Chapter 3 Field Investigations

3.1 Basin Overview (Helicopter Survey)

To see overview and characteristics of the Nadi River basin, the Team performed helicopter survey in dry season. Flight course is shown in Fig. 3 1.

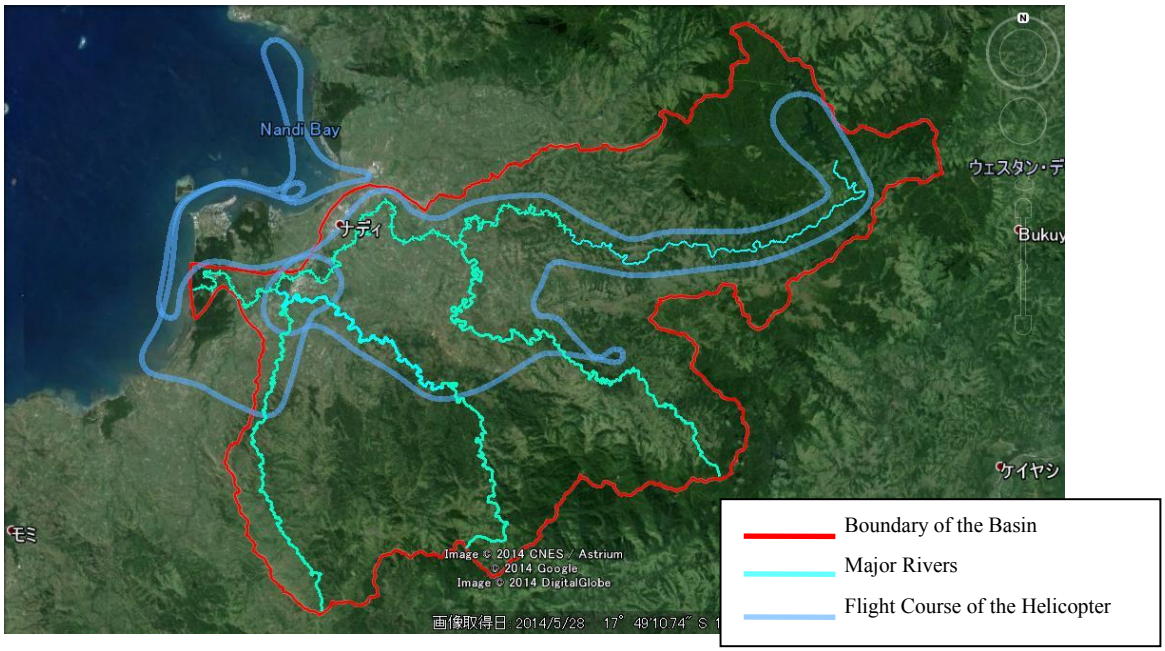

Figure 3-1 Helicopter Survey Flight Route

The mangrove forests stretched out on the river mouth area of the Nadi River. This mangrove forests area was neither designated as National Park nor Conservatory of natural environment. Not at the river mouth area, but nearby coastal area, there was recreational facility under development.

The down-stream region was low-lying flood plain. There were sugar cane farm lands and scattered settlements. The Nadi Town existed on this low-lying area along the Nadi River. Thus the Nadi Town has often suffered from the flood damages. Longitudinal-gradient of the Nadi River in this area is low. The Nadi River is meandering and it shows significant sedimentation. During survey period, the Ministry of Agriculture was dredging along the river channel.

The mid-stream region was low-hilly area. There were grass land and sugar cane farm lands. The up-stream region was hilly area as well. However, the valley was deeper with fewer trees on the slope, and more trees along the valley. The Vaturu Dam area at the uppermost region is covered by natural forest.

Picture 3-1 Photos from Heli-borne Survey

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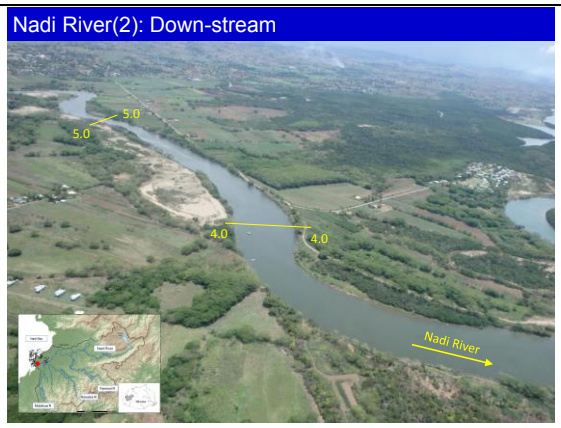
</td><td> 
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<tr><td>River Mouth of the Nadi River</td><td>Down-stream of the Nadi River</td></tr>
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<tr><td>Nadi River near the urban zone</td><td>Mid-stream of Nadi River</td></tr>
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<tr><td>Up-stream of Nadi River</td><td>Uppermost stream of Nadi River Vaturu Dam</td></tr>
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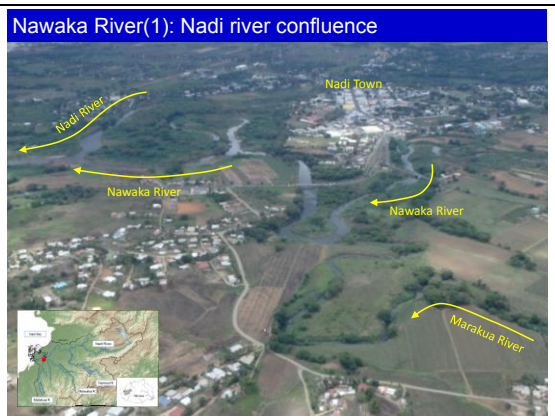
</td><td> 
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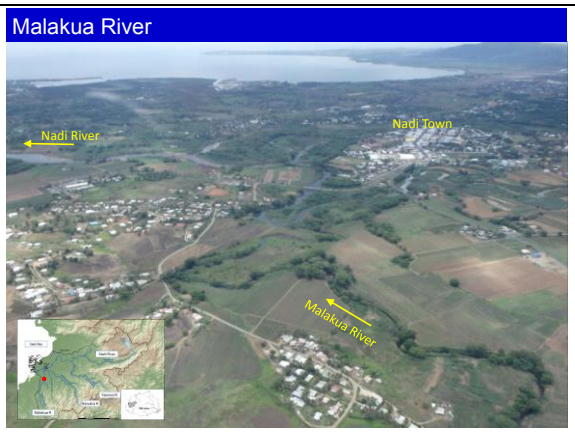
<tr><td>Namosi River</td><td>Nawaka River</td></tr>
<tr><td> 
</td><td></td></tr>
<tr><td>Malakua River</td><td></td></tr>
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3.2 River Survey

3.2.1 River

The following sections shows result of river survey. Reconnaissance sites are shown in Figure 3-2, and photos are shown in Picture 3-2 to Picture 3-4.

(1) Main River (Nadi River)

1) Down-stream (0km - 10km from River Mouth)

The mangrove forest grew thickly on either side of the bank around the river mouth (see Figure 3-2, and P-01). The Nadi River meandered through the river mouth area, and its river width was around sixty (60) to eighty (80) meters. The material of the river-bed consisted of silt and sand gravel. Around three (3) kilo-meters from the river mouth, at the right bank of the Nadi River, there was a branch into the mangrove forest. According to the local habitats, it flows into the Denarau bay.

At seven point five (7.5) kilo-meters from the river mouth, one of the tributary stream Nawaka River joined together with the Nadi River. There was a short cut at upper-stream of this confluence, which became a main river channel. It was formulated by previous flooding events (Source: interview with chief engineer of MOA).

Water gauge was placed on Nadi town bridge (built 1965), around ten (10) kilo-meters from river mouth. The observation was conducted by the Meteorological Office (FMS). The foundations (foundation piles) of the piers were dug out from the ground. It considered as a cause of scouring (see Figure 3-2, and P-02).

The down town area of Nadi Town along the river was crowded by the tourists and local shoppers. On year 2009 and year 2012, most part of the town was inundated (see Figure 3-2, and P-03).

From river mouth to down-stream of the river, there were several sites where bank erosion and falling of the bank were seen. There were no river structures at down-stream. At eight (8) kilo-meters from river mouth, there was a revetment at right bank of the river. Around nine (9) kilo-meters from river mouth at right bank, there were revetment works with gabion and spur dike (see Figure 3-2, and P-04).

2) Mid-stream (10km - 30km from River Mouth)

The width of the mid-stream of the river was around sixty (60) meters. It seemed excavated river channel. The channel bends at several places, and it is thickly covered by trees and vegetation. Dike, revetment, and weir were not found. The sugar cane farms were found in the inside part of the protected lowland.

Around sixteen (16) kilo-meters from the river mouth, Magunia Bridge was placed. The bridge combined tram way and road. The tram way is used for transporting sugar cane (see Figure 3-2, and P-07). The foundation of the bridge was exposed on the riverbed, which was recognized degradation of riverbed (see location map and P-07)

At seventeen (17) kilo-meters from the river mouth, one of the major roads, Back-road Bridge, crossed the river channel.

Around twenty three (23) kilo-meters from the river mouth, from left bank, the tributary stream of the Namosi River joined the Nadi River. Around twenty seven (27) kilo-meters from the river mouth, at the right bank, water gauge was placed (Votualevu Observatory). The geographical characteristics became steeper at upper stream of this area.

There were several sand banks found in river-bed. Since vegetation was limited, sediment transportation and disturbance of the river-bed seems to be high (see Figure 3-2, and P-06).

3) Up-stream (30km from River Mouth - Until Vaturu Dam)

There were submerged bridges at around thirty (30), and thirty five (35) kilo-meters from the river mouth. There was bridge which collapsed by previous flood at Natawa village, fifty five (55) kilo-meters from the river mouth (see Figure 3-2, and P-08).

Up-stream was mountainous area. There was a mountain event, and eroded slopes were observed. Trees could be found only at low altitude area along the river (see Figure 3-2, and P-09).

In river-bed, sedimentation of sand gravel was seen. It appeared sedimentation rate is very high (see Figure 3-2, and P-10).

4) Vaturu Dam

The Vaturu Dam existed around sixty (60) kilo-meters from the river mouth. Its construction was completed thirty two (32) years ago in 1982. The Vaturu Dam is rock-fill dam with total storage volume of twenty seven (27) million cubic meters. The height of the dam is fifty six (56) meters. It is used for the city water supply (see Figure 3-2, and P-20).

At left bank of the Vaturu Dam, there is a multi-perforated selective water-intake. The water withdrawn by the intake is sent to the water treatment plant in the Nagado village. After the water purification works, the water is supplied to the Lautoka and Nadi regions (see Figure 3-2, and P-21).

(2) Tributaries (Namosi River, Nawaka River, Malakua River)

1) Namosi River

At three (3) kilo-meters up-stream of confluence with Nadi River, water gauge (Mulomulo Observatory) was placed. At five (5) kilo-meters up-stream of the confluence, there is Mulomulo Bridge.

In the Mid-stream of Namosi River, there is a retention dam. However, it is already fully filled with trapped sand. In upper-stream there is another construction of retention dam (see Figure 3-2, and P-11,

P-12). Detail of the retention dam is described in 3.2.2 River Structure.

The Namosi River basin is mostly mountainous. Similar to up-stream of Nadi River, a burning mountain was observed.

The river-bed of the Namosi River mainly consisted of medium gravel and boulder. Smaller sand gravel also widely existed. Therefore, it assumed sedimentation rate is low in this area (see Figure 3-2, and P-13).

2) Nawaka River

At one (1) kilo-meters from the confluence (Navu Bridge), and two (2) kilo-meters from the confluence (Qeleloa Bridge) there were bridges. The Navu bridge combined tram way and road.

At five (5) kilo-meters from confluence, and ten (10) kilo-meters from confluence, there were retention dams. The apron of the retention dam at upper stream was left collapsed. This collapse was caused by the flood of 2012 (see Figure 3-2, and P-14, P-15).

At area of eight (8) kilo-meters to nine (9) kilo-meters from the confluence, there was gravel mining (see Figure 3-2, and P-16).

At down-stream of Nawaka River, there were Nawaka Village settlements along the river bank. At mid-stream, there were sugar cane farms. At upper-stream, pine tree forest was observed (see Figure 3-2, and P-17).

At mid-stream, sedimentation of sand gravel was widely observed on the river-bed. Up-stream was rapid stream. There was craggy area and boulders were widely observed on the river-bed.

At right bank, five (5) kilo-meters from the confluence, there was the Nawaka Lake, which is natural lake. Fishing and aqua farming of shrimps were observed.

3) Malakua River

Malakua River joins the Nawaka River at one-point-four (1.4) kilo-meters from confluence of Malakua and Nandi rivers.

At Vunayasi Village, two-point-two (2.2) kilo-meters from the confluence, the JICA Expert team conducted an interview survey. The inhabitants experienced flood with the height of up to space under the floor (see Figure 3-2, and P-18).

The sugar cane farms were widely found in mid-stream and up-stream of Malakua River.

Texture grades of sand to medium gravel were widely found on the river-bed of mid-stream and up-stream of Malakua River (see Figure 3-2, and P-19).

