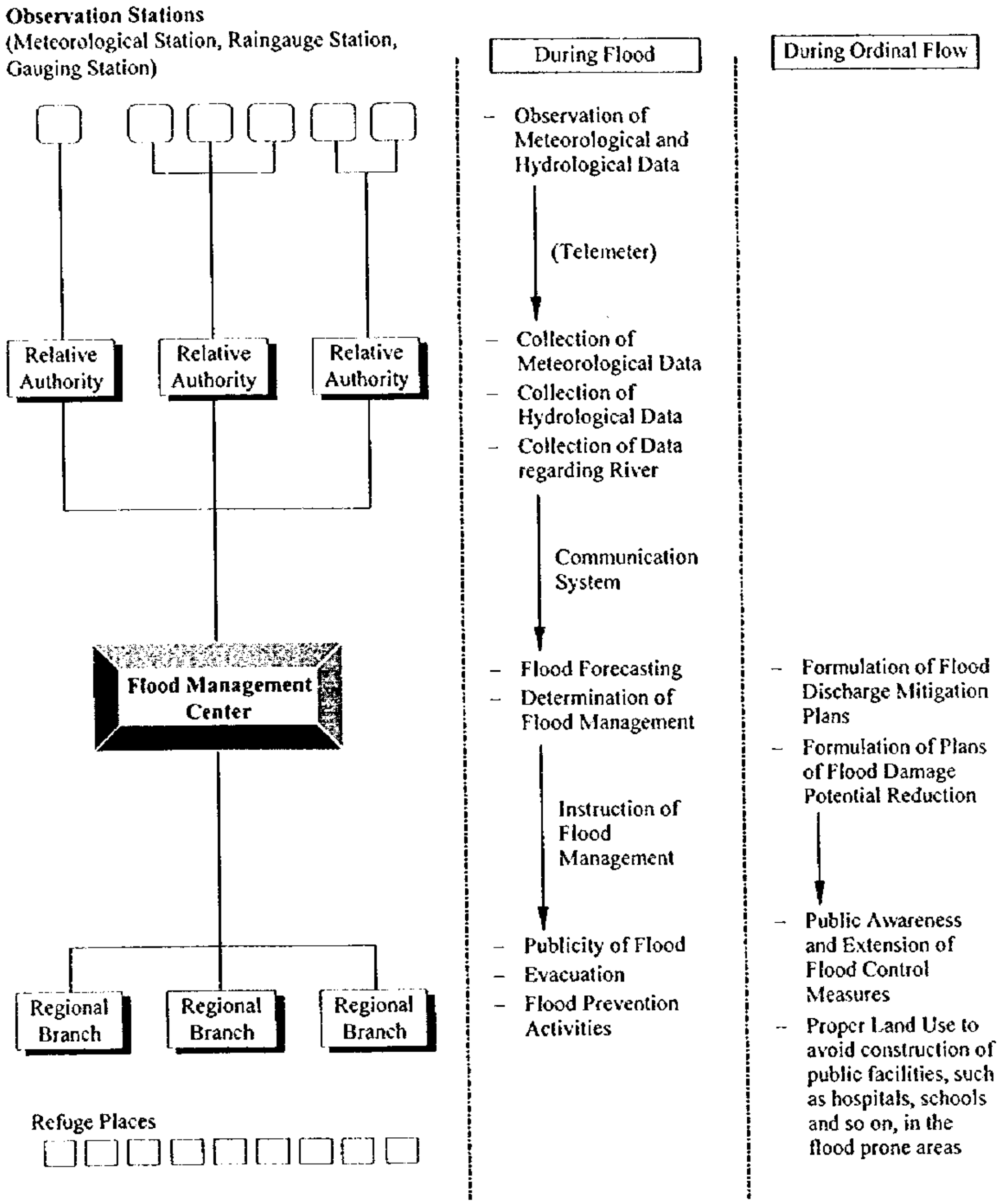

Figure-6.27 Conceptual Diagram of Flood Management

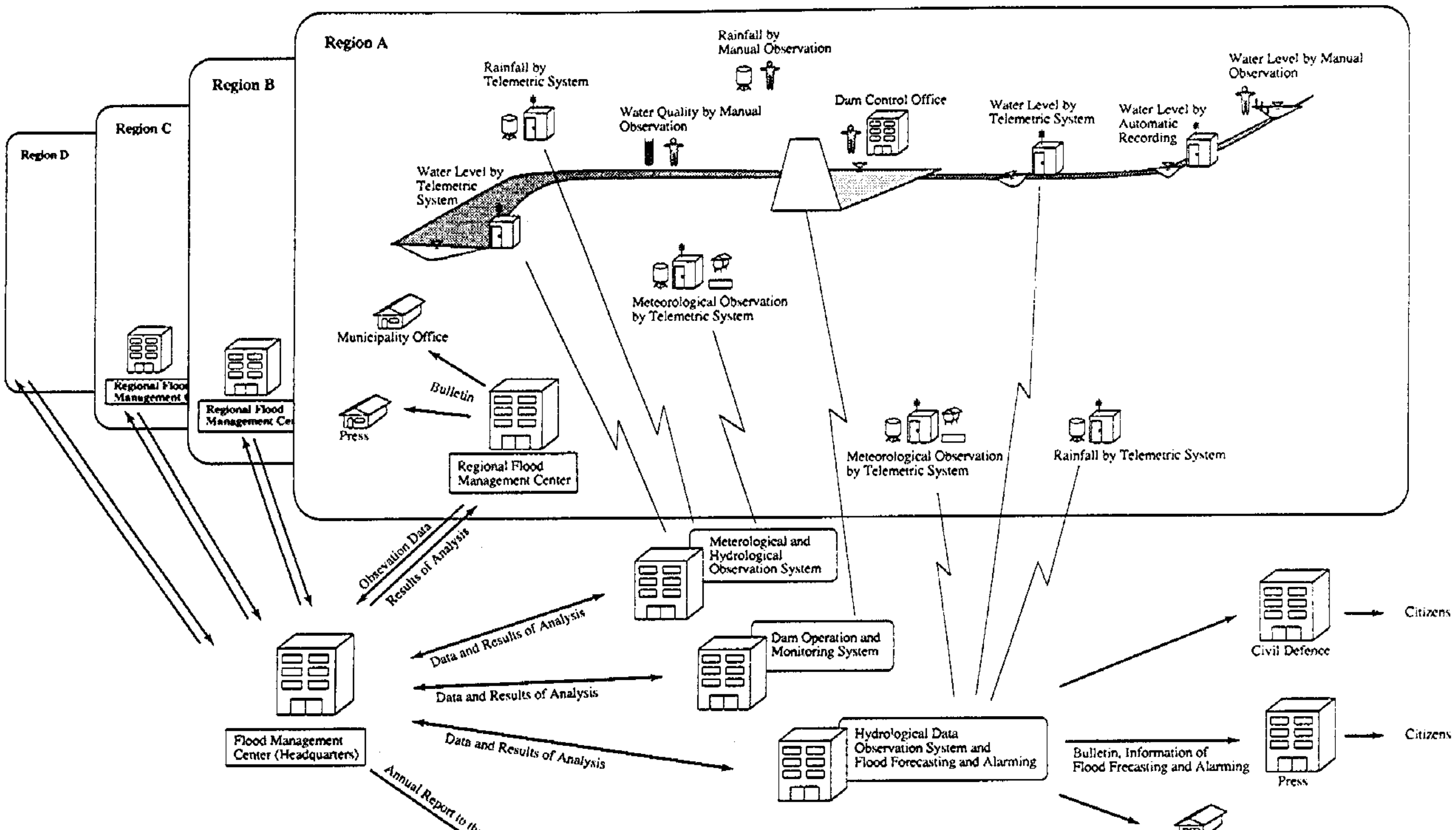

Figure-6.28 Flood Forecasting and Alarming System

6.7.4 Case Study of Flood Forecasting & Alarming System in Rewa Watershed

The facilities to be required for the flood forecasting and alarming system in the Rewa watershed, which is the largest watershed in Viti Levu, are examined. Those for other watersheds can be determined by the same considerations.

Flood forecasting would be enabled by the proposals in the section 6.7.3. Traveling time of flood in the Rewa delta around Nausori is approximately 12 hours. Assuming that it takes 3 hours to inform the public of flood, forecasting future rainfall in 3 hours is necessary so that flood alarming can be conducted 12 hours before flood occurs.

In general, media of flood alarming are radio, TV, speaker facilities and vehicles with speaker. Since inundated areas in the Rewa is very large, lots of speaker facilities would be required. Therefore, realistic media are radio, TV and vehicles with speaker. One vehicle can cover 5 km^2/hour with speed of 10 ~ 20 km/hour. To conduct flood alarming in flood prone areas of 50 km^2, 10 vehicles are necessary.

Evacuation is conducted by residents themselves; however, refuge places have to be informed to them during the ordinal time. Schools and public halls located on hill are suitable for refuge places.

The following authorities should be involved in flood forecasting and alarming system considering the present task of those authorities.

Table-6.38 Authorities for Flood Forecasting & Alarming

Item	Authority	Necessary Equipment
Collection of Rainfall Data	FMS PWD	Raingauge Stations
Collection of Discharge Data	PWD	Gauging Stations
Projection of Rainfall	FMS PWD	Computers
Application of Runoff Model	PWD	Computers
Flood Forecasting	PWD	Computers
Communication	Flood Management Center Civil Defense Mass Media	Communication Equipment
Flood Alarming	Flood Management Center Mass Media	TV & Radio Vehicles

Facilities to be required for flood forecasting and alarming system in the Rewa watershed are shown in Table-6.38 and their costs were also estimated.

Table-6.39 Necessary Facilities and Cost for Flood Forecasting and Alarming System (Rewa)

Item	Necessary Total Number	Required Number to be established	Unit	Unit Price F$ 10^3	Cost F$ 10^3
Raingauge Station	12	5	station	5	25
Gauging Station	9	1	station	10	10
Telemeter Facility	1	1	lump sum	1,000	1,000
Computer	10	10	unit	10	100
Office	8	8	building	To use existing government buildings (Headquarters = 1, Regional office =7)	
Vehicle for Alarming	10	10	car	40	400
System Development	1	1	lump sum	100	100
Reserved Fund	1	1	lump sum	165	165
Total					1,800

6.7.5 Radar Application to Flood Forecasting

Applicability of radar to flood forecasting was examined to overcome insufficient network of raingauge stations. Fiji Meteorological Service (FMS) has two sites for meteorological radar in Viti Levu so that rainfall intensity of cloud with a scale of 5 km x 5 km in the whole Viti Levu can be measured. Sites for radar are Nausori airport and Nadi airport and the radar system at Nadi was recently improved by JICA (Japan International Cooperation Agency). Although rainfall intensity of cloud is different from actual rainfall at land surface, once calibration was conducted to link rainfall intensity of cloud and rainfall at land surface, it would overcome difficulties to install raingauge in remote areas where there is no access and improve data availability.

To determine the relation between rainfall intensity of cloud and rainfall at land surface, it is necessary to observe rainfall continuously and recommendable to have a raingauge network with 20 km distance to understand spatial variation of rainfall. As recommended in the section 6.7.3, five new raingauge stations are required for the Rewa watershed, two for the Sigatoka watershed and one for the Ba watershed to satisfy the minimum requirement of the raingauge network.

After calibrating the rainfall intensity of cloud, runoff model which converts rainfall to discharge is applied and also analysis to understand a relation between rainfall distribution and route of cyclones is conducted. The runoff model is calibrated by comparing discharge simulated with discharge observed. As a result, discharge and stage can be forecast by analyzing future movement of cloud and change of rainfall distribution.

Radar is applicable to flood forecasting; however, it still requires lots of works and analyses. Fiji Meteorological Service is in charge of collection and processing of radar data, while Hydrological Section, PWD is in charge of hydrological analysis. Therefore, their cooperation is essential to achieve this task.

6.8 Case Study of Multi-Purpose Dam in Nadi Watershed

Although a dam was excluded from the Master Plan, the case study was conducted for a dam in the Nadi watershed in order to assess its feasibility compared to the Master Plan. The site for dam considered is the most possible site (N-3 in Figure-6.14), which was examined in the section 6.6.1.

(1) Flood Control

The effect of dam on flood control should aim at the same effect as the Master Plan for the Nadi proposed in the section 6.6.4, which consists of a diversion channel and a short cut channel. The Master Plan controls the following amount of flood (20 year return period flood).

- Discharge at river mouth before implementation of measures: 2,100 m^3/sec
- Discharge at river mouth after implementation of measures: 600 m^3/sec
- Effect: 1,500 m^3/sec

However, since the inflow at dam site (N-3) is limited to 1,060 m^3/sec, it is not possible to have the same effect as the Master Plan even if the dam controls all inflow. Therefore, it was assumed that the dam has the flood control capacity at maximum, 1,000 m^3/sec, and its effect on flood control was examined. The results are summarized below.

- Discharge at river mouth before implementation of dam: 2,100 m^3/sec
- Discharge at river mouth after implementation of dam: 1,100 m^3/sec
- Effect: 1,000 m^3/sec
- Flood control capacity: 38,800,000 m^3
- Annual average damage reduction: F$ 8,428,000/year

(2) Water Supply

The necessity of domestic water supply was examined in the section 5.3. Based on the examination of water demand, the storage capacity of dam as water resource and the benefit was determined. The benefit of dam is considered as revenue born from water supply charge and was computed with applying the revenue rate of F$ 85.5/year/(m^3/day) adopted from "Nadi - Lautoka Regional Water Supply Master Plan", PWD. The results are as follows.

- Water demand: 20,000 m^3/day
- Storage of dam required: 10,000,000 m^3
- Annual benefit: F$ 1,710,000/year

(3) Specifications of Multi-Purpose Dam and Economic Evaluation

Considering the flood control and domestic water supply, the specifications of dam was determined and the result is shown in Tble-6.40 with its construction cost.

Table-6.40 Specifications and Cost of Dam

Specification	Quantity
1) Dam	N-3 Dam
2) Catchment Area	109 km^2
3) Sediment Storage	49.0×10^6 m^3
Sediment Storage per Unit Area	4,500 $m^3/km^2/year$
Design Sedimentation Year	100 years
4) Capacity of Water Utilization	10.0×10^6 m^3
5) Flood Control Capacity	38.8×10^6 m^3
6) Reservoir Capacity	97.8×10^6 m^3
7) Base Level	EL. 30.0 m
8) Normal Water Level	EL. 77.4 m
9) Surcharge Water Level	EL. 89.7 m
10) Top of the Dam	EL. 94.7 m
11) Height of Dam	64.7 m
12) Volume Content of Dam	2.175×10^6 m^3
Construction Cost	F\$ 217.5×10^6

* Unit Cost = F\$ 100/m^3 (per unit volume content of dam excluding tax)

The economic evaluation of the multi-purpose dam (N-3) was conducted based on the economic benefit and cost. The benefit consists of the annual damage reduction by flood control and revenue by water supply. The cost here does not include the land acquisition cost. As shown in Table-6.41, EIRR of the dam project is "negative" and B/C of 0.29 at the discount rate of 10 % implies that the project is not feasible. Since the economic evaluation of the Master Plan which consists of a diversion channel and a short cut channel shows EIRR of 15.06 and B/C of 1.61, the Master Plan is much more feasible and effective compared to the multi-purpose dam.

Table-6.41 Economic Evaluation of Dam

	Nadi Multi-Purpose Dam
Economic Benefit (10^3 F\$/year)	*10,138
Economic Cost of Project (10^3 F\$)	295,143
Annual Maintenance Cost (10^3 F\$)	223
EIRR (%)	negative
B/C (Ratio) (Discount Rate: 10 %)	0.29
NPV (Discount Rate: 10 %)	-166,747

Note: a) The project life of the Multi-Purpose Dam is assumed to be 80 years.
b) *: Total of F\$ 8,428,000 (benefit of flood control) and F\$ 1,710,000 (benefit of water supply)
c) Project cost does not include the land acquisition cost.

6.9 Case Study of Dredging in Rewa River

Dredging has been conducted in Rewa river, and Table-6.42 shows its work in the last 5 years, from 1992 to 1996.