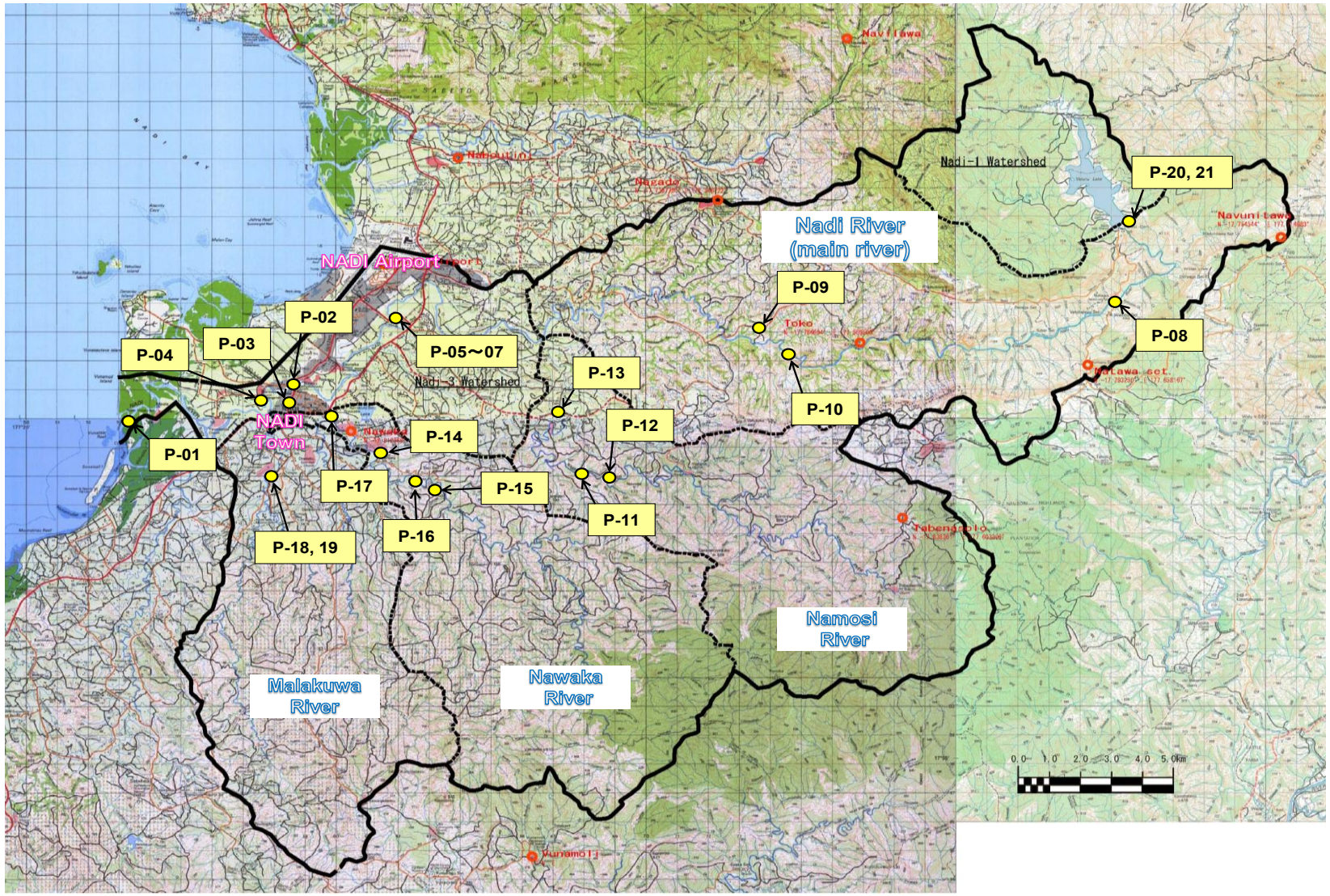


Figure 3-2 Major Reconnaissance Sites (River Area)

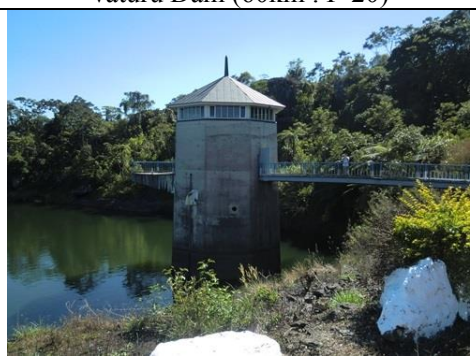
Picture 3-2 Reconnaissance Result (River Area) 1/3

	
Mangrove Forest in the River Mouth Area (P-01)	Main Stem 9km at Right Bank Groyne (P-04)
	
Nadi Town Bridge (10km: P-02)	Magunia Bridge (17km :P-05)
	
Down Stream from Nadi Town Bridge (10km :P-02)	Down Stream from Magnia Bridge (17km:P-06)
	
Down Town Crowded by the Tourist (P-03)	Exposed Foundation at Magnia Bridge (17km :P-07)

Picture 3-3 Reconnaissance Result (River Area) 2/3

	
Nadi River Up-stream Abandon Bridge (P-08)	Retention Dam Filled by Sand at Namosi River (P-11)
	
Up-stream of Nadi River Mountain-Burning Events (P-09)	Namosi River Retention Dam Under Construction (P-12)
	
Up-stream of Nadi River Mountain-Burning Events (P-09)	Sedimentation on River-bed of Namosi River Up-stream (P-013)
	
River-bed of Nadi River up-stream (P-10)	Retention Dam at Nawaka River (5km :P-14)

Picture 3-4 Reconnaissance Result (River Area) 3/3

	
Retention Dam at Nawaka River (10km :P-15)	River-bed of Malakuwa River mid-stream (P-19)
	
Gravel Mining at Nawaka River (8km :P-16)	Vaturu Dam (60km : P-20)
	
Sugar Cane Farm Lands at Nawaka River down-stream (P-17)	Vaturu Dam Water Intake Facility (P-21) Withdrawn water is sent to treatment Plant
	
Settlements (Bunayasi Village) Along the Malakuwa River (P-18) The water reached below the floor level (2012 Flood)	

3.2.2 River Structure

River structure developments in Nadi River Basin were not really systematic at all. Until now, the Ministry of Agriculture has developed revetment, groyne, small retention dam, and tide prevention gate for drainage channel for protecting local settlements and farm lands. At upper-most area of this basin, Vaturu Dam has been built for water supply.

Figure 3-3 shows position of the river structures. Photos of each structure were shown below. In addition, result of the survey for revetment and groyne, retention dam, and Vaturu Dam shall be complied as inventory of river structures in Appendix-2.

Picture 3-5 Revetment and Spur Dike

	
Revetment as of 2009. After completion of the Construction (Source: LWRM)	Close-up Picture of Revetment (as of 2014)
	
Groyne (as of 2014)	Close-up Picture of Groyne (as of 2014)

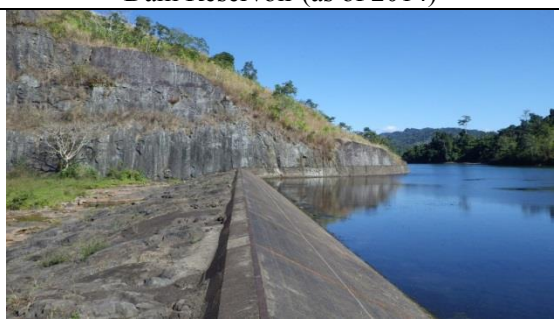
Picture 3-6 Retention Dam

	
Vatutu Dam in Nawaka River (as of 2014)	Taci Dam in Nawaka River (As of 2014)
	
Namulomulo Dam in Namosi River (As of 2014)	Namosi II Dam Under Construction in Namosi River (as of 2014)

Picture 3-7 Tide Prevention Gate

	
Tide Prevention Gate in Service (As of 2014)	Tide Prevention Gate Under Construction (As of 2015)

Picture 3-8 Vaturu Dam

	
Dam Body of Vaturu Dam (as of 2014)	Dam Reservoir (as of 2014)
	
Intake Tower (as of 2014)	Free Overflow Spillway (as of 2014)

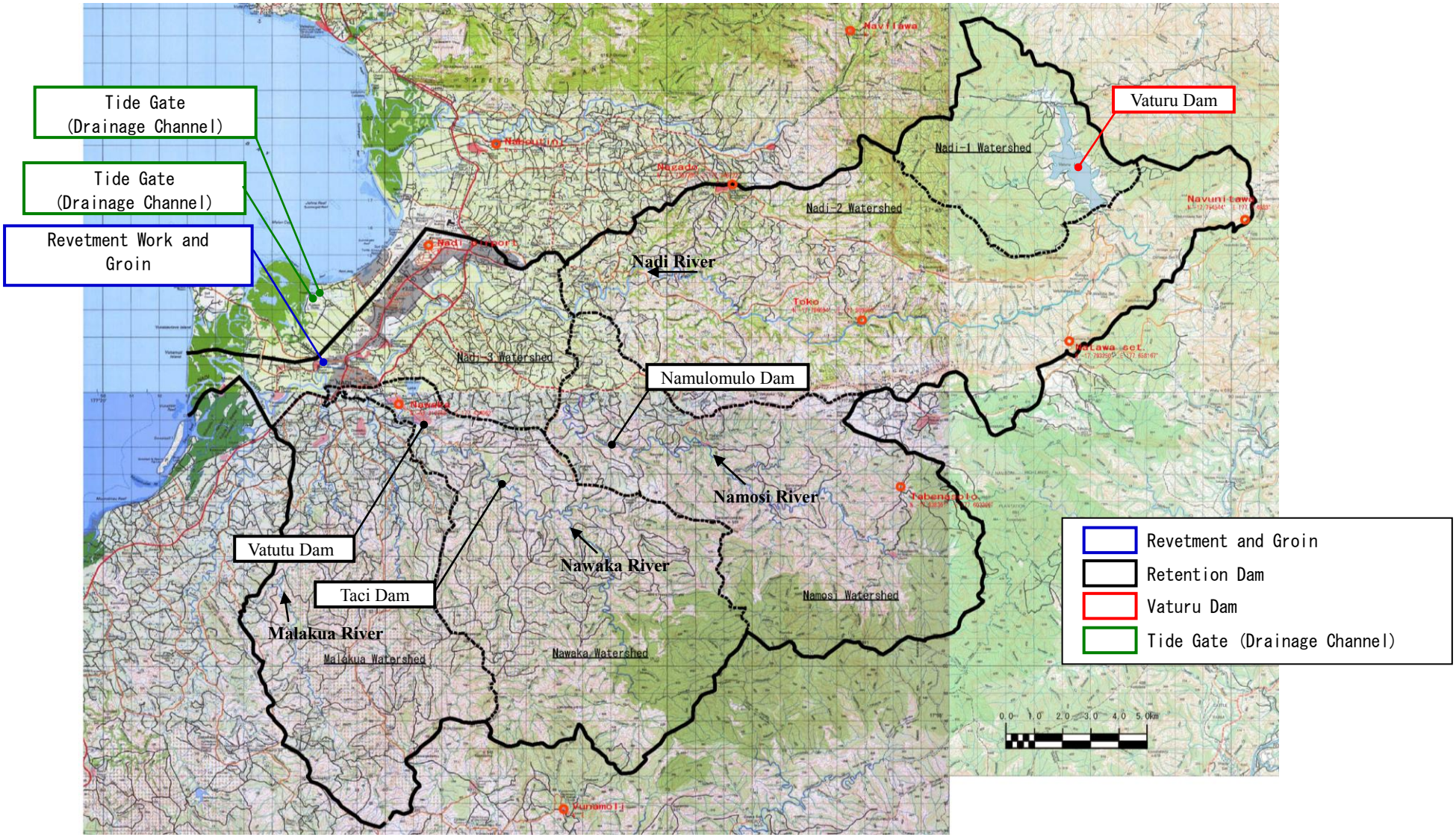


Figure 3-3 Position of River Structure

3.3 Coastal Area Survey

3.3.1 Coast

The following shows result of the coastal area survey. Reconnaissance sites are shown in Figure 3-4, and photos are shown in Pictures.

(1) Nadi Bay (Northern Area)

At Northern side of Nadi bay, Vuda Port exists. Marina and petroleum unloading facility (berthing dolphin) were in use (see Figure 3-4, and PS-01, 02). Vuda Port is facing ocean, and it has a shelving bottom at its sea area.

The sea-coast in front of Veiseisei Village had a shoaling beach of rock reef. The sand found in the beach of Veiseisei Village consists of dark colored fine sand with relatively bigger grain diameter around zero point three (0.3) to zero point six (0.6) millimeters. Since it was not the season for sea-bathing, there were no sea bathers or anglers (see Figure 3-4, and PS-03).

Next to Veiseisei Village area, the coastal beach of Lomolomo area which also had shoaling beach and seashore area was thickly covered by vegetation along the shoreline. The cliffs, with height of around fifty (50) centimeters, were found in part of this beach. The sand found in Lomolomo area beach was dark colored fine sand with grain diameter of around zero point one (0.1) to zero point three (0.3) millimeters.

The sand found in the beach at southern part of Vuda River's mouth was whity coarse sand. Its grain diameter was relatively bigger, around zero point three (0.3) to one (1.0) millimeters (see Figure 3-4, and PS-04, 05).

(2) Nadi Bay (Southern Area)

At Naisoso area, a housing developer brought in white sand to nourish the beach (see Figure 3-4, and PS-06). The Naisoso area (Naisoso island resort) was in its second stage of expansion project. There was pleasure boat harbor in the inner bay and stone bank protection was placed along the shoreline until the port entrance. The sea area in front of Nadi International Airport's runway had poles of course lights and power poles. The accretion of the sand has become serious, that it is unnavigable even for the small size vessels during low tide.

The beach near-by the Nadi Airport consists of dark colored fine sand with grain diameter of around zero point one (0.1) to zero point three (0.3) millimeters. It was not sea-bathing season, and only few people (four (4) to five (5)) were found (As of August 2014).

By comparing the January 2015 survey results with that of August 2014, it was found that the distribution of dark fine sand turned into whity coarse sand at some part of the beach. The cause was assumed to be the influences of nourishing the artificial beach for the ongoing development in Nasoso area and reclamation at the Fantasy area. Geological characteristics of this area were clearly separated by sea level. At above sea level, it was sandy soil and gradient was relatively steep. At below sea level, it was silty clay with shelving gradient.