Table-6.42 Dredging in Rewa River

Year	Dredging Section (distance from river mouth, km)			Total Length (km)	Cost (F$)
	13.0 ~ 15.5	16.5 ~ 17.5	19.0 ~ 20.0		
1992	402,000 m^3	--	--	2.0	1,085,229
1993	256,000 m^3	--	--	2.0	1,090,560
1994	*160,000 m^3	*80,000 m^3	--	2.0	756,171
1995	*142,795 m^3	--	* 90,000 m^3	2.0	1,033,389
1996	292,109 m^3	--	--	2.5	914,682
Total	1,252,904 m^3	80,000 m^3	90,000 m^3	10.5	4,880,031

*: The data is available only for total volume and river section dredged. Therefore, the total volume (240,000 m^3 and 232,795 m^3) was divided by a ratio of section length to obtain the volume of each section for 1994 and 1995.

Source: Drainage and Irrigation, MAFFA

The current flow capacity of river was compared with the flow capacity after dredging to assess the effect of dredging on flood control. Since only volume of dredging and river section are available, the cross section of dredging was assumed to be as follows.

1) 13.0 ~ 15.5 km: 300 m (width) x 1.67 m (depth) x 2,500 m (length) = 1,252,500 m^3
2) 16.5 ~ 17.5 km: 80 m (width) x 1.00 m (depth) x 1,000 m (length) = 800,000 m^3
3) 19.0 ~ 20.0 km: 90 m (width) x 1.00 m (depth) x 1,000 m (length) = 900,000 m^3

Non uniform flow was applied to calculate the flow capacity before and after dredging based on results of cross section survey. Stages at discharge of 5,000 m^3/sec, which flows without overspill from a river channel, were also calculated by non-uniform flow to examine the effect of dredging as shown in Table-6.43.

As shown in Table-6.43, the maximum effect of dredging is an increase in flow capacity of 280 m^3/sec, approximately 4.5 %, and an increase in stage of about 17 cm. This result is based on the assumption that there is no sedimentation after dredging and dredged bed material is dumped outside of river channel. If dredged material was dumped along the river bank within the channel, dredging would be effective only to maintain water course but not effective on increase in flow capacity. As a result, the dredging is not effective in a large scale flood control but effective to maintain the current cross section of river.

Table-6.43 Effect of Dredging in Rewa River

Section (Distance from River Mouth)	Flow Capacity				Stage at 5,000 m^3/sec		
	①	②	③	④	⑤	⑥	⑦
	before dredging	after dredging	②-①	③/①	before dredging	after dredging	⑤-⑥
	m^3/sec	m^3/sec	m^3/sec	%	EL. m	EL. m	m
15.0	5,710	5,850	140	2.5	5.088	5.008	0.080
18.5	6,700	6,980	280	4.2	5.913	5.743	0.170
19.0	5,160	5,380	220	4.3	6.048	5.891	0.157
20.0	5,740	5,970	230	4.0	6.244	6.083	0.161
25.0	5,480	5,620	140	2.6	7.362	7.251	0.111

6.10 Case Study of Flood Mitigation by Afforestation / Reforestation

6.10.1 Case Study Area

The Sigatoka watershed was selected for the case study of flood mitigation by afforestation/reforestation, with the following reasons;

- The most part of the Sigatoka watershed is located in "dry zone", and the forest cover is less than 50 % of the watershed area (section 5.5).
- The difference between the design flood discharge (1/20 probability) and the current flow capacity in the Rewa, Nadi and Ba watershed is so large that non-structural measures can not deal with it. However, the difference in the Sigatoka watershed is as low as 300 m^3/sec that could be solved by non-structural measures.
- As the native villages are distributed along Sigatoka river and Sigatoka town extends up to the river bank, land acquisition for structural measures would be difficult and only river bed excavation (dredging) could be considered as a structural measure, which is not a permanent countermeasure. Therefore, the non-structural measure (afforestation) should be examined as a possible countermeasure.

The afforestation area in the Sigatoka watershed is planned to be 233 km^2. Priority shall be placed on the area around the divide of the Sigatoka-Ba watersheds where urgent countermeasures for soil erosion are required as the decrease of forest has been remarkable recently and the annual rainfall is large.

The discharge to be reduced by afforestation is 300 m^3/sec which is the difference between the design flood discharge (1/20 probability) and the current flow capacity.

6.10.2 Flood Mitigation Effect of Afforestation

The runoff model to assess the effect of afforestation quantitatively was made based on the storage function method used for the runoff analysis in this Study. Effects of forest on flood mitigation are;

a) To reduce a part of flood discharge temporarily and drain it as normal runoff after flood

b) To increase the water retention capacity of watershed

The storage function method discussed in the section 6.3 and the kinematic wave method to evaluate the effect of b) were applied to examine flood mitigation effect of afforestation.

The result of the runoff model application for afforestation is shown in Table-6.44. If the total forest area of 952 km^2 (currently 719 km^2) was achieved by afforestation of 233 km^2 in the Sigatoka watershed, the flood discharge of 270 m^3/sec would be reduced by the effect of the forest. Since 270 m^3/sec is almost same as the difference (300 m^3/sec) between the design flood discharge and present flow capacity, afforestation in the Sigatoka is possible to replace the structural measures.

Table-6.44 Effect of Afforestation in Sigatoka Watershed

Sigatoka Watershed	Flood Discharge (m^3/sec)	Total Discharge (1,000 m^3)
Present Condition	2,900	80,049
After Afforestation	2,630	73,948
Effect by Afforestation	-270	--

Note: Design flood is 20 year return period flood in accordance with the runoff analysis (Section 6.3).

6.10.3 Evaluation

Annual average flood damage reduction by afforestation was estimated with the same method and conditions described in the section 6.4. As a result, the benefit of afforestation which is equivalent to annual average flood damage reduction is F$ 186,000/year.

Economic evaluation was conducted to assess feasibility of afforestation in the Sigatoka watershed assuming that the project life is 100 years. As shown in Table-6.36, EIRR is negative and B/C is equal to 0.1. The benefit here was estimated only in terms of flood damage reduction. However, the benefit from forests should include various aspects, such as prevention of soil erosion, mitigation of sedimentation, conservation of water resources, protection of river turbidity, conservation of diversified animals, plants and coral reef or eco-system, contribution to tourism etc. whose quantitative estimate is difficult. Taking into account the total benefit of afforestation, it would be safely said that the afforestation should be feasible.

6.11 Potential Flood Control Measures for 50 Year Return Period Flood

The flood control plans were examined and formulated for 20 year return period flood. Considering the current flow capacity and assets located in the flood prone areas, the flood damage would be reduced enormously by implementation of structural measures and non structural measures proposed.

However, the characteristics of the target 4 watersheds require a flood control plan for 50 year return period flood. As the development expands and population increases in future, the potential of flood damage will be high resulting in the necessity to formulate the flood control plan for 50 year return period flood. As shown in Figure-6.14, there are still applicable structural measures. Based on those measures and methodologies adopted by the Study Team, the flood control plan for 50 year return period should be examined and formulated when required.

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CHAPTER 7 ENVIRONMENT

7.1 Present Situation

7.1.1 Environmental Management in Fiji

Since 1971, Fiji has presented some environmental policies and objectives, but there have been no national environmental policies which have formed the basis of practical application. In 1990, the Asian Development Bank provided a technical assistance grant for the National Environment Management Project (NEMP) which was commenced in August 1990 and completed in October 1992. The most important output of the NEMP is "The National Environment Strategy, Fiji" (Watling D. & Chape S. 1993) which has set a strategy framework for sustainable development and put forward action plans for environmental legislation, natural and cultural heritage protection and land use. Projects have also been proposed for implementing the National Environment Strategy (NES). Table-7.1 shows the progress state of the major projects proposed in the NES.