The coastal beach at Wailoaloa area is similar to that of Lomolomo. The shoaling beach shoreline area was thickly covered by vegetation. From the north end to the south end of this coastal beach, there were Nadi International Airport, Hydro airplane base, hotel, golf course, Rock jetty, Fantasy Island, flood gate, and mangrove forests. Since to the Rock Jetty has corridor, there were many people who rest under the trees.

The development in Fantasy area was in progress. Reclamation area was surrounded by the stone bank protection and the dredged soil from Denarau Port mouth and Nadi River was used in the reclamation (see Figure 3-4, and PS-07, 08). The developer transported white sand for nourishment of beach in Naisoso (see Figure 3-4, and PS-06).

(3) Denarau Area

In Denarau area, there are many resort hotels. Denarau Port is the base of island transport; therefore the port's ship route was maintained by dredging.

Hotels were surrounded by the stone bank to protect their land from erosion. The bank protection in front of Hotel Sheraton was made of concrete and stone masonry (see Figure 3-4, and PS-15, 16). In addition, according to Denarau area administrator, Denarau area beach is nourished by white sand.

Stone-masonry bank protection can be found in beach with no reef and reclaimed area that was originally mangrove forest. In the afternoon, steady sea breeze increased the surf which hit hard. Therefore, stone bank protection is necessary as a coastal structure in this area.

From entrance of Denarau Area, branch of Nadi River could be reached. The depth of channel was around one (1) meter. At the left bank of channel, there were cottages. At the right bank there were mangrove forests. Since there was a slash in the mangrove forests, the JICA Expert team could not reach to the Nadi River (see Figure 3-4, and PS-09). Steel sheet piles are utilized for the revetment of the tributary near the Denarau Area's entrance.

(4) Sonaisali Area

Sonaisali Island is the island formulated on Muanatirau Reef. The Serua Reef in the northern part of Sonaisali Island was occluded by sedimentation and the area is covered by dense mangrove forest.

The sea area between Muanatirau Reef and main land has a shoaling beach with a depth of approximately one point five (1.5) meters and there is a fishing industry. In addition, fish boat was parked in the boat yard on the shore and trolley is used to bring it back to the beach (see Figure 3-4, and PS-19).

The area facing the open ocean in Sonaisali Island (Resort Fiji) was protected from ocean waves by concrete and stone bank. However, there were many fallen trees which could be the result of tidal waves in the northern beach area.

The Sonaisali Island sand consisted of dark colored fine sand with grain diameter of around zero point one (0.1) to zero point three (0.3) millimeter.

At the southern edge of the Sonaisali Island, Mulonitubei Reef stretched perpendicular to the shore line. However from the southern edge, the Muanatirau Reef lays parallel to the shoreline. It was laid to prevent entry of ocean wave. The stone bank protections were provided in the area the sugar cane transportation tram approaches shoreline. The bank is meant for protecting the railroad from erosion.

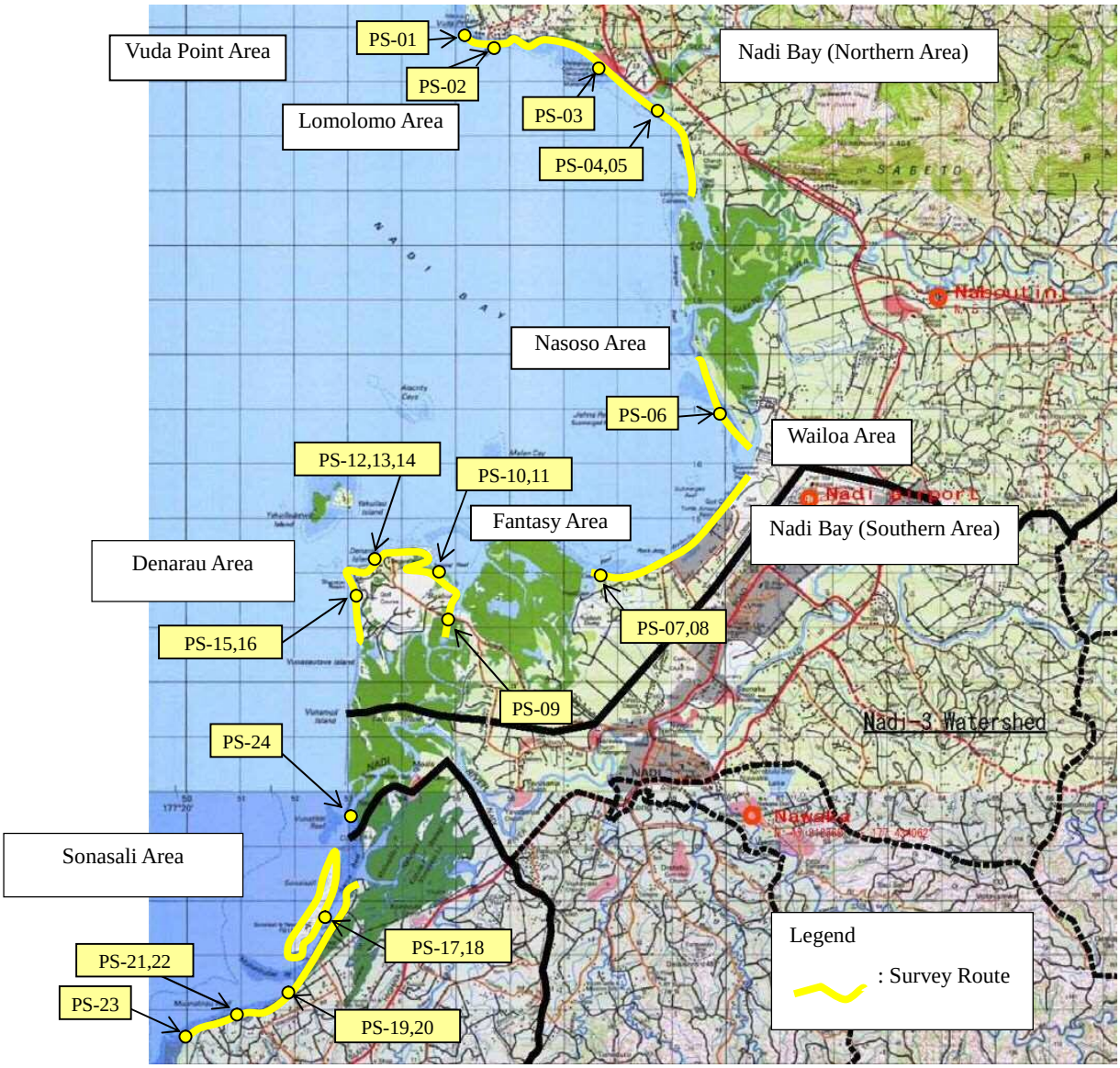


Figure 3-4 Major Survey Area (Coastal Area)

Picture 3-9 Reconnaissance Result (Coastal Area) 1/3

	
Nadi Bay: Vuda Port Entrance of Marina (PS-01)	Nadi Bay: Vuda Port Sea Shore Outside of Petroleum Station (PS-02)
	
Nadi Bay: Veiseisei (PS-03)	Nadi Bay: Lomolomo View of North (PS-04)
	
Nadi Bay : View from the South (PS-05)	Nadi Bay: Naisoso Northern Side of Administration Building (PS-06)
	
Nadi Bay: North Side of Fantasy (PS-07)	Nadi Bay: South Side of Fantasy (PS-08)

Picture 3-10 Reconnaissance Result (Coastal Area) 2/3

	
Deranau Area: Tributary Stream of Nadi River (PS-09)	Deranau Area: Port During Low Tide (PS-10)
	
Deranau Area: Sand Bank at Left Side of the Bay Entrance (PS-11)	Deranau Area: Beach Near by the Regent Hotel (PS-12)
	
Deranau Area: Beach Near by the Regent Hotel (PS-13)	Deranau Area: Sea Weeds Drift Down on the Beach (PS-14)
	
Deranau Area: Beach Near by the Sheraton Hotel (PS-15)	Deranau Area: Beach Near by the Sheraton Hotel (PS-16)

Picture 3-11 Reconnaissance Result (Coastal Area) 3/3

	
Sonaisali Island: Landing Bridge at Inner Bay (PS-17)	Sonaisali Island: Cottage Under Construction (PS-18)
	
Muanatirau Reef: Resort Area Facing Ocean (PS-19)	Muanatirau Reef: North Side of Resort Area Facing the Ocean (PS-20)
	
Muanatirau Reef: North Side of Inner Beach (Tidal Wetland) (PS-21)	Muanatirau Reef: South Side of Inner Beach (PS-22)
	
Muanatirau Reef: View of North at South Edge (PS-23)	Muanatirau Reef: Nadi River Mouth (PS-24)

3.3.2 Coastal Structure

(1) Costal Revetment

In the Nadi River basin, coastal revetments were in place for mainly protecting the marina, settlement, reclaimed land and sugar cane transportation tram's railroad. Stone bank revetment was mainly used for protection. Natural coast were remain if it is not protected. At Denarau Area and Nasoso Area, beaches in front of the hotels nourishment were carried out by putting white sand.

Positions of the coastal revetments are shown in Figure 3-5

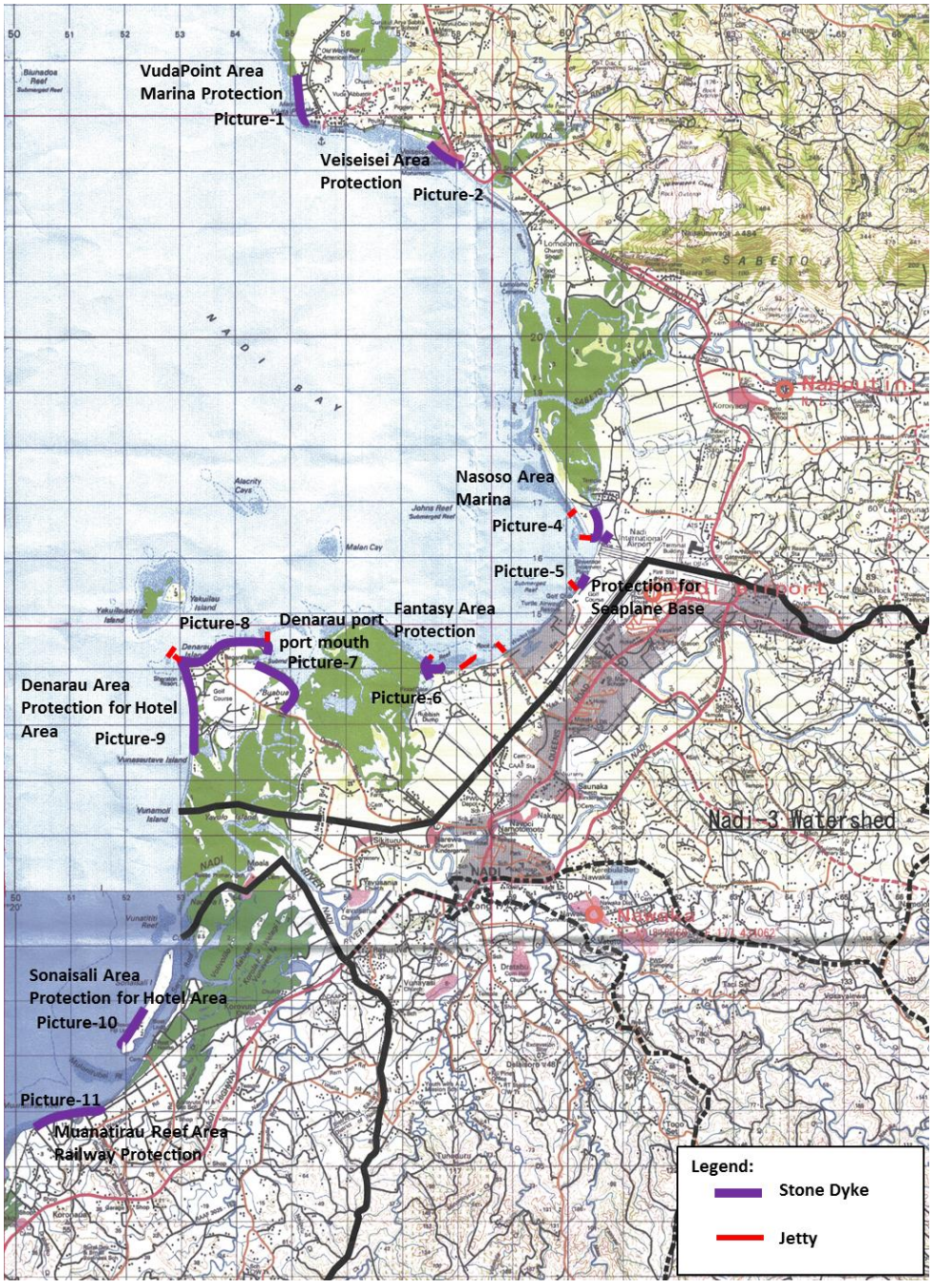


Figure 3-5 Positions of Coastal Revetments

The Vuda Point Area, at northern part of Nadi Bay, is shallow water area facing the ocean. Many pleasure boats were mooring at Vuda Port protected by the stone bank protection from ocean wave. There is a boat slip for landing and loading petroleum. The breakwater is placed at the entrance of boat slip and the boat slip is protected by stone bank.

The sea area in front of the settlements in the Veiseisei area is rock reef. The settlements and road in this area is protected by the stone bank.

The inner bay in the Nasoso Area had berth for pleasure boats. It is protected by stone bank until entrance of the berth.

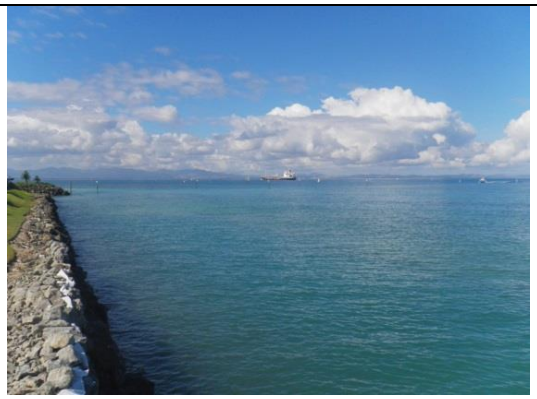
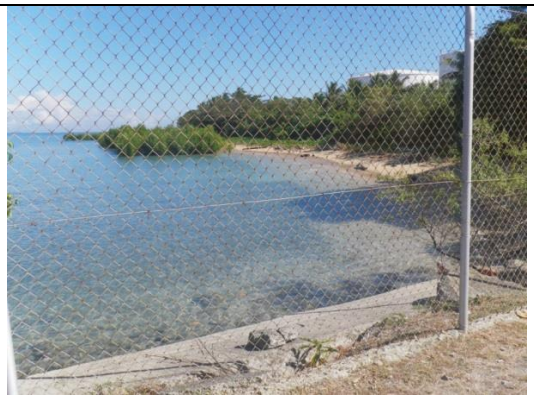
The sea area in front of the sand beach in Wailoaloa is shallow water area. The lands along the shoreline were covered by vegetation.

At the Fantasy area, land reclamation was going on. The reclaimed area was surrounded by stone bank protection.

The hotel resorts were clustering around Denarau area. In order to protect the compounds from erosion, stone bank protection has been in place. At the right bank of the up-stream area, development of revetment of a branch of Nadi River was also in progress. Steel sheet pile was adopted for the revetment area near by the Denarau Area entrance.

In Sonaisali Area, the front of the hotel facing the ocean had stone bank protection. It is meant to protect the reclaimed land from erosion by ocean wave. At nearby Mulonitubei Reef, southern part of Sonaisali Area, stone bank protections win the area the sugar cane transportation tram is built. It is meant for protecting the railroad from erosion.

Picture 3-12 Photos of Coastal Revetment

	
Picture-1(1)：Shore Protection of Vuda Pt. to Port Mouth	Picture-1(2)：Shore protection of Vuda Pt. to the hotel nearby
	
Picture-2(1): Vuda Pt. petroleum tank	Picture-2(2): Wave breaker for oil loader pier
	
Picture-3(1): Shore protection, north side of Veiseisei Village	Picture-3(2): Shore protection, south side of Veiseisei Village

	
Picture-4(1): Beach at north side of Veiseisei Village	Picture-4(2): Beach at south side of Veiseisei Village
	
Picture-4(3): Beach scarp at south side of Veiseisei Village	Picture-5(1): Shore protection in Naisoso inner bay
	
Picture-5(2): Mangroves in Naisoso inner bay	Picture-5(3): Shore protection in front of runway

	
Picture-6(1): Flood gate, next to the Fantasy Island	Picture-6(2): Ships for reclamation in Fantasy Island
	
Picture-7(1): Nadi River branch in Denarau Port	Picture-7(2): Nadi River branch in Denarau Port
	
Picture-8(1): Hilton Hotel in Denarau Island	Picture-8(2): Hilton Hotel in Denarau Island
	
Picture-9(1): Sheraton Hotel in Denarau Island	Picture-9(2): Sheraton Hotel in Denarau Island

	
Picture-10(1): Northern area of Sonaisali (Ocean side)	Picture-10(2): Southern area of Sonaisali (Ocean side)
	
Picture-11(1): Muanatirau Reef	Picture-11(2): Shore protection for railway

(2) Jetty

Drifting sand (sediment transportation at coastal area) has several patterns, one is drifting towards perpendicular to the shoreline and the other is drifting parallel to the shoreline. If jetty is in place to block this parallel drift, it will cause sedimentation on front side of the jetty and cause scouring on back side of the jetty. Those geomorphic processes are well known side effects. Therefore, the JICA Expert Team carried out a site survey for collecting the dimensions of jetty and difference of sediment level.

In Nadi River Basin, many jetties are in place along Nadi Bay's shoreline. Most of the jetties are made of stone masonry structure. Boulders are mostly used concrete waste for the structure. The crown of the jetties was relatively low. During high tide, several jetties (two of them) were submerged.

In Denarau Area, continuous coastal revetment was in place. In addition, jetties were in place to reduce ocean wave load.

The following figure (Figure 3-6) shows jetties found in the site survey. The result of the survey is also compiled as inventory of coastal structures in Appendix-3.

Figure 3-6 Position of Jetties

Picture 3-13 Photos of Jetties

Picture1-1 Malan Cay,the situation under low tide
Photo taken in 24 Jan, 2015

Picture1-2 Malan Cay, the situation under high tide
Photo taken in 24 Jan, 2015

Picture2-1 Stone Jetty at Denarau Sheraton

Picture2-2 Stone Jetty at Denarau Sheraton

Picture3-1 Stone Jetty at Denarau Peninsula

Picture3-2 Stone Jetty at Denarau Peninsula

Picture4-1 F1 Stone Jetty at Fantasy Island

Picture4-2 F2 Stone Jetty at Fantasy Island
Photo taken in 06 Feb, 2015

Picture5-1 Stone Jetty

Picture5-2 Stone Jetty

Picture 6-1 Left Side of Jetty at TURTLE Airways

Picture 6-2 Right Side of Jetty at TURTLE Airways

Picture7-1 Left Side of Jetty at NAISOSO

Picture7-2 Left Side of Jetty at NAISOSO

Photo taken in 30 Jan, 2105

Picture8-1 Left Side of Jetty at NAISOSO

Picture8-2 Right Side of Jetty at NAISOSO

Chapter 4 Summary of Present Conditions and Issues of Flood Control and Basin Management in Nadi River

4.1 Present Conditions and issues of Flood control and Basin Management

In this section, present conditions and issues of flood control and basin management, legal system and policy, and institution and structure in Fiji focusing Nadi River Basin is summarized in order to develop Flood Control Master Plan.

In addition, details of flood control measures in Nadi River Basin are described in section "4.2 Summary of Present Conditions and Issues of Flood control measures in Nadi River Basin".

4.1.1 Present Conditions and Issues of flood control and Basin Management

(1) Flood Control

1) Present Conditions of Flood Control

Prevention of flood and its damage by comprehensive utilization of flood control facilities, such as dam, weir, retarding basin and river dike is one of the important themes of basin management.

Present conditions of the management of flood control in the Nadi River Basin, such as development of flood control plan, design and construction of flood control facilities, and its operation and maintenance are specified below.

a) Present Conditions of Flood Control Planning

Systematical flood control plan considering the whole river basin and flood control facilities have not been established in the Nadi River Basin, and only local protection work to protect the village and agricultural land and small-scale retention dam have been established by MOA.

Moreover, there is neither guideline nor standards for development of flood control in Fiji, and technical method is not established. Therefore, each organization refers to the standards used in Australia, New Zealand and Western countries, and development of plan is based on certain engineers', (such as Principal Engineer); knowledge and experience even in the main C/P organization, River Engineering Section of LWRM.

b) Present Conditions of Design of Flood Control Facilities

The same as above, Fiji does not have its own design standards / criteria and guideline for flood control facilities. Therefore, River Engineering Section of LWRM refers to the technical criteria and the technical standards for Australia, New Zealand and Western countries for designing of retention dam and culvert, and the engineers design by themselves based on the knowledge and experience of certain engineers. Since not all of the technical criteria are collected and kept in their section, the engineers refer to the internet as needed and do not keep the design documents.

c) Present Conditions of Construction of Flood Control Facilities

Similar to the design criteria, Fiji does not have its own guidelines and technical criteria for construction in. Therefore, design and planning of construction works are based on the knowledge and experience of certain engineers.

Construction of river structures is outsourced to private construction companies and construction supervision is implemented by engineers in the River Engineering Section of LWRM. Bidding for construction of flood control facilities of LWRM, such as retention dam, is conducted and private construction companies hand in their bidding documents to the Government Tender Board. Cost and the technical capability are evaluated and the best qualified company is selected as a contractor, and then the result is approved by the director of LWRM. According to the principal engineer of LWRM, private construction companies in Fiji are accumulating and improving their know-how and technology.

Construction situation of retention dam is shown in Picture 4-1.

Picture 4-1 Construction situation of retention dam (as of August 2014)

	
Construction Situation (1)	Construction Situation (2)
	
Concrete placement (1)	Concrete placement (2)
	
Earth-fill cofferdam	After concrete placement
	
Situation of formwork and bar arrangement	Site survey (At the back of the picture)
	
Cutting slope	Construction materials (Boulder)

d) Present Conditions of Operation and Maintenance of Flood Control Facilities

Flood control facilities (river structures) in the Nadi River Basin are described in detail in "3.2.2 River structure" and Appendix-2. The River Engineering Section in LWRM has not conducted periodical inspection and maintenance work of the river structures and damage investigation including cost estimation for rehabilitation work is implemented only when a large-scale flood occurs. The budget for rehabilitation work needs to be allocated from the regular budget since there is no extraordinary budget, and this is making the rehabilitation work of the damaged river structures difficult. Furthermore, the reports of the damage investigation are not kept in the River Engineering Section.

The damage situation of the river structures in the March 2012 flood is shown in Picture 4-2. A part of plans regarding the rehabilitation situation of Namulomulo Dam in the Namosi River is kept and is shown in Appendix-2.

Picture 4-2 Damage situation of river structures in the Nadi River Basin

	
Vatutu Dam in the Nawaka River after the March 2012 flood	Vatutu Dam in the Nawaka River after the rehabilitation
	
Taci Dam in the Nawaka River after the flood	Taci Dam in the Nawaka River after the rehabilitation
	
Namulomuro Dam in the Namosi River after the March 2012 flood	Namulomuro Dam in the Namosi River after the rehabilitation
	
Wreckage of the damaged bridge in the Nadi River at Natawa Village (as of 2014, year of damage is unknown)	Wreckage of the damaged Qeleloa Bridge in the Nawaka River (as of 2014, year of damage is unknown)

Source: LWRM

2) Issues of Flood Control

Issues of Flood Control in Nadi River Basin are described as below.

a) Issues of Flood Control Planning

- ✓ Systematical flood control plan considering whole river basin and flood control facilities have not been established yet. Therefore, comprehensive flood control plan using both structural measures, such as dam, retarding basin, river improvement and diversion channel, and non-structural measures is required.
- ✓ Although the diversion channel and river channel short cut were proposed in the JICA Study in 1998 in the Nadi River, revision of flood control measures including the review of design scale is an urgent need, because the large-scale floods both in the Nadi River and in the tributaries occurred since 1998.
- ✓ Own design standards / criteria and guideline of flood control planning are not established in Fiji. It is required to refer to certain technical standards to develop a flood control plan. The characteristics of river basin and river course in Fiji and Japan are considered to be similar since both Fiji and Japan are the island countries, and the rivers are flowing from the mountains and flow through low-lying land to the sea in a short time, and the flood / runoff characteristics is also considered to be similar. Therefore, Japanese guidelines, such as "The Japanese Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Planning and Survey" and "Handbook for Examination of River Planning" and so on can be utilized as a reference to develop a flood control plan.
- ✓ In the future, development of own guideline or technical standard for flood control planning in Fiji and training and capacity development of river engineer will be desired
- ✓ Issues of Design of Flood Control Facilities
- ✓ Same as flood control planning, own design standards / criteria and guideline of flood control facilities are not established in Fiji.
- ✓ Under this situation, since the river channel characteristics of Fiji and Japan are similar and the technology and knowledge for designing, such as hydrology, physics, geo-technique, river engineering, and concrete technology and so on are universal, design criteria of Japan can be utilized same as flood control plan. Therefore, Japanese guidelines, such as "Government Ordinance for Structural Standard for River Administration Facilities" and "The Japanese Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Designing" and so on will be utilized as a reference for designing.
- ✓ Regarding as flood control structural measures in Nadi River Basin, such as excavation, embankment, revetment, dam, retarding basin, and diversion channel are considered as the flood control facilities to be designed at the moment, but the certain facilities will be selected in the M/P and priority project. Here, main design items and basic concept for design criteria regarding river works in the Nadi River basin are described in Appendix-5. Even though, the content in Appendix-5 is a draft and it will be revised in line with progression of project.
- ✓ In the future, development of own guideline or technical standard for design of flood control facilities in Fiji and training and capacity development of river engineer will be desired. In addition, it is important to keep the design documents and review them later.

b) Issues of Construction of Flood Control Facilities

- ✓ Same as flood control planning and design, own design standards / criteria and guideline of construction are not established in Fiji. Therefore, same as flood control planning, Japanese guidelines for constructions will be utilized as a reference. On the other hand, it is important to consider Fiji's local construction conditions such as rainy season and working conditions.
- ✓ In the future, development of own guideline or technical standard for design of construction in Fiji and training and capacity development of engineer will be desired.

c) Issues of Operation and Maintenance of Flood Control Facilities

- ✓ Same as flood control planning, design, and construction, own design standards / criteria and guideline of operation and maintenance of flood control facilities are not established in Fiji.
- ✓ In addition, operation and maintenance such as periodical inspections and rehabilitation works after damaged are not implemented enough because of budget problem and lack of number of engineers. Therefore, establishment of operation and maintenance system will be urgently required.
- ✓ Under above situation, it is required for C/P to understand importance of operation and maintenance of flood control facilities such as retarding basin and dikes, and establishment of operation and maintenance system included in flood control master plan as one of non-structural flood control measures.