Table-7.1 Progress State of the Major Projects Proposed in the NES

Project Name	Planned Duration and Target	State of Progress
Institutional Strengthening of the Department of Environment	5 years from the end of 1993	1 Director, 1 Principal Officer, 1 Senior Officer, 2 Environment Officers, 1 Technical Officers, 1 Secretary, 1 Clerical Officer
National Waste Management - Pollution Control Strategy	Completion by the end of 1993	Workshop held in 1994. Following up waste feasibility study of Suva landfill
Environmental Impact Assessment Legislation	EIA Legislation to be drafted by the end of 1993 and enacted by mid 1994	Draft legislation by Dec. 1, 1996
National Land Use Plan	3 years from mid 1994 (TOR by mid 1993)	Working with MAFFA, Land Use Section and D&I to carry this out. Project proposal to be submitted to the European Union.
Introduction of Soil Conservation Practices	8 years minimum from early 1994	as above
Examination of the Feasibility of a Comprehensive Resource Management Act for Fiji	6 months from early 1994	to be included in the environmental legislation drafted by Dec. 1, 1996

Source: JICA Study Team based on information provided by Nawadra S., DOE
Reference: DOE 1996.12; MAFFA, DOE & NLTB 1996.7; Nawadra S. 1994

The Department of Environment (DOE) was established in 1993 for environmental management at the national level. With a staff as shown in Table-7.1, DOE is engaged in environment awareness, legislation and database. These include: a directed public awareness campaign, upgrading environmental education, environmental impact assessment legislation, examination of the feasibility of a comprehensive resource management act, and development of a national environment database.

In addition, DOE is also engaged in meeting the obligations ratified in treaties and conventions signed by the government. In view of that, DOE looks after the following projects: ozone depleting substance, bio-diversity and Pacific Island Climate Change Assistance Program (PICCAP). DOE works in partnership with WWF on conservation and development. DOE is also involved with SPREP (South Pacific Regional

Environmental Program) initiated projects such as Capacity Building in Environmental Management Project (CBEMP), Persistent Organic Pollutants (POP) and international waters project. DOE is also engaged in promoting waste minimization activities through its Pollution and Waste Minimization Unit.

The environmental legislation was drafted at the end of 1996 under the title of "Fiji's Draft Sustainable Development Bill" (Ministry of Urban Development, Housing and Environment 1996. 11) , which included 19 parts covering all fields of the environment. It will be cited as the "Sustainable Development Act" after approval by the Parliament.

7.1.2 Environmental Impact Assessment (EIA)

In the draft environmental legislation mentioned above, EIA procedures were proposed for all developments in Fiji (see 7.2.1 for details). An Environmental Assessment Unit shall be established within DOE for environmental assessment administration.

For river improvement projects, the Food & Agriculture Organization (FAO) of the United Nations proposed the "Environmental Guidelines for Dredging and River Improvement in Fiji" (Tortell P. et al, 1992) which explained the environmental policy, basic environment items and fundamental methods of assessment such as checklists and matrices.

The Drainage and Irrigation Division (D & I) conducted EIA for a dredging project for Ba River (D & I, 1995a, 1995b, 1996) basically following the FAO environmental guidelines. For other river improvement project, such as the Rewa River dredging project (Hine P. et al, 1992), environmental study was conducted to certain extent on some individual items but not a complete EIA.

An environmental study was conducted by CEE Pty Ltd for Kinoya Treatment Plant and Lauthala Bay (Wallis I et al, 1995) regarding effluent discharge from the sewage treatment plant to Lauthala Bay adjacent to Suva City. Some physical and biological characteristics of Lauthala Bay were studied and a water quality monitoring program was proposed.

Few EIA reports for projects of other fields were collected during this study period. It is expected that EIA will be integrated into the planning process of all the envisaged projects after the enactment of the EIA legislation.

7.1.3 Environmental Sanitation

To understand the present situation of environmental sanitation in the Study Area, the Study Team collected information on water supply, sewage treatment and solid waste management and visited water treatment plants, sewage treatment plants in Suva, Lautoka and Nadi. The general condition is summarized in Table-7.2 based on the data of 1994 (PWD 1994, Nawadra S. 1994). Master Plans have been prepared for water supply and sewerage for the large cities and towns in the Study Area such as Suva, Nausori, Ba, Nadi and Sigatoka.

For drinking water supply, WHO Guidelines for Drinking-water Quality (WHO 1993) are applied. For domestic and industrial effluent discharge, there have been no regulations. But it is reported that effluent from all the public sewerage systems achieves a BOD below 30 ppm and SS below 20 - 40 ppm (PWD 1994). However, Water Quality Management Criteria and Guidelines have been proposed in the newly drafted environmental legislation which classify waters in accordance with their uses and set water quality objectives (DOE 1996. 5).

Table-7.2 Water Supply, Sewerage and Solid Waste Dumps in Viti Levu

(1) Water Supply

Center	Consumers	Capacity (m^3/day)	Population Served
Suva (Tamavua)	Urban/Rural	45,454	271,495
Suva (Waila)	Urban/Rural	45,454	(Suva total)
Korovou	Urban/Rural	340	2,010
R.K.S.	School	650	980
Q.V.S	School	550	520
Colo I Suva	Rural/Forestry	75	730
Naboro	Rural/Prison	1,636	735
Deuba	Rural/Tourism	2,7.17	14,406
Navua	Urban/Rural	909	1,050
Lautoka	Urban	13,090	121,810
Nadi	Urban/Rural	43,000	78,380
Sigatoka	Urban/Rural	5,160	22,890
Ba (including Varavu, Navoli, Koronubu and Veisaru)	Urban/Rural	11,210	42,755
Tavua/Vatukoula	Urban/Rural	5,500	15,825
Rakiraki	Urban/Rural	1,090	8,650
Korotogo	Urban/Tourism	454	(Linked to Sigatoka)
Keiyasi	Rural/Government	440	155

(2) Sewerage Systems

Center	Consumers	Capacity (Equiv. No. of Persons)	Quality of Effluent			No. of Connections	Population Served
			BOD (ppm)	SS (ppm)	F. Coli (No./100ml)		
Kinoya	Urban	80,000	30	20	$3x10^4$	11,000	60,000
Raiwaqa	Urban	15,000	30	20	$3x10^4$	2,136	15,000
Nadi	Urban	10,000	30	20	$3x10^2$	1,800	10,000
Lautoka	Urban	25,000	30	40	$2x10^2$	4,300	29,500
Sigatoka	Urban	4,000	30	40	$2x10^2$	100	700
Nausori	Urban	6,000	30	40	$4x10^2$	160	1,000
Ba	Urban	6,500	30	40	$2x10^2$	(Under Construction)	
Pacific Harbour	Urban	10,000	30	20	$3x10^2$	334	2,000

(3) Solid Waste Dumps in Operation

Dump	Served Population	Dumping Area	Surface Area (ha)	
			Total	In Use
Lami (Suva)	145,000	Mangrove	5	5
Navua	25,000	Mangrove	1	0.2
Sigatoka	2,700	Sand Dunes	1	0.2
Lautoka (Lautoka/Nadi)	106,000	Mangrove	15	3
Ba	8,000	Forest	5	1
Tavua	33,000	Near Hill	2	1
Vaileka	5,000	Mangrove	2	0.2
Korovou	321	Forest		
Nausori	5,000	River Bank	1	1

Source: PWD 1994 Annual Report
Nawadra S. (DOE) Proposed Waste Minimization and Management Strategy for the Republic of Fiji (1994)

7.1.4 Sites of Historical and National Significance

The Study Team visited Fiji Museum and government agencies concerned and collected information on the sites of historical and national significance in the Study Area.

(1) Historical and Archaeological Sites

In Fiji Museum, archaeologists including some international cooperation volunteers from Japan, Australia, etc. are engaged in sorting data and information on historical and archaeological sites and building a computer data base. However, due to lack of systematic investigation in the past and short of financial and manpower source, their work has not yet been at a stage to provide information on the distribution of these sites in the Study Area except some data for Rewa Delta and Sigatoka Valley area where certain archaeological sites have been identified by air-photo interpretation (Parry J. T. 1977 & 1987). Ring-ditch fortifications of various settlement sizes dating back to the 16th century are found to be distributed in the Rewa Delta area. Similar ring-ditch and also hill & ridge fortifications are discovered along two sides of the downstream of Sigatoka River.

One of the most important archaeological sites in the Pacific is located in Sigatoka Sand Dune where a burial ground of more than 100 people dating back nearly 2000 years has been found (Chape S. and Watling D. 1992). Many pottery vessels and discs have been excavated there (Birks L. 1973).

(2) Sites of National Significance

Registration of sites of national significance is one of the projects proposed in the NES (Watling D. and Chape S. 1993). It is in progress under the participation of the Native Land Trust Board (NLTB), Department of Forestry (DOF), DOE and Fiji Museum. A preliminary register of these sites has been compiled in the NES with a list of 140 sites selected on the basis of their biological, ecological, geological, geomorphological, landscape or other natural values, of which 47 are located in Viti Levu including Sigatoka Sand Dunes, Fiji's first National Park.

7.1.5 Natural Environment

(1) Flora and Fauna

Regarding flora and fauna, the present condition is well described in the "Country Report for UNCED - Fiji" (Chape S. and Watling D. 1992) and "Environment: Fiji - the National State of the Environment Report" (Watling D. and Chape S. 1992). 476 indigenous Fijian plants genera have been identified, of which 10 % are endemic. A book published by DOF has illustrated major species of indigenous Fijian trees as a result of the Fiji German Forestry Project (GTZ) (DOF 1996). As for wildlife, there exist several species of bat, birds, reptile etc.

Vuleito palm and barred-wing rail are reported to be endangered plant and wildlife, respectively, in Fiji.

(2) Mangroves

The Study Team visited DOF, Lands Department, South Pacific Commission (SPC), University of the South Pacific (USP) and Fisheries Department and collected information about mangroves in the Study Area.

In Viti Levu, the largest mangrove forests are found in deltaic formations at the mouths of Ba, Rewa and Nadi Rivers. A "Mangrove Management Plan for Fiji" (Watling D. 1987, 1988) estimated the area of mangrove resource in the 3 Deltas to be 3714, 5130 and 3614 ha, respectively. Mangrove forests are very important ecosystem which supply valuable sources of wood, yield large amount of finfish and shellfish, stabilize coastline and act as filter for sediments and nutrients. There are also studies on using mangrove swamps for the removal of nutrients from sewage treatment plant effluent (Banner S. E. T. et al 1996).

(3) Coral Reefs

There are few data available on coral reefs in the marine area related to this Study except certain studies done by USP, South Pacific Applied Geoscience Commission (SOPAC) and some local consultants dealing with coral reefs in other areas.

Generally speaking, coral reefs are only formed in warm salt water where the light can penetrate sufficiently (Knox M. 1990, Squires D. F. 1962). Therefore, estuaries of large rivers are not suitable for coral reefs to grow because of the inflow of less saline river water with possible runoff of sediment resulting in reduction of light penetration. In the Study Area, existing coral reef systems which may be affected by river flow are thought to be Yarawa and Cakau na Sasi Reefs outside Ba River and Ucuisila and Wainita Reefs outside Rewa River. A study on coral reef ecosystem of Yarawa and Cakau na Sasi was conducted by the Fisheries Department for the Ba River Dredging Project (D & I 1996).

The "International Coral Reef Initiative (ICRI) Pacific Region Strategy" stresses the effects of freshwater runoff on coral reefs and calls for actions to develop and implement appropriate watershed management and drainage plans (South Pacific Regional Environment Programme 1996).

7.1.6 Environment Hazards

There are few data available to show the present condition of environmental pollution related to air, soil, noise and vibration. Regarding water quality, data were collected from the National Water Quality Laboratory PWD (Deb S. C. 1995), USP (Anderson E. P. et al 1995, Sulu R. J. 1994, Reddy V. et al 1995) on drinking water, sewage, river water in Ba and Rewa.

The existing data have shown that water pollution is not severe for these rivers except that a low value of dissolved oxygen (DO) has been detected at a section of Ba River where industrial pollution is suspicious.

The Study Team also conducted water quality survey during this Study for the four major Viti Levu Rivers. The results are described in the section 5.4.

7.2 Consideration on Environmental Impact Assessment

7.2.1 Procedures of Environmental Impact Assessment in Fiji

In November 1996, "Fiji's Draft Sustainable Development Bill" (hereafter referred to as the Bill) was published by the Ministry of Urban Development, Housing and Environment. After public review, this document will be finally enacted by the Parliament and cited as the "Sustainable Development Act, 1997". The Bill has established the basic governmental policy on environmental management, especially on administration, environmental impact assessment (EIA), waste management and pollution control, resource management and conservation. It is specified that all proposed developments which are likely to have significant environmental, human health or social impacts, or which have caused, or are likely to cause public concern, shall be subject to the EIA process. The EIA procedure proposed in the Bill can be described schematically in Figure-7.1. This includes mainly the following processes:

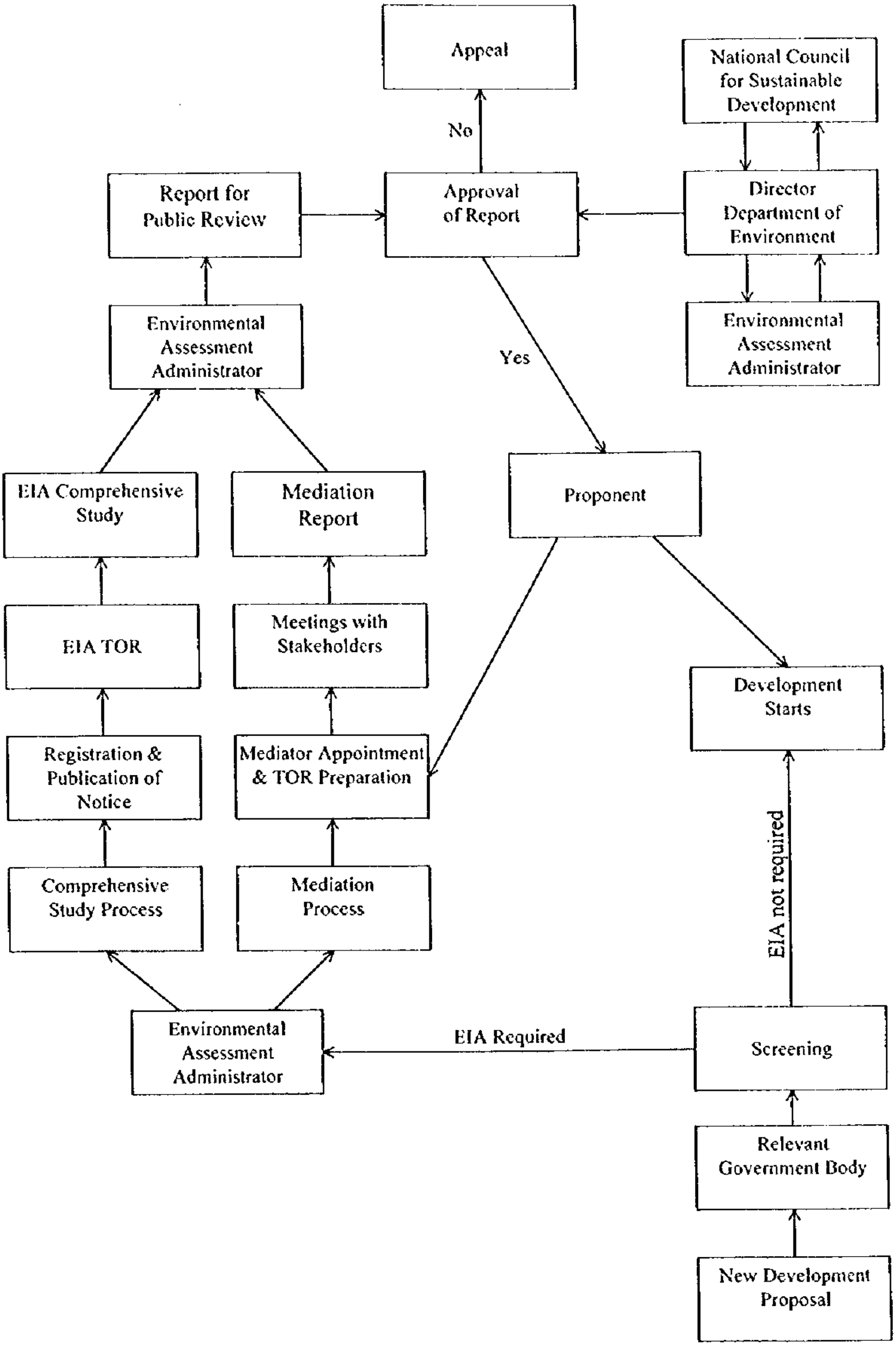
- Screening by the relevant ministry, department or statutory body to determine whether an EIA may be required;
- Registering the matter and publishing a notice for public awareness;
- Comprehensive EIA study;
- Environmental mediation process;
- Review and approval of the EIA and mediation reports.