(2) Water Use

1) Present Conditions of Water Use

Present water use in the Nadi River Basin is mainly for drinking and Vaturu dam, located upstream of the Nadi River is the only source for the water supply in the basin, and groundwater is not used. Irrigation system and water intake for irrigation are not existed since the agriculture land uses only rain water in the Nadi River Basin. Moreover, there is no large-scale of water use of industrial water use.

WAF is the administrator of water supply and has been established in 2007 as a government corporation by Fiji government. The main purpose of WAF is providing access to good quality drinking water and waste water services. WAF secures water resources during and after disasters as a part of flood disaster counter measures even though, WAF does not play an important role in the disaster prevention. On the other hand, utilization of multipurpose dam is now being examined, and the flood control is considered as one of the purposes. Moreover, Water Supply Scheme Master Plan 2013-2033 (Draft) is currently under development by WAF.

Details of present situation and issues regarding water resource management are described in "**4.3** Present Situation and Issues on Water Resources"

2) Issues of Water Use

- ✓ River water is used not only for daily life water, such as drinking water, but also for agriculture and fishery. Therefore, preserving river water quality and discharge and water use management to prevent illegal use of river water is required.
- ✓ Presently Fiji has some agencies responsible for the water sectors, but there is no agency responsible for integrated water resources management (IWRM). An organization vested with the authority and responsibility to carry out IWRM is, therefore, recommended to be established.

(3) Environment

1) Present Conditions of Environment

Mangrove grows thickly near the Nadi River mouth and it contributes to the diversity of ecosystems, such as a habitat for fishes and mud crab, and sugar cane and grass field spread in the basin create good natural environment. And a part of the upstream of Nadi River (Nausori High land) is designated as conservation area

The information of natural environment in the Nadi river Basin is limited. Only appeared in existing EIA reports, fish inventory research. There is no continuity monitoring activities of water or air pollutions.

Details of present situation and issues regarding environment and social consideration are described in "4.8 Present Conditions and Issues of Environmental and Social Consideration"

2) Issues of Environment

- ✓ Preserving natural riches of river environment and great scenery of river is one of the important topics the of river management.
- ✓ Flood discharge and sediment movement situation to the coastal area will change depending on the flood control facilities, and it might cause the decrease of mangrove, coastal erosion and sedimentation and so on. Therefore, comprehensive understanding of the sediment management from the source of sediment to coastal area, impact assessment, and examination of mitigation measures

have to be considered at the stage of selection of flood control measures.

- ✓ Moreover, coastal area has been developed as a resort area, such as Denarau Island, since 1980s and land issues, such as Native Land issue are typical problems in Fiji particularly in the basin. Furthermore, there is a regional development planning, such as Nadi Town Scheme in the region. Considering the above issues, environmental and social impacts caused by the flood control plan / facilities should be examined based on the concept of "Strategic Environmental Assessment (EIA)", which will examine the alternative solutions from the early stage of planning. Moreover, EIA process should be in line with the legal system of Fiji and it should be conducted at the stage of execution of priority projects.

4.1.2 Present Conditions and Issues of Legal System and Policy

(1) Present Conditions of Legal System and Policy

Political framework of natural disaster management in Fiji has been established for around 20 years. The main purpose of the framework is not disaster prevention or disaster risk reduction but disaster response. The policy which was made by Fiji government contributed to the improvement of the institutional capacity and to the establishment of bases for administrative functions for disaster response through establishment of NDMO and other institutional mechanism.

On the other hand, dramatic change of climate pattern, which is happening in the world, affects by not only increasing the sea level, but also by causing huge cyclone, and the climate change coupled with recent urbanization is viewed as a direct threat to the Pacific countries. The international society also points out the necessity to move from disaster response to disaster prevention.

(2) Issues of Legal System and Policy

- ✓ Even though disaster risk reduction is mentioned in the political documents, implementation of flood control measures is not positive response but rather passive response. Disaster prevention and risk reduction should be given more importance in the framework of flood control, and both social and engineering approaches for disaster prevention and risk reduction are required.
- ✓ There is no legal framework / system for technical concept, such as retarding basin and diversion channel in Fiji, since flood control measures targeting the entire river basin have not been implemented before. Detail regulations / concepts for flood control facilities such as retarding basin and so on should be examined in cooperation with Fiji government in order to implement the flood control measures which will be proposed in this project.
- ✓ Regular process for land acquisition will be applied even for the lands which will be affected by river works and construction of diversion channel and so on, like other public works. Land acquisition and its process are required.
- ✓ The act and the plan regarding national disaster management will be revised considering climate change and occurrence of disasters. NDMC decided the revision of Natural Disaster Management Act in 2015. Since the National Land Act is also under discussion for revision, the revised contents have to be reflected in the river management project at the stage of implementation.

4.1.3 Present Conditions and Issues of Institution and Structure

(1) Present Conditions of Institution and Structure

Institutions and roles of organizations related to flood prevention were described in "**Chapter 2, 2.5**". Even though each organization's division of duties specifies the approach to disaster response and they are making efforts to prevent the disaster, there is no organization responsible for the reduction of the flood disaster risk considering the entire river basin and for implementing a comprehensive river management for flood prevention at the moment. Therefore, an institution or an organization which can implement integrated river management is required to be established in the future.

(2) Issues of Institution and Structure

- ✓ Institutional mechanism which enables a comprehensive river and river basin management aiming at flood disaster risk reduction and integrated flood control is required.
- ✓ Capacity building of planning, designing, construction planning, and operation and maintenance of

flood control facilities in order to implement the planning of flood disaster risk reduction and flood control measures is required.

- ✓ As for implementation of river basin and river management, comprehensive approach including hydrological and meteorological data acquisition, land issue and civil engineering work is required and cooperation with FMS is important. Moreover, present organizational structure of LWRM puts emphasis on "Reduction of flood which poses a risk for agricultural crops, livestock, property and human life". Therefore, improvement of manpower resources and technical knowledge related to flood prevention are necessary for implementation of comprehensive river basin and river management.
- ✓ Present disaster prevention measure focuses on emergency response and disaster response, and disaster prevention and disaster risk reduction are not emphasized. Therefore, disaster prevention and disaster risk reduction should be emphasized and mainstreamed in each plan and policy, and development of organization / structure to take the lead in disaster prevention is required.
- ✓ Knowledge and experience regarding flood control and river management as described below are to be improved.
    - Capacity of planning of comprehensive flood control plan, M/P and hydrological analysis
    - Capacity of planning and designing of flood control facilities
    - Capacity of construction planning and construction supervising of flood control facilities
    - Capacity of operation and maintenance of flood control facilities, etc.

4.2 Present Conditions and Issues of Flood Control Measures in Nadi River Basin

As for the flood control projects implemented or in operation in the Nadi River Basin including structural and non-structural measures, the current situation and issues of the projects are described in Table 4-1 to Table 4-3.

4.2.1 Present Conditions and Issues of Structural Measures

The details of structural measures are described in "Section 2 2.5.2 and 2.7.1"and as mentioned above, systematical flood control plan considering the whole river basin and flood control facilities have not been established in the Nadi River Basin, and only local protection work to protect village and agricultural land and small-scale retention dam have been established.

Therefore, rainfall, runoff and flood should be analyzed based on scientific basis to understand the flood characteristics in the basin at the beginning, and then a comprehensive flood control plan should be developed. Examination of flood control measures / facilities considering priority protection area, safety level of flood control, priority level of construction section and its feasibility is required in the second place. Moreover, since completion of structural measure needs long period of designing and construction and so on, it is important to utilize / implement non-structural measures to supplement the lack of structural measures.

The main study items required to consider structural measures are shown below.

- Rainfall analysis, run-off and flood analysis and evaluation of flow capacity based on scientific evidence.
- Planning of design scale, setting of design rainfall, examination of flood discharge
- Planning of design reference point, setting of important protected area
- Study of flood control measures, optimal combination of flood control measures
- Flood control planning and river channel planning
- Stage development plans and annual plans, etc.

4.2.2 Present Conditions and Issues of Non-Structural Measures

A lot of projects regarding strengthening of institutional capacity, disaster prevention training and education, and community-based disaster prevention are conducted by international aid agencies as a non-structural measures. Even though these projects are conducted relatively well, they are conducted sporadically and have challenges of continuity.

On the other hand, development of hydrological observation network, flood forecast based on technical and analytical methods, and establishment of early warning system and information dissemination system are

not focused on compared to the capacity building projects mentioned above. Since development of hydrological observation network and results of flood forecast and so on will be utilized as fundamental information in order to issue flood warnings and to judge the necessity of evacuation, it is important to utilize / implement non-structural measures to supplement the lack of structural measures.

As for non-structural measures, 6 measures described below are considered as the assumed characteristic measures in the Nadi River basin through the project activity as of summarization of progress report. Examined contents are as shown in Table 4-2

Details of non-structural measures are described in "Chapter 10 Non-structure measures".

- Development of regional disaster management plan
- Development of flood hazard map
- Implementation of disaster prevention education and training
- Regulation of land use
- Early warning system
- Flood damage analysis

Table 4-1 Present situation and evaluation of structure measures in the Nadi River Basin

Present situation of structural measures						Evaluation
Item		Administrator	Present situation of structural measures			
Present condition of flood control measures	Structural Measure	MOA	Revetment and spur	Name of Project	Nadi River Training Works (Construction of Gabion Works) at Narewa Village	➢ Revetment was installed at local area considering prevention of river bank erosion near farmland and farm village in the past. Revetment was not planned and installed considering the entire river channel, eroded place of the river channel, priority of river improvement and sediment movement and so on. ➢ River bank where the revetment was installed is in stable condition as of 2014. However, it is not clear whether revetment is safe or not against flood flow because there are not design criteria and guidelines for revetment in Fiji. ➢ Future, although river channel widening, normalization and the like are considered as flood control measures, it is required to plan and design revetment considering river channel widening shape, flood flow velocity and so on. When considering channel widening, it is required to consider possibility of rebuilding of existing 3(three) bridges
				Purpose	Protection of village and agricultural land along the Nadi River, such as Narewa Village	
				Plan, Design, and Construction	・ This structure was planned by the principal engineers of LWRM in order to locally-protect village and agriculture land, and it was installed at the outside of river bend. Even though, it was not planned and installed considering eroded place of the river channel, priority of the river improvement and sediment movement and so on. ・ Design plan and documents are not compiled. Structural safety of revetment against water flow is not examined. This structure is designed by the principal engineer of LWRM based on his knowledge and experience. ・ Quality criteria and technical standard for construction is only described in the contract documents of construction. This contract document was prepared based on the knowledge and experience of the principal engineer of LWRM. Construction work was conducted by private construction company.	
				O & M	・ Periodical inspection and repair are not conducted.	
		MOA	Retention dam	Name of Project	Basin management project	➢ Scale of the facility is relatively small considering the scale of flood that may occur. Therefore, the effect of the facility is assumed to be limited. Moreover, one of facilities has already been filled with sediment and effect of retention dam is considered to be small. On the other hand, the facility may have the function of groundsill, such as stabilization of river bed, protection of river bank and so on. ➢ It is required to do rainfall analysis, run-off and flood analysis, and evaluation flow capacity of channel and setting of design scale in advance in order to consider flood control structural measures. ➢ In addition, it is required also to set design reference point for flood control planning and important protected area based on location of Nadi Town, main road, international airport and so on. After setting them, it is required to consider suitable flood control structural measures and combinations.
				Purpose	Peak cut of flood and small scale retention	
				Plan, Design, and Construction	・ This structure was planned by the principal engineers of LWRM for the peak cut of flood and small scale retention. Plan documents are not compiled and the detail of this structure is unknown. 15 retention dams are planned to be constructed and 3 of them had been constructed and one of them was under construction as of December 2014. ・ Design plan and documents are not compiled. Structural safety of revetment against water flow is not examined. This structure is designed by the principal engineer of LWRM based on his knowledge and experience. ・ Quality criteria and technical standard for construction is only described on the contract documents of construction. This contract document was prepared based on the knowledge and experience of principal engineer of LWRM. Construction work was conducted by private construction company.	
				O & M	・ Periodical inspection and repair are not conducted. The facility was damaged by flood in 2012 and repaired.	
		MOA	Excavation of river channel	Name of Project	River channel dredging project	➢ Maintenance dredging is not implemented periodically. ➢ It is required to analyze river bed fluctuation and plan future maintenance, dredging plans, etc. ➢ There is a possibility that flood control structural measures proposed by the Study will affect sediment movement in Nadi River Basin. Therefore, if affect seems to be large, mitigation method should be considered. ➢ In addition, sediment movement will affect also to seashore line. Therefore, it is required to analyze seashore change and seashore environmental impact. ➢ Especially at Denarau area, it is said that coastal erosion has occurred currently. Therefore, it is required to confirm the impact of flood control structural measures.
				Purpose	Removal of sand deposit at the river mouth	
				Plan, Design, and Construction	・ The structure was planned by the principal engineers of LWRM. The project was conducted from 2008 to 2012 at the river mouth of the Nadi River. Total dredging volume is 1,651,000 m^3. ・ Dredging was conducted by Australian company	
				O & M	・ Periodical monitoring of sedimentation of river bed by river survey is no conducted.	
		WAF	Vaturu Dam	Name of Project	Vaturu Dam	➢ Examination of applicability of raising spillway for flood control is considered by WAF because lack of future demand of water use. It is necessary to consider the possibility of utilization as flood control. ➢ Periodical sand deposit survey for the dam lake, removal of sand deposit and operation and maintenance including renewal of intake facility are required.
				Purpose	Securement of drinking water	
				Plan, Design, and Construction	・ The structure was planned and designed by WAF. The construction was completed in 1982 before 32 years has passed. Vaturu Dam is a rock fill dam and its total storage capacity is 27,000,000 m^3, dam height is 56m, and main purpose is to supply drinking water. Free overflow style spillway is located at the left bank of the dam. Porous selective intake is located at the left bank of the dam lake. ・ Water Supply Scheme Master Plan for 2013-2033 (Draft) was being prepared by WAF as of December 2014. Raising of Vaturu Dam spillway is under study in the plan. The safety analysis (to raise spillway by 2.0 meters) has been commissioned to an Australian Consultant. Feasibility study is planned to be conducted. Examination of applicability of cascade energy dissipater is also planned to be conducted. ・ Construction work was managed by the Ministry of Infrastructure and Transport	
				O & M	・ Operation and maintenance is conducted by WAF ・ Sand deposit in the dam lake has not been surveyed. ・ Water leakage from water conveyance pipe, water intake facility is found.	