Table-7.3 shows the required items as the contents of the comprehensive EIA report. The environmental mediation is a process for mediating among affected parties regarding the environmental impacts caused by the development. A mediator shall be appointed by the Environmental Assessment Administrator in consultation with the proponent for undertaking duties and responsibilities for the mediation process. The mediation report shall also be submitted for review and approval.

Table-7.3 Contents of the Comprehensive EIA Report

1	Introduction of the proposal
2	Description of the purpose and scope of the proposed activity or undertaking
3	Description of the proposed action and any alternatives
4	Description of the environmental setting
5	Description of the social and environmental impacts
6	Description of adverse environmental and social impacts that cannot be avoided
7	Environment management plan
8	Environment monitoring and surveillance program
9	List of individuals and organizations consulted
10	Recommendations on the selected project alternative, mitigation measures etc.
11	Other matters specified by Regulation

Source: Fiji's Draft Sustainable Development Bill, 1996. 11.



(Source: Department of Environment)

Figure-7.1 Schematic Representation of Proposed EIA Procedure

7.2.2 EIA Methodologies for This Study

The EIA for this Study shall basically follow the EIA procedures specified in the Bill. At the same time, JICA Environmental Guidelines (JICA, 1992) and other international organizations' environmental guidelines such as that of FAO for dredging and river improvement in Fiji (Tortell, 1992) will be referred.

Environmental assessment for this Study includes an initial environmental examination (IEE) for the Master Plan and an EIA for the priority project. Table-7.4 shows the environmental elements to be considered in the IEE and EIA.

Table-7.4 Environmental Elements to be Examined

(1) Social Environment	(2) Natural Environment	(3) Environment Hazards
- Resettlement - Economic Activity - Traffic & Public Facilities - Community Separation - Archaeological & Cultural Properties - Water Right / Right of Common - Public Health & Sanitation - Solid Wastes - Risk of Disaster	- Topography & Geography - Soil Erosion - Groundwater - Lake & Rivers - Coastal Area - Flora & Fauna - Meteorology - Landscape	- Air Pollution - Water Pollution - Soil Pollution - Noise & Vibration - Ground Subsidence - Offensive Odor - Hazardous Substances*

Source: JICA (1992) Environmental Guidelines V. for River and Sabo Engineering.
* Item suggested by Department of Environment.

The IEE to be conducted in Phase I of the Study for the Master Plan shall use an environmental matrix to examine the possible impacts of each of the project activities envisaged in the Master Plan on each of the environmental elements. Items on which adverse impacts are anticipated will be identified, and the Master Plan will be examined from an environmental viewpoint.

The EIA to be conducted in Phase II of the Study for the priority project shall be conducted on the basis of the IEE results. The environmental items identified by the IEE shall become the objectives of the EIA study. Qualitative and semi-quantitative analysis methods such as hazard identification, vulnerability analysis, risk analysis and benefit analysis will be applied. The EIA will also include recommendation of countermeasures to erase or relieve any of the adverse impacts and environment protection and environmental monitoring plan as has been required in the Bill.

The Study Team have discussed with the Department of Environment and reached consensus that at the feasibility study stage, the EIA process shall mainly follow JICA's environmental guidelines with considerations of the procedures shown in Figure-7.1. The EIA results shall be compiled into the Final Report of this Study and referred in the future when the proposed project is to be implemented.

7.3 Initial Environmental Examination

7.3.1 Objectives

The objectives of Initial Environmental Examination (IEE) are to examine the possible impacts of each of the project activities proposed in the Flood Control Master Plan on the environment, to identify the environmental items on which significant adverse impacts are anticipated and to evaluate the Master Plan from an environmental viewpoint.

The IEE results shall also provide basis for the Environmental Impact Assessment (EIA) to be conducted in the next phase of this study for the priority project.

7.3.2 Guidelines and Methodologies

For the IEE, the following environmental guidelines were applied and/or referred:

1) Fiji's Sustainable Development Bill, Part III-Environmental Impact Assessment (Ministry of Urban Development, Housing and Environment, 1996);
2) Environmental Guidelines V. for River and Sabo Engineering (JICA, 1992);
3) Environmental Guidelines for Dredging and River Improvement in Fiji (FAO, 1992).

The first document will become the Sustainable Development Act - the first legislation of this kind in Fiji after Parliament approval, and the principles given in this document shall govern all the activities or undertakings that are subject to environmental examination. The second document establishes the basic policy of environmental consideration for JICA technical cooperation projects and specifies the environmental elements on which impacts may be caused by the projects. The third document is currently applied in Fiji for carrying out environmental impact assessment for dredging and river improvement projects, and some of the methods proposed were referred in this study.

The IEE was conducted mainly by using an environmental examination matrix which enables a screening of all the impacts on each of the environmental items from each of the project activities proposed in the Master Plan, for an identification of the significant environmental impacts. As shown in Table-7.5, the environmental examination matrix has vertical axis consisting of rows for project activities, and horizontal axis consisting of columns of environmental elements grouped in 3 categories: social environment, natural environment and environment pollution. The project activities include all those proposed in the Master Plan for Rewa, Sigatoka, Nadi and Ba Rivers. For each of the project activities, both the construction phase and operation phase are considered. The environmental elements include 23 items specified in the JICA Environmental Guidelines and 1 additional item - Hazardous Substances suggested by the Department of Environment. Three kinds of symbols are used to identify the extent of the impact according to an examination of the environmental condition at the proposed project sites and a prediction of the environmental quality in the future. Since environmental impacts identification is the main objective of the IEE, qualitative and semi-quantitative examination by analogical method and professional judgment are the main methodologies used at this stage.

Table-7.5 Environmental Examination Matrix

Project Activities			Social Environment									Natural Environment								Environmental Pollution						
Project Phase	River Basin	Project Item	Resettlement	Economic Activity	Traffic & Living Facilities	Community Separation	Archaeological & Cultural Properties	Water Right / Right of Common	Public Health & Sanitation	Solid Waste	Risk of Disaster	Topography & Geography	Soil Erosion	Groundwater	Lake and Rivers	Coastal Area	Flora & Fauna	Meteorology	Landscape	Air Pollution	Water Pollution	Soil Pollution	Noise & Vibration	Ground Subsidence	Offensive Odor	Hazardous Substances
Construction Phase	Rewa	Diversion channel	×	△	×			△		×		△				×	△		△		△		△			
		Dike construction	×	△	△					△											△		△			
	Sigatoka	Dredging					△			×											△		△			
	Nadi	Diversion channel	×	△	×			△		×		△				×			△		△		△			
		Short cut channel		△	△					△											△		△			
	Ba	Dike construction	△	△	△					△											△		△			
Operation Phase	Rewa	Diversion channel						△						△		△	△									
		Dike construction																								
	Sigatoka	Dredging																								
	Nadi	Diversion channel						△						△		△					×					
		Short cut channel																								
	Ba	Dike construction																								

×: Significant Adverse Impact △: Possible Adverse Impact Shade: No Adverse Impact

7.3.3 Impacts Examination

As a result of screening through the environmental examination matrix shown in Table-7.5, significant adverse impact was identified on 4 environmental elements, and possible adverse impact was envisaged on 13 environmental elements from some project activities. The following paragraphs give the rationale.

(1) Social Environment

1) Resettlement, Economic Activities and Traffic & Living Facilities

Table-7.6 summarizes the general condition at the project sites related to resettlement and land acquisition, economic activity, traffic & living facilities. For the diversion channels, with their broad width, e.g. 368 m for the Rewa and 352 m for the Nadi, acquisition of larger areas of land will be required, and within these areas certain number of residential houses will be involved in a resettlement program although the routes have been carefully chosen in order to reduce the resettlement scale as far as possible. For the dike construction in Rewa river, land acquisition area will be much smaller but since the left bank of the river near Nausori Town is densely populated, the number of houses for resettlement will be larger. As for public facilities, 1 elementary school at Vunimono will be affected by the dike construction for Rewa river, and 1 nursery at Saunaka will have to be relocated for the Nadi diversion channel. Land acquisition and resettlement often cause significant social impacts and therefore have to be carefully coped with.

Table-7.6 Condition Related to Resettlement etc. at Project Sites

Project Sites	Land Acquisition Area (ha)			Number of Houses	Public Facility	Traffic Facility
	Free hold	Native	State			
(1) Rewa River						
Diversion channel	0	179.6	101.7	40	None	Cross Kings Road, Vuci Road, Vusuya Road and Mara Road
Dike construction	0	7.5	6.1	53	1 elementary school	May affect Kings Road and Wainibokasi Road
(4) Sigatoka River						
Dredging	None			None	None	None
(3) Nadi River						
Diversion channel	29.3	0	42.8	35	1 nursery	Cross Queens Road, Wailoaloa Road and a tram line
Short cut channel	0	3.3	0	None	None	Cross a small access road
(4) Ba River						
Dike construction	12.6	12	0	4	None	May affect some small access road

Possible impacts on economic activity are envisaged, since farmers with their land lost may have to seek other ways of production and villagers separated apart from their farms or workplaces by the project construction may have to take longer time for commuting. The commercial activities of shops and restaurants near the project sites may also be affected during the construction. Therefore, countermeasures have to be taken regarding such kind of impacts.

During project construction, a large number of vehicles will be employed. This may affect the traffic condition of all the roads in and leading to the project area in addition to the direct hindrance of traffic from the project at several locations such as the places where the diversion channels cross Kings Road at Nausori and Queens Road at Nadi. Preparation of temporary bypass roads and traffic regulation may have to be considered.

2) Archaeological & Cultural Properties

Talbe-7.7 shows the sites of archaeological and cultural properties, national reserves and protected areas in the project area. Their approximate locations are shown in Figure-7.2. These sites have been cited in the National Environment Strategy (Watling D. and Chape S. 1993) as preliminary register of sites of national significance. Although all the proposed project locations are not in the vicinities of these sites, it is still recommendable that consideration should be given on their protection during project implementation, especially in the Rewa and Sigatoka river basins where numbers of unidentified ruins of ancient fortifications are said to be scattered along the valleys.

Table-7.7 Sites of Archaeology, Culture and National Significance in the Project Area

Site Number	Site Name	Significance
Rewa River		
1	Wailotua Limestone	Limestone ecosystem and cave
2	Waidawara	Geological site-river process
3	Wabu Creek	Intact Fiji dakua montane rainforest
4	Wainsabulevu Falls	Water fall
5	Monasabu	Dam, hydro catchment protection, rainforest
6	Monasabu Swamp	Rare montane swamp community
7	Wainibudi R.	Geological site-rock type
8	Naqali	*Neovetchia storckii* palm habitat
9	Sovi Basin	Rainforest, wilderness area, high scenic value
10	Sovi Gorge	River gorge of high scenic value
11	Korobasabasaga Range	High scenic value
Sigatoka River		
12	Sautabu Cave	Limestone cave
13	Naqalimare Limestone	Limestone ecosystem
14	Tatuba Cave	Limestone cave system
15	Rairaimatuku Plateau	Mountain rainforest
16	Korokune	*Veitchia johannis* palm forest
17	Yadua Quarry	Geological site-rock type
18	Makasiko	Geological site-rock type
Nadi River		
19	Nausori Highlands	Dry zone mountain rainforest
20	Vaturu Dam Catchment	Catchment protection; dry zone rainforest
Ba River		
21	Nadarivatu Nat. Res	Dakua dominated rainforest

Source: Watling D. and Chape S. (1993). "The national environment strategy: Fiji". Government of Fiji and IUCN - The World Conservation Union

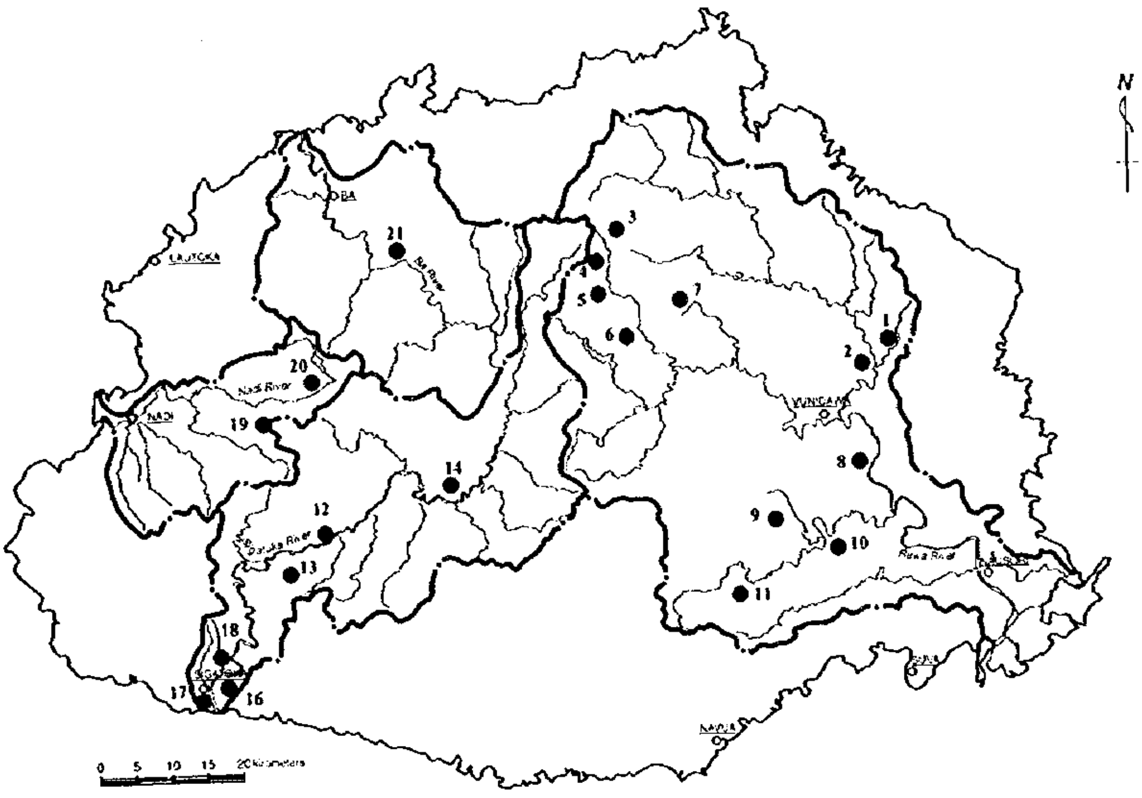


Figure-7.2 Sites of Archaeology, Culture and National Significance in the Project Area

3) Water Right / Right of Common

The implementation of the flood control projects may not involve the problem of water right. However, since rivers are very important for fishery in Fiji and many residents live on fishing from the river or mangrove forest in the estuary area, the impact on the Customary Fishing Rights should be taken into consideration.

The diversion channel planned for Rewa river will finally go through the mangrove forest area toward the sea. In this case, certain area of the mangroves may have to be cleared for the construction, and diverged flood flow may result in a change of the biological condition in the mangrove forests (refer to (2) under natural environment). This will more or less affect fishing in the related area.

There have been cases of compensation for Customary Fishing Rights loss related to developments in mangrove area in Viti Levu.

4) Solid Waste

The construction of the diversion channels and work for river dredging will need a large scale excavation and result in generating large quantity of earth and river sediments. Although most of the earth and sediments will be used at the site for dike construction, transport and disposal of certain amount of construction wastes will still be required.

Therefore, solid waste disposal has to be well planned. Similar problem may also be encountered during the construction of other facilities.

(2) Natural Environment

1) Topography/Geography and Soil Erosion

Among the proposed flood control projects, the constructions of the diversion channels are of great scale and may more or less cause a change in the topography at the project sites. Consideration should be given on this impact.

As described in Chapter 5, soil erosion is a serious problem in the four river basins and a total soil loss of about 30 million ton per year has been estimated. During project construction, prevention of soil erosion should be stressed.

2) Groundwater

Regarding groundwater, possible impacts may be caused by the diversion channels in the operation phase.

Since the diversion channels head to the sea, backward tidal flow through the channels will be unavoidable. For example, Nadi river often experiences a tidal flow backward up to the bridge in Nadi Town. In such a case, sea water may probably intrude into the diversion channel up to more than half of its length. If the bottom of the channel is not well sheeted, sea water may infiltrate into groundwater aquifer and result in groundwater pollution.

The extent of the above mentioned impacts depends on the condition of groundwater utilization in the related area. Further identification of the impacts is necessary at the feasibility study stage.