Table 4-2 Present situation and evaluation of non-structural measures regarding flood in the Nadi River Basin

Present situation of non-structural measures						Evaluation
Item		Non-structural measures considered as the assumed characteristic measures in the Nadi River Basin	Related organizations	Input by International aid agency and so on	Present situation of non-structural measures	
Present condition of flood control measures	Non-structural measures	Development of regional disaster management plan	・ Commissioner Western Division (CWD) ・ District Office of Nadi (Do-Nadi) ・ Nadi Town Council (NTC) ・ Community Disaster Management Committee (CDMC) ・ Denarau area and group of resort hotels and so on		・ Disaster management plan has not yet been developed in CWD and district office (DO), such as DO Nadi. On the other hand, Nadi Town Council and CDMC developed disaster management plan. ・ The plan for CWD will be developed as soon as the revision process of National Disaster Management Plan: (NDMP 1995) and Natural Disaster Management Act: (NDMA 1998) is complete. ・ There are limited resources (human resource, funding and ability) within CDW and DO for development of the plan. ・ The importance of preparedness before disaster happens and utilization method of disaster management plan are not fully understood. Present disaster prevention measures focus more on emergency response and disaster response. ・ Even though NTC and CDMC have plans, the plans and how to utilize them are not well-known among staffs and residents. There are limited resources (human resource funding and ability) for utilization of the plan. ・ Denarau area developed its own disaster management plan and SOP in order to reduce disaster risk in the resort area, and meeting is hold once a month or once a week especially during cyclone season among the persons concerned.	➢ Disaster management plan is not formulated by CWD and Do-Nadi. On the other hand, disaster management plan is formulated by NTC and CDMC. Therefore, it is required to formulate disaster management plan according to revision process of National Disaster Management Plan and Natural Disaster Management Act. In addition, even though present disaster prevention measure gives more importance to emergency response and disaster response, disaster preparedness and disaster risk reduction are needs to be involved in the plan. ➢ Present disaster management plan is formulated sporadically. Therefore, systematical approach which enables to implement continuous, effective and efficient disaster prevention activity in cooperation among all Division, District, and Town and Village levels is required. Establishment of disaster prevention system in the whole river basin, implementation of training, awareness activities for disaster prevention is also important. In addition, cooperation with the resort area such as Denarau area is also important. ➢ It is required to formulate disaster management plan cooperating with the flood control plan proposed by the Study. ➢ Resources (human resources, budget, and capacity) to utilize and implement the regional disaster prevention plan is not enough.
		Development of flood hazard map	・ Analysis of hazard: Department of Irrigation and drainage, MOA (for flood) Department of Mineral Resources, Ministry of Urban, Mineral Resources, Environment and Energy (for sediment disaster and earthquake) ・ Flood warning: FMS and so on	・ The project managed by SPC/SOPAC using WB fund. Flood analysis was conducted by NIWA in 2014 ・ As for Tsunami hazard map, WMO implements Coastal Inundation Forecasting Demonstration Project, CIFDP as JCOMM	・ Even though the responsible organization for hazard assessment is specified as Department of Irrigation and drainage, MOA especially for flood, and Department of Mineral Resources, Ministry of Urban, Mineral Resources, Environment and Energy for earthquake in Natural Disaster Management Act (1998), responsible organization for hazard mapping is not specified. ・ In Nadi River Basin, currently there are three kinds of hazard related map: 1) Inundation map based on past flood: providing information on the 2009 and 2012 floods by SPC/SOPAC in IWRM project; 2） Inundation simulation result by NIWA; 3) Map of annual average economic loss by Natural Disaster (PCRAFI). ・ Tsunami hazard map in coastal area has been examined by FMS in the Coastal Inundation Forecasting Demonstration Project, CIFDP.	➢ Even though hazard map provides important information which helps residents to evacuate, such as evacuation centers, evacuation route and disaster risks and so on, there is only flooded inundation map at the moment. ➢ In addition, importance of the hazard map and how to utilize are not well understood among government officers and residents. Moreover, securement of resources (human resource, funding and ability) to develop a hazard map and awareness program and evacuation drill using developed hazard map in order to make people understand the importance of hazard map are not enough. ➢ As for assumed flood / inundation risk, even though the flood simulation result by NIWA in 2014 exists, there is scope for improvement in analytical method and accuracy as shown in Table 4-3.

Present situation of non-structural measures					Evaluation
Item	Non-structural measures considered as the assumed characteristic measures in the Nadi River Basin	Related organizations	Input by International aid agency and so on	Present situation of non-structural measures	
	Implementation of disaster prevention education and training	・ National Disaster Management Office (NDMO) ・ Ministry of Education, Heritage and Arts and so on		・ Since the budget for trainings is not included in the national budget, the frequency and areas to be covered by the trainings tend to be affected by the availability of the international organizations funding. Two trainings on disaster risk reduction have been implemented in Fiji so far. ・ Ministry of Education developed the Education in Emergencies and School Safe Policy and implements disaster prevention education and activity.	➢ Trainings on disaster prevention were implemented sporadically by aid of international aid agencies in the past. They were not implemented systematically and they seem to be poor in continuity. In additions, cooperation among international aid agencies is not enough. ➢ Securement of national budget for disaster prevention activity and resources (human resource and ability) to implement disaster prevention training, ownership building and mainstreaming of disaster prevention are required. ➢ Such as in particular flood-prone area, to continuously carry out disaster prevention training, it is necessary to devise such as carried out by region depending on the flood damage property. ➢ It is required for international aid agencies to implement disaster prevention training to suit natural disaster risk and needs in Fiji, unified approach, implementation of systematic activities, and collaboration among international aid agencies.
	Regulation of land use	・ Ministry of Lands & Mineral Resources ・ MOA and so on		・ River and Streams Act stipulates the land easement on both sides of river bank as "the banks of the said rivers to the breadth of 20 feet from the ordinary water-line in the wet season and the highest spring tide shall be subject to an easement in favor of the public for all purposes necessarily incident to the free use of the rivers" (Reference: Chapter 136 Rivers and Streams). ・ There are no laws and legal systems which regulate land use regarding flood other than those mentioned above. ・ Ministry of Agriculture develops Fiji Land Use Capability (LUC) classification system.	➢ Currently, land use regulations for the purpose of flood control have not been implemented. It is required to regulate land use and development in flood prone area and retarding basin with land use law and to regulate building (e.g. in flood prone area, the buildings need to be stilt houses, or with raised foundations, etc.) with building law in the future.
	Early warning system	・ FMS ・ NDMO ・ MOA and so on		・ FMS monitors river water level and rainfall when there is a risk of flood, and issue the warning regarding flood to relevant organizations. ・ Even though FMS uses the hydrological observation stations with telemetry system which were installed by IWRM project in the Nadir River basin, the number of stations is not sufficient. ・ FMS forecast the water level within the basin based on the observed water level and their knowledge and experience, but it does not have a scientific basis. ・ NDMO disseminate disaster information to residents. Even though information sharing between government organizations is very smooth, local community sometimes does not receive real-time disaster information and the information is not utilized for evacuation especially in the Nadi River Basin.	➢ It is necessary for early warning system to grasp and provide accurate data and information of rainfall and water lever for evacuation, to develop an accurate flood forecasting model which has a scientific basis and to increase the accuracy of it, to set evacuation judgment water level and so on. As mentioned in Table 4-3, hydrological observation network was installed in IWRM project. However, there is scope of improvement by the view of flood control planning and early warning such as lack of observation stations in Nawaka River Basin. In addition, currently FMS predict flood based on their experience and knowledge of past lessons and technicians, and not based on scientific evidence. ➢ For early warning system based on scientific evidence, establishment of accurate flood forecasting model and improvement of it, Improvement of hydrological observation network, and accumulation of data for verification of model are important. Moreover, since local rain area and rainfall tend to significantly affect flood scale and characteristics in Nadi River Basin, it seems to be effective to acquire rain area and rainfall using X-band radar. ➢ Securement of resources (human resource, funding and ability) to improve the early warning system is required. ➢ Since flood prevention activities, such as issuing of flood warning is implemented by FMS and information dissemination to public is implemented by NDMO, there is a time lag in transmission of disaster information. Nadi river basin has a short flood arrival time. On the other hand, there are many tourists, etc. Therefore, early warning system to inform them of rainfall and water level information in upstream area is required.

Present situation of non-structural measures					Evaluation
Item		Non-structural measures considered as the assumed characteristic measures in the Nadi River Basin	Related organizations	Input by International aid agency and so on	Present situation of non-structural measures	
		Flood damage analysis	・ NDMO ・ CWD ・ Do-Nadi and so on		・ Situation report is handed in to Do-Nadi by community, and it is transferred to NDMO via CWD. NDMO will evaluate the necessity for delivery of emergency relief goods and so on based on the report. NDMO makes damage report / situation report after the disaster. ・ Because only hardcopy of situation report is prepared, damage situation / situation report is not compiled and the reported contents vary considerably in quality. Therefore, it causes NDMO to take much time to analyze it.	➢ Currently, although situations of flood damage are surveyed and reported by NDMO, they are not implemented systematically. Therefore, unified form of situation report, database of damage situation, risk assessment and analysis utilizing the compiled data are required. ➢ Securement of resources (human resource, funding and ability) to improve the analysis of damage situation is required.

Table 4-3 Present situation and evaluation of other main projects regarding flood control measures in the Nadi River Basin

Present situation of other main projects regarding flood control measures in the Nadi River Basin				Evaluation
Item	Name of Project / Plan	Implementing organization and Donor	Present situation and contents of main projects	
Other main projects regarding flood control measures in the Nadi River Basin	PI-IWRM: Pacific Islands Integrated Water Resources Management Programme (2006-2012) (hereinafter, IWRM project)	・ SPC/SOPAC ・ Fund: Global Environmental Facility (GEF)	・ Investigation regarding water resources management of the Nadi River Basin including flood control was implemented in this project. Moreover, hydrological and meteorological observation system, early warning system and Nadi Basin Catchment Committee, NBCC, were established in this project.	➢ Hydrological observation network was installed in IWRM project. However, there is scope of improvement and optimal relocation planning of the network by the view of flood control planning and early warning such as lack of observation stations in Nawaka River Basin. ➢ It is important to establish a committee such as NBCC in order to implement river basin management. Although project for NBCC is completed, it is desired to establish a committee of the same type as NBCC
	Integrated Flood Management in the Pacific (Nadi pilot)	・ SPC/SOPAC ・ Fund: World Bank (WB)	Flood simulation model targeting Nadi town and surrounding area were developed and flood control measures were examined in this project. Moreover, 1) Development of inundation record map for the 2009 and 2012 floods (Nadi Integrated Flood Management Project, SPC/SOPAC), 2) LiDAR survey (Aerial LiDAR and Photographic Survey Nadi Integrated Flood Management Project, October 23 2012, Network Mapping Limited) and 3, Flood simulation (Nadi River Flood Risk Assessment Report Prepared for Applied Geoscience & Technology Division, SOPAC of the Secretariat of the Pacific Community, SPC, April 2014, NIWA), regarding the Nadi River Basin were implemented in this project.	
			・ Nadi Integrated Flood Management Project, SPC/SOPAC	➢ Inundation record map for the 2009 and 2012 floods were developed based on the flood mark survey and interview survey. Those maps are very important documents since only limited data regarding past flood damage are available. ➢ However, inundation area and depth at the coastal area where the mangrove grows are not investigated. They should be improved. ➢ Inundation record map is not utilized as hazard map. It is required to utilize inundation record map as hazard map which mentions disaster risk, evacuation center and evacuation route, etc. and as basic information for disaster prevention planning and evacuation training, etc.
			・ Aerial LiDAR and Photographic Survey Nadi Integrated Flood Management Project, October 23rd 2012, Network Mapping Limited, United Kingdom	➢ LiDAR survey was conducted by a British company. The data is very accurate and it has a margin of error of plus or minus 10cm in vertical direction and plus or minus 30cm in horizontal direction. Its coordinate system is Fiji Map Grid, and elevation is expressed in Mean Sea Level, MSL, in the same way as geodetic reference network in Fiji.
			・ Nadi River Flood Risk Assessment Report Prepared for Applied Geoscience & Technology Division (SOPAC) of the Secretariat of the Pacific Community (SPC), April 2014、NIWA	➢ Flood simulation using the flood with occurrence probability of one hundredth was conducted, and effect of the diversion channel which was proposed in the JICA Study in 1998 was also examined. ➢ However, the rainfall of the basin which is used for the flood simulation is set based on only one observation station, Nadi Airport, and it cannot represent the rainfall of the basin properly since Nadi Airport observation station is located at the downstream of the enter river basin. Moreover, even though the actual flood damages in 2009 and 2012 are bigger than the damage caused by the flood in 1999, the calculated occurrence probability of rainfall of flood in 2009 based on only the observed data of Nadi Airports is bigger than the ones in 2009 and 2012. It seems that the calculated rainfall and flood characteristics were not replicated properly comparing with the actual situation. Therefore, rainfall analysis and flood simulation have to be improved.