3) Coastal Area

For the diversion channel in the Rewa, its outlet will be in the mangrove forest area. Clearance of some mangrove trees for channel construction is one reason for the impacts and intrusion of the diverged flood water into the mangrove forest is another. Figure-7.3 shows the mangrove communities at the Rewa diversion channel site where there are mainly the Dogo Forest Alliance (dominant species: Dogo) and Mixed Alliance (dominant species: Dogo and Selala). According to the Mangrove Management Plan for Fiji (Watling, 1987; 1988), the mangroves at the Rewa have been designated as the Traditional Use Zone - mangrove areas which are subject to continual use and are required for the sustainable subsistence needs of rural communities. The traditional use zone is thought to be of secondary importance in mangrove management and conservation in comparison with the Resource Reserve Zone which is the mangrove area identified as being of primary importance specifically in the sustenance of the capture fisheries.

When the diversion channel introduces flood water into the mangrove area, possible impacts may mainly caused by two factors: 1) accumulation of sediments and 2) reduction of salinity. The former may alter the structure of the substrate where mangroves lay their roots in, and the later may affect the nutrient balance necessary for mangroves to grow. However, environment studies have pointed out the problem of drought (lack of fresh water) which makes mangroves stunted in some mangrove forests in Fiji (Raj, U and Seeto, J, 1986). Such a condition is observed in the Rewa Delta area. From this viewpoint, positive impacts are envisaged when the diversion channel brings more fresh water to the mangrove forest, but possible adverse impacts may be caused by sediments accumulation.

For the Rewa diversion channel, because Bau Island lies at the offshore not far from the Namata river mouth and several coral communities are scattered around the island, sediments carried to this area may increase sea water turbidity and affect its scenery. Further study on this impact shall be required before project implementation.

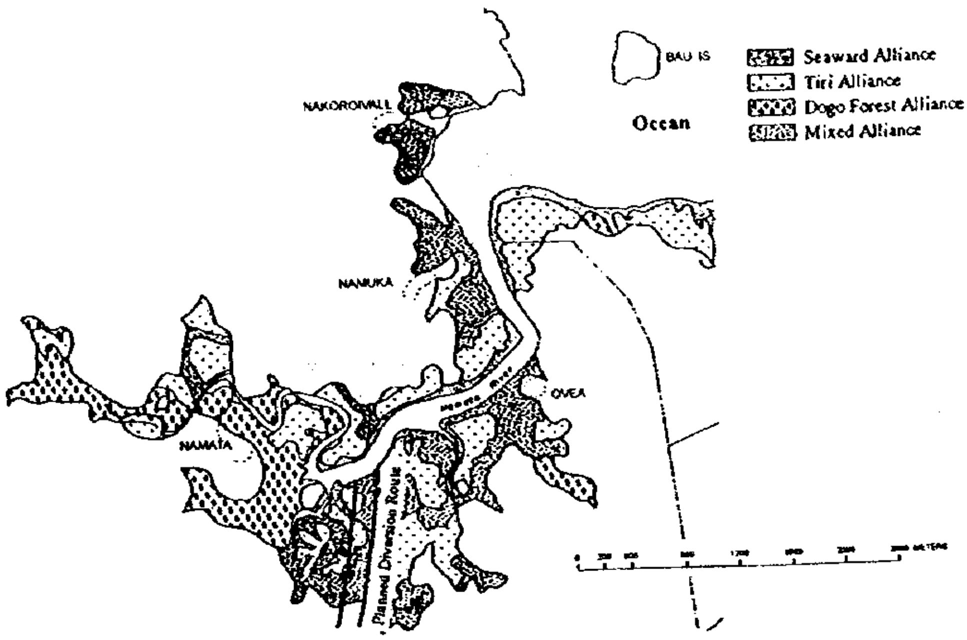


Figure-7.3 Mangrove Communities at the Site of Diversion Channel for Rewa River

As for the Nadi diversion channel, the impacts anticipated are coastal erosion and sediment accumulation since the channel's outlet will be at the sand beach area with shallow water depth and naturally shaped coastal line. This problem shall be investigated at the feasibility study stage. There exist no coral reefs in the vicinity area.

4) Flora & Fauna

Generally speaking, all the proposed projects will not pose impacts on flora and fauna except the Rewa diversion channel with its outlet at the mangrove area. The impacts on the mangroves have already been discussed above.

5) Landscape

The proposed projects at the downstream areas of Rewa and Nadi Rivers may change the landscape, because the diversion channels are large river engineering constructions. However, the impacts may become positive if aesthetic factors are taken into consideration in the engineering design.

(3) Environmental Pollution

1) Water Pollution

For the Nadi diversion channel, water quality in the main river course downstream of the diversion point has to be well considered regarding the distribution of flow to the river course and channel course during the non-flooding period. Although the total population of Nadi Town is not big, most of the residents and commercial activities are concentrated in the town area which lies in between the diversion point and the confluence of the Nawaka creek to the Nadi river. With a comparatively high pollutant load (including that from a sewage treatment plant outlet and many septic tanks and sewers) discharged into this section of stream but no additional flow from any tributary to contribute to pollutant dilution, river water pollution progresses up to the confluence point where the Nawaka creek carries an amount of flow from a large catchment area into the Nadi river. Based on the results of water quality survey conducted by the Study Team (JICA, 1997. 3), COD is estimated to have increased for about 20 % as river flows through this section. The National Water Quality Laboratory, PWD has even noticed nuisance condition in Nadi River at extremely dry period (no recorded data).

If part of the flow is diverged through the diversion channel, water quality in the main river will be more or less deteriorated. Table-7.8 is a rough estimate of the change in river water quality corresponding to flow distribution ratio.

Table-7.8 Estimate of Change in River Water Quality [a]

Case	Flow Distribution Ratio River : Channel	COD Increase [b]
1	2 : 1	about 9.5 %
2	1 : 1	about 19 %
3	1 : 2	about 38 %

Note : (a) Estimate based on water quality survey results;
(b) Results can only be given as percent because of lack of flow rate data.

From a viewpoint of river water quality conservation, it is recommendable that for Nadi river, diversion channel construction should not worsen the sanitary condition of the main stream, and diversion of a large amount of flow during the non-flooding period should be avoided.

For the Rewa diversion channel, because the flow in the main stream is much larger and river water quality is better at present, the above mentioned problem is less serious. However, during project construction, deterioration of river water may also happen, such as an increase in suspended solids from the work site. This is a common problem for all the proposed projects. Therefore, suitable countermeasures have to be taken.

2) Noise & Vibration

Noise and vibration from construction machinery and vehicles may more or less affect the life of residents near a work site and/or transportation road for the project constructions in the populated area. Restriction and regulation of working hour etc. should be considered for mitigating the possible impacts.

(4) Other Environmental Items

Regarding the other environmental elements, no adverse impacts are anticipated from any of the project activities for the following reasons:

- Community Separation: The implementation of any of the proposed projects may not result in this problem.
- Public Health & Sanitation: All the projects may not cause any adverse impact on this item. On the contrary, flood damage mitigation can improve the residents' living condition and benefit public health.
- Risk of Disaster: Flooding is the most serious natural disaster in Fiji, and all the flood control projects can mitigate the risk.
- Lake and Rivers: Impact is positive since the projects are for river improvement.
- Meteorology: The projects are not liable to cause any change in the weather.
- Air Pollution: There may not be any source to cause air pollution from the projects.
- Soil Pollution: No pollution source is anticipated.
- Ground Subsidence: Impossible to be induced by the projects.
- Offensive Odor: No source to emit offensive odor.
- Hazardous Substances: Although hazardous substances management is important from a view point of water resource conservation, the implementation of the projects may not impose adverse impact on this item.

7.3.4 Environmental Impact Assessment for the Priority Project

The IEE is a preliminary examination of all the environmental elements related to the projects proposed in the Flood Control Master Plan. Its output shall provide 1) the basis for the environmental impact assessment (EIA) to be conducted in the next phase of the study for the priority project, and 2) a reference for the EIA for the other projects when they are implemented in the future as is suggested in the Master Plan.

For the priority project, the environmental elements on which significant or possible adverse impacts have been identified by the IEE shall be further studied in accordance with the detailed plan of the project at that stage. The EIA study shall mainly include 1) description of the environmental setting, 2) assessment of environmental impacts, 3) recommendation of mitigation measures, 4) environmental management and monitoring plan and 5) consideration on environmental mediation.

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