4.3 Present Situation and Issues on Water Resources

The purpose of the Study is to formulate comprehensive flood control master plan in Nadi River Basin. On the other hand, it is a world trend that flood control is considered as a part of Integrated Water Resources Management (IWRM).

In the Nadi River Basin, the *Pacific Islands Integrated Water Resources Management (PI-IWRM)* was studied in 2006 to 2012 as shown in Table 4-3. Result of PI-IWRM consists of "① Watershed Management", "② Sewerage Management and Sanitation", "③ Evaluation of Water Resources and Conservation", and "④ Improvement of Water Utilization Efficiency and Drinking Water Security". Out of them, "①" and "③" are related to the Study and deeply related to formulate a flood control master plan.

Therefore, especially in above two perspectives, the analysis of the present conditions and issues of water resources in the Nadi River Basin is required and recommendations of measures for efficiency of water resources management are to be proposed in the flood control master plan proposed by the Study.

4.3.1 Present Situation of Water Resources

(1) Water Resources Management Facilities

The present water source of the Nadi River Basin is the Vaturu Dam located at the upper reach of the Nadi River. The water from Vaturu Dam is purified at Nagado Water Treatment Plant (WTP) and supplied to Nadi and Lautoka areas, about 100% of the domestic water of Nadi and 75% of that of Lautoka. The remaining 25% of the domestic water of Lautoka comes from the other three intakes; namely, Buabua Intake, Nalau Intake and Varaqe Intake. The supplied water amount from Vaturu Dam was reported as 83.27 ML/d in 2013.

Picture 4-3 Vaturu Dam and Nagado WTP

<table>
<tr>
<td>  </td>
<td>  </td>
</tr>
<tr>
<td>Basic Specifications of Vaturu Dam
Storage Capacity : 23.5million m^3
Surface Area : 200ha (2.0 km^2)
Catchment Area : 40 sq. km.
Crest Level : 532.0 amsl
Maximum Flood Level : 528.0 m amsl
Full Supply Level : 527 m amsl
Minimum Operating : 502.00a. amsl
Maximum Depth : 37m</td>
<td>Basic Specifications of Nagado WTP
Water Supply Capacity : 104 ML/day
Water Supply Amount in 2013 : 83.27 ML/day</td>
</tr>
</table>

(2) Water Resources in the Nadi River Basin

The water resources in the Nadi River Basin is comparatively blessed with the annual rainfall amount of 1,500 mm to 3,000 mm, and the water resources is utilized for domestic water, agricultural water and exportable mineral water.

Presently, Nadi urban areas depends 100% on Vaturu Dam for domestic water, and its reservoir, and groundwater is not utilized. Though there are large agricultural fields such as sugar cane (9200 ha), dry field (4,000 ha) and grazing field (9,300 ha), they are mostly rain-fed agriculture and there is no irrigation systems and irrigation intakes at national level in the Nadi River Basin. Also no large scale industrial water intakes exist.

The water service area is still limited to the urban areas of Nadi and Lautoka towns and their rural periphery areas. Most of the rural communities have their own water supply systems, of which the water

resources depend on surface water, springs or groundwater, developed by the Water Authority of Fiji (WAF) and maintained by each community. The Water Authority of Fiji (WAF) is planning to expand the water service areas gradually to the rural area.

The Non-Revenue-Water (NRW) or the rate of leakage of water of the current water supply system is estimated at over 50%. The major causes of the NRW are presumed as the superannuated (asbestos) pipe network, which causes frequent burst of the main pipes by water pressure. At the present the replacement and rehabilitation of the pipe network are conducted by the technical assistances of Fukuoka City in order to improve the water supply system. The M/P of WAF set a target to reduce the NRW of over 50% to 20% by 2018.

About rainwater, there is some information of rainwater storage with roof tanks as good quality water resources, however the WAF has not conducted any rainwater harvesting yet, and about sea water, the WAF has proposed a desalination project as an option of water resources development, but not included in the targets of water resources development.

About water quality management and public hygiene, the WAF is promoting the sewerage system of the water supply service area. The WAF is reporting that the sewerage system is separate system and the ratio of sewer networks covers 60% of the water supply service area. The current sewerage system is at primary treatment level and discharges to the Nadi River. According to the HQ of WAF at Suva the WAF has started the preparation of industrial waste water discharge standards and adaption of secondary treatment. Also the WAF has a plan to formulate a M/P of Sewerage System.

Groundwater in the Nadi River Basin, exist fissure and artesian types are identified, and the major aquifer is Meigunyah Aquifer (60 km^2) which are located at the alluvial plain downstream of the Nadi River and Sabeto River. The Ministry of Land and Mineral Resources (MLMR) is presently implementing the survey on groundwater and it has installed 3-4 observation/monitoring wells in Meigniya Aquifer and reported that the groundwater is not affected by sea water and possible to be utilized as potable water.

(3) Hydropower Generation

Hydropower generation for Fiji depends on Wailoa Hydropower Station on the Wailoa River and in the upper basin of the Rewa River which takes water from Monasavu Dam. The Fiji Electricity Authority (FEA) has a plan to conduct a study for a cascade hydropower station on the Ba River, at downstream of the existing hydropower station. Although there is a potential to develop a hydropower station in the Navua River Basin, the priority is low because of the lack of infrastructure such as access roads. There is no plan for hydropower development on the Sigatoka River and Nadi River, but there is a hydropower station built at the Nagado WTP in the Nadi River Basin.

In order to cope with the drought periods and power demands, the FEA has been developing thermal power generation facilities. The contribution of the hydropower is about 50-60%; the rest is mostly generated from thermal power. Although there is solar and wind energy generation, the contribution is less than 1%. Since the economic efficiency of thermal power generation depends on the oil price, the efficiency of thermal power generation is one of the major issues for Fiji. .

Hydropower at Nagado WTP in the Nadi River generates three (3) megawatts while small hydropower at the Wailoa River generates six (6) megawatts, Wailoa hydropower station at the Wailoa River generates 80 megawatts and Nadarivatu hydropower station at the Ba River delivers 40 megawatts, so that the total hydropower generation from the four hydropower stations is about 129 megawatts.

(4) Water Resources Management Organization

The IWRM Demonstration Project was conducted for the Nadi River Basin by Global Environmental Facility (GEF) Fund in 2013. It was the first IWRM project in Fiji. The project was conducted by the integrated flood management approach, aiming to improve flood preparedness and carry out integrated land and water management in the basin.

The implementation agency was the Land and Water Resources Management Division of the Ministry of Agriculture as the leading agency in cooperated with the Department of Mineral Resources of the MLMR and the Fiji National Water Committee. NBCC (Nadi Basin Catchment Committee) was also established, but after the completion of the project, the NBCC became inactive.

As for Water Resources Management each of the water sectors like water supply/sewerage, agriculture and

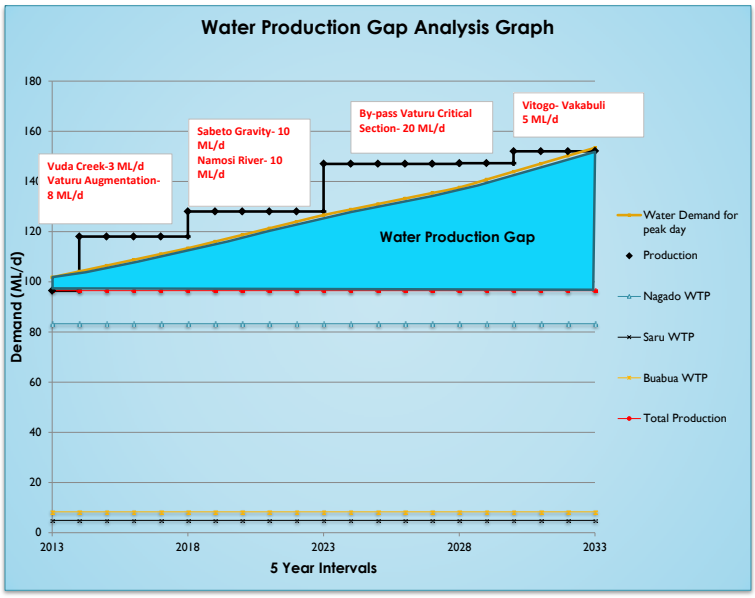
environment has a responsible agency, but definite agency with the sole responsibility for IWRM has not been established to date. In 2001, the Fiji National Water Committee was established as a coordination committee for water resources management, but has not been able to conduct its coordination functions because of delay of enactment of the National Water Policy. The National Water Policy is expected to be enacted within 2015.

The National Water Policy was prepared as "National Water Policy Document in 2005 (Draft) by the Mineral Resources Department (MRD). Since then it has been examined, and will be expected to be enacted as "National Water Resources Management and Sanitation Policy" within 2015. The policy is to cover surface water, groundwater, sea water and rain water as water resources and to give a policy of integrated management of water resources (quantity and quality).

This policy is to establish "National Water Committee" as an advisory organization of which members are representatives of line ministries and NGO, and give a function of technical committee to the National Water Committee. Also the policy is to strengthen the system to collect information and data which are required for optimum decision making, and to give the role to Department of Water and Sewerage (DWS) of Ministry of Infrastructure and Transportation. By enactment of the National Water Policy the water resources management system is expected to be forwarded.

(5) Outline of the Water Supply Scheme Master Plan for 2013-2033 (Draft) prepared by WAF

In Nadi and Lautoka areas, the water service population (both urban and rural) is predicted to increase due to the expansion of water service areas. As the result, it will be necessary for the WAF to increase its current capacity by about 1.6 times the water supply capacity in 2013 was 96 ML/day for Nadi and Lautoka, but in 2033 the water demand is estimated to be 150 ML/day (1.6 times).



Source: WAF

Figure 4-1 Water Production Gap Analysis Graph (Draft)

As an emergency response to the current NRW situation (over 50%), the water supply master plan (M/P) has set up a plan to reduce the NWR to 20% with the replacement or rehabilitation of the pipe networks. Alternative water resources development plans have been proposed; namely, (1) raising the top of Vaturu Dam Spillway which is free overflow type to increase of reservoir capacity, (2) developing water resources at the Nawaka River and (3) developing dams at the Namosi River. Other proposals are to prepare for groundwater development, introducing low water consuming devices to reduce water consumption, and to promote demand management and rainwater harvesting.

The Water Supply Master Plan recommends three packages; namely Package 1: Consolidation and Optimization Program, Package 2: Augmentation Program, Package 3: Long Term Program. However no detailed information has been collected yet and the Retention Dam development at the Namosi River and raising of Vaturu Dam Spillway are under Package 2.

Table 4-4 Package Cost (Draft) (WAF)

Package	Cost ($)
Package 1 – Consolidation and Optimisation Programme	**71,441,719.15**
Package 2 – Augmentation Programme	
Water Sources	49,580,149.20
Raw Water Trunk Main Augmentations	13,977,075.00
Water Treatment Plant Construction and Expansion	48,000,000.00
New and Additional Reservoir Capacity	31,020,000.00
Trunk Main Augmentations	29,400,643.15
Pumping Station	1,500,000.00
Distribution Mains	10,141,423.51
Package 2 Total	**193,760,714.57**
Package 3 – Long Term Programme	
By-pass Critical Section	23,500,000.00
Progressively Duplicate	10,000,000.00
Package 3 Total	**33,500,000.00**
Total Cost	**298,702,433.72**

Source: WAF

More detailed information regarding water resources development at the Nawaka River and dam development at the Namosi River will be collected. According to the Master Plan, the project costs for the Nawaka River intake and reservoir construction is FJD 3,211,528 (about JPY 200 million) and FJD 33,880,000 (about JPY 2,100 Million) for the Namosi small dam construction for the Namosi River is.

Table 4-5 Potential Water Sources (Draft)

Source	Catchment Area (km²)	Average Flow (ML/d)	Length of Trunk main (km)	Cost ($)
Sabeto Gravity (Navilawa)	8.6	56	8 km of DN 450 DI main	9,435,382
Sabeto Pumping Option	35	164	1.5 km of DN 450 DI main	2,441,538
Nawaka River (Vatutu)	86.3	125	1.8 km of DN 450 DI main	3,211,538
Buabua – Vakabuli Creek	32.7	10 (minimum)	5 km of DN 450 DI main	4,178,460
Saru- Vuda Creek	18.30	7.3	1 km of DN 450 DI main	1,077,692
Namosi River	65.8	131	15 km of DN 600 DI main	33,880,000

Source: WAF

Raising of Vaturu Dam Spillway proposed in the previous Master Plan (1996–2016) was not realized and is still under study. The safety analysis (to raise spillway by 2.0 meters) has been commissioned to an Australian Consultant (GHD: Gutteridge Haskins and Davy). The WAF will start the preparation works after confirmation of the results of analysis and safety. The study was commenced in November 2014, and as of July 2015 the study has concluded the safety of raising the spill way by 2.0 meter, and the WAF has decided to start their preparation.

According to the M/P, water resources development of the Nadi River is to increase the storage volume of Vaturu Dam and construction of an intake facility (10 ML/d) at the Sabeto River which is located in the north side having a common boundary with the Nadi River Basin. Development of multipurpose dams at the Namosi and Nawaka River Basins in the M/P (Draft) has not studied yet by other sectors such as flood control and agriculture sectors.

4.3.2 Usage of Water Resources

(1) Surface Water

The Nadi River Basin the usages of surface water are agricultural use except the surface water of Vaturu Dam Catchment. Management of agricultural water is the Ministry of Agriculture. Agriculture in the Nadi

River Basin is said that sugar cane is 70% and other crops (root crops, vegetables, and fruits) is 30%, but share of crops are varied annually. Agriculture in the Nadi River Basin is rain-fed agriculture. However, currently some farmers are conducting irrigation by pumps from the Nadi Rivers because of drought and cash crop markets.

According to Nadi Agriculture Office, there are 250 farms taking water from the Nadi River and 50 farms using groundwater. Average size of irrigation farms is 1.5 acre (0.607 ha) and irrigated areas are 182 ha, which is 1.4% of Agricultural area (13,200 ha), and annual use is estimated 0.73 million m^3. But irrigation area in the Nadi River Basin is supposed to increase because the national policy is to increase cash crops to exports and increase non-sugar crops.

(2) Groundwater

The Mineral Resources Department (MRD) of MIMR is responsible for groundwater. Presently there are no permits and licenses system for drilling boreholes and drilling boreholes are conducted freely and the situation of groundwater use is not grasped by MRD.

According to MRD, about 4%~9% of the annual rainfall is estimated to be recharged. If we estimate 4% ~5% of the annual rainfall to recharge, large amount of groundwater may be expected as water resources. In order to conduct optimum groundwater development it is necessary to introduce groundwater management (monitoring and control).

Groundwater uses now are agriculture, domestic water sources in communities in the alluvial plain, mineral water for export, but not used for water resources of urban domestic water. According to the agricultural office in Nadi, farms using groundwater for irrigation are about 50 farms (estimated farm area: 30 ha). Groundwater for irrigation farms and domestic water for rural communities depend on the groundwater of fissure type and Meigunyah Aquifer.

The water volumes pumped up in the Nadi River Basin are as follows:

- Mineral water : 1 ML/Month =12,000 m^3/year
- Irrigation water : 30.35 ha x 4,800 m^3=145,680 m^3/year

MRD has conducted groundwater surveys by foreign experts in the Nadi River Basin and has correct understandings of the importance of groundwater investigation, development of database and adaption of groundwater management. MRD is a promotor of National Water Policy and it is said that MRD is examining the introduction of basic data preparation, groundwater investigation and a permits and licenses system for borehole drilling.

4.3.3 River Basin Conservation

The forest area in the upper reach of the Nadi River is changing to farm land and grass land by logging and devastated.

The forest area covers 48% of the Nadi River Basin and for soil and requires sustainable forest management for soil and water conservation of the basin. In order to reduce sediment discharge and conserve the forest area it is necessary to recover the forest area by planting at thin wood area and grass land. Dense Natural Forest (3,943 ha) in the Nadi basin is identified only at the watersheds of Vaturu Dam and the upper reach of the Sigantoka River basin, and the other basins requires to promote to reforest of natural forest and grass land (11,455 ha).

However, the forest area belongs to land owners and no national property. In order to promote maintenance and management of the forest area, afforestation and control of logging it requires to discuss with landowners. Because it is necessary to pay guaranty money to the land owners in order to designate a forest area for control of logging, it is advisable to recover the forest area to have sustainable production.

4.3.4 Issues for Water Resources

(1) Introduction of water resources management system

Presently the Republic of Fiji has some agencies responsible for the water sectors, but there is no agency responsible for integrated water resources management (IWRM). Therefore, it is recommended to establish an organization vested with the authority and responsibility to carry out IWRM.

(2) Effective use of water resources

As for the water resources in the Nadi River Basin (516 km^2) the surface water resources of Vaturu dam (38.6 km^2) is only used. The current potential not small and the water resources are expected to be effectively used.

As for groundwater, it is said that it has no quality problems for drinking water use, and it is possible for Nadi area to utilize groundwater as supplementary water supply resources. It is, therefore, necessary for the Department of Mineral Resources of the MLMR to grasp the potential of the groundwater resources and to manage the groundwater resources efficiently. The forest area which covers 48% of the Nadi River basin is required to be conserved from sustainable water resources aspects.

Examination of integrated water resources use such as new water resource development and study on potential of groundwater will be an effective use of the water resources and countermeasure against drought.

4.4 Present Situation and Issues on Comprehensive Sediment Management

Comprehensive sediment management, which is the concept that focus on sediment movement, deposition and erosion by various particle size of sediment in basin from the river basin to coastal area, is an important point of view in formulating a flood control master plan of the Nadi River Basin in the Study

In Nadi River Basin, especially impact on sediment movement, riverbed fluctuation and seashore line change by flood control structural measures in the future is focused on. Therefore, it is required to select flood control structural measures considering impact on sediment problems and if necessary, it is also required to consider mitigation method to reduce the impact.

4.4.1 Present Conditions of Comprehensive Sediment Management

Regarding sediment movement in the Nadi River Basin, it is considered that sediment movement is relatively balanced as sediment dynamics currently because extreme bed reduction and deposition is not observed by site survey so far. Study for comprehensive sediment management, analysis of present situation, and examination of issues on sediment and so on are described in 「Chapter 8 Comprehensive Sediment Management」.

Comparing Nadi main stream with tributaries, sediment is relatively fine at Namosi tributary and sediment runoff characteristics seem to be different between Nadi main stream and tributaries.

Sand beach has spread out at the coastal area of the estuary of Nadi River and sand beach is utilized as fishing grounds and tourist destination. It is considered that sediment movement of sand which composes sand beach is important to sediment analysis.

4.4.2 Issues of Comprehensive Sediment Management

- ✓ In order to analyze impact on sediment movement and river bed fluctuation by flood control structural measures and evaluate impact on them numerically, it is required to observe data related to sediment movement which is not observed and recorded in the Study area. Therefore, it is required to implement various kind of field survey such as riverbed material investigation, sediment volume investigation, flow discharge observation, and so on in order to grasp present conditions. In the case of Nadi River basin, there is a particular need to pay attention to actual conditions and impact by flood measures regarding the movement of the fine ingredients (wash load) which are thought to affect seashore line change.
- ✓ On the other hand, even if numerical evaluation for sediment movement and impact by flood control structures in the future is conducted with field observations and analysis, results of analysis include uncertainty because the results are predicted using only short term data from 10 to 20 years. Therefore, in the long term, it is important to propose a periodical survey plan of river cross section and a periodical monitoring plan of sediment in the flood control master plan proposed in the Study in order to adapt an impact by flood control structures.

4.5 Present Situation and Issues on Seashore

Seashore composes one area of comprehensive sediment management from river basin to seashore and it is an important area where sediment problem related to sediment deposition, erosion and movement appears as a result. It is also important concept in formulating Flood Control Master Plan in the Study.

In Nadi River Basin, especially impact on seashore line change by change sediment supply volume by flood control structural measures in the future is focused on. Therefore, it is required to select flood control structural measures considering impact on sediment problems and if necessary, it is also required to consider mitigation method to reduce the impact. In addition, it is said that coastal erosion has occurred currently at Denarau area especially at west coast of Denarau area. Therefore, it is important to analyze impact on Denarau area.

4.5.1 Present Conditions of Seashore

Regarding seashore in the Nadi River Basin, it is considered that seashore is relatively balanced as sediment dynamics currently because extreme seashore erosion and sand deposition is not observed by site survey so far, and waves are gentle because seashore is surrounded by coral reef. Regarding sand drift direction, by observation results of current flow direction and current flow velocity and analysis of shoreline changes in the coastal areas so far, a fixed direction is confirmed in Nadi River estuary and Denarau are at west coast.

Seashore in the Nadi River Basin is very shallow and especially in Nadi Bay. At the Nadi River mouth, estuary terrace is formed by sediment which is flowing out from the Nadi River. Sediment material constituting beach has become finer as seawater depth is deeper, of which content rate of fine-grained fraction is more than 50% at a deeper position than 5.0m and more than 98% at a deeper position than 7.5m where most of sea bed materials is occupied by fine particle fraction. On the other hand, seashore is composed of mainly sand fraction or the like. Therefore, it is required to analyze considering particle size distribution of sediment flowing out from river in shoreline change analysis.

In addition, according to the Denarau district officials, coastal erosion has progressed in west coast part and it was confirmed in the field survey. It is said that sand nourishment and sand covering is conducted, but at present, details of that are unclear. In addition, Denarau district is artificially reclaimed area in the past. Therefore, it is required to evaluate based on the sediment transport direction and shoreline change analysis results of the coastal zone.

Analysis and details of present situation of seashore is described in "**Chapter 9 Seashore**".

4.5.2 Present Conditions of Seashore

- ✓ In order to analyze impact on shoreline change by change of sediment volume by flood control structural measures and evaluate impact on it numerically, it is required to observe data and information which is not observed and recorded in the Study area. Therefore, it is required to implement various kinds of field survey such as grasp of shoreline changes with shoreline survey and bathymetry survey, superposition of aerial photographs and charts, seabed material analysis, observation of direction of sand drift and current flow, and so on. Target area for investigation is not only Nadi River mouth but also Nadi Bay which might be an exit of diversion channel.
- ✓ On the other hand, even if numerical evaluation for shoreline change and impact by flood control structures in the future is conducted with field observations and analysis, results of analysis include uncertainty because the results are predicted using only short term data from 10 to 20 years. Therefore, in the long term, it is important to propose a periodical survey plan of shoreline and a periodical monitoring plan of shoreline in the flood control master plan proposed in the Study in order to adapt an impact by flood control structures.

4.6 Present Situation and Issues on Climate Change

4.6.1 Present Conditions of Climate Change

The perspective of governmental organization on the Fifth Assessment Report, AR5 of the intergovernmental panel related to climate change, IPCC, has not been presented. As for the island

countries including Fiji, the followings are the issues and prospects pointed in AR5 as described in "2.1.7 Climate Change".

- ✓ Interaction between average sea level rise of the world and high water level phenomenon in 21 century will threaten the lower coastal area (Certainty Factor is high)
- ✓ If the ratio of coastal area compared to the whole area of land, adaptation will be big problem as economic situation and natural resource for islands.
- ✓ The options for adaptation are maintenance and restoration of coastal topography and ecosystem and suitable Building Standards Act and residence pattern.

4.6.2 Issues of Climate Change

- ✓ Present safety level of flood control of the Nadi River is only for occurrence probability of once in several years or less so that there is a constant flood risk. Therefore, immediate establishment of flood control facilities are required. In flood control, it is important to set target scale of flood control and to establish flood control facilities to suit the target scale first of all.
- ✓ In addition, it takes long period and huge budget to construct all flood control facilities in Master Plan. Therefore, it is necessary to establish facilities urgently for important protected area as priority project and continuously establish facilities for other areas remained step-by-step. Safety degree against flood will be improved according to establishment of facilities step-by step in whole river basin.
- ✓ Therefore, adaptation to climate change and extra ordinal flood is considered as one of risk management and mitigation plan after achieving the target of flood control master plan.
- ✓ As for effect on flood by climate change and excess flood, since there are limitations to protect a target area against flood damage by structural measures, it should be combined with non-structural measures, such as land regulation, early warning system and so on for risk reduction. Regulation, early warning system and so on is required from the point of view of disaster risk reduction.

4.7 Present Conditions and Issues of Land Use and Regional Development

4.7.1 Present Conditions of Land Use and Regional Development

- ✓ Nadi town is located in floodplain and it is vulnerable to flood damage topographically. On the other hand, Nadi town is commercial capital for tourism and urbanization is accelerating with an increase in population and development of industry. Currently, there is a risk that future flood damage will be increased by implementation of disorderly urban development because there is not a comprehensive flood control master plan and urban planning considering flood risk, etc., development planning, land use regulations are not implemented.

4.7.2 Issues of Land Use and Regional Development

- ✓ In planning Mater Plan in the Study, it is required to consider existing town planning and development plans and to corroborate other plans (refer to 4.8(3), (4)). The town scheme of Nadi Town shows the asset concentration area, it can be referred to as a candidate for important protected area in the flood control plan.
- ✓ In addition, some of the area might be utilized as a retarding basin as a part of flood control measures, and those areas will be needed to be tolerant of inundation once in several years or decades. Therefore, countermeasures, such as land regulation, establishing the building which has an inundation tolerance, institutionalization of land compensation for retarding basin are needed to be implemented at the same time.
- ✓ Moreover, after approval of Master Plan, it is desired to review town scheme considering flood risk and implement town development and regional development in parallel with implementation of countermeasures for flood control against river flood and for drainage against rainfall.
- ✓ Nadi Town Council, as part of its preparation to extension of its town boundary and in becoming a city in 2017, simultaneously is revising its town planning scheme. Preparatory works have already begun on this exercise with both the Nadi town Council and Ministry of Local Government, through the Department of Local Government and the Department of Town and Country Planning. New chapters

into the town planning schemes revision include climate change, disaster management and resilience and hazard mapping for Nadi.

4.8 Present Conditions and Issues of Environmental and Social Consideration

4.8.1 Present Conditions of environmental and social consideration

Environmental and Social Consideration is important view for project implementation by international aid agencies in the donor countries, and it is also important view for the Study.

Currently, there is an EIA scheme in Fiji and it is necessary to follow the scheme under laws to implement project. On the other hand, there is some difference between Fiji's scheme and JICA Guidelines. The information of natural environment in the Nadi river basin is limited. Only appeared in existing EIA reports, fish inventory research. There is no continuity monitoring activities of water or air pollutions.

Moreover, there is a unique land ownership system in Fiji. Buying and selling of land is basically prohibited and it is required to get consensus from landowners to secure native land, except free hold land bought and sold freely and state land owned by Fiji Government.

4.8.2 Issues of Environmental and Social Consideration

(1) Issues on Gaps between JICA Guidelines and Fiji Laws

The major gaps between Fiji laws and JICA guideline are; (1) Fiji law does not require compensation payments to affected persons who have no recognized legal right or interest in the land (2) Fiji law only requires compensation on a depreciated/book value basis for structures. Therefore, the consent of Fiji side to the compensation for persons who have no recognized legal right or interest in the land, and compensation value calculated based on reacquisition price, is needed.

(2) Issues on EIA Related regal Systems

The Priority Projects are considered as Part1 Project of the Environment Management Act in Fiji. Part1 Project is required to implement EIA and to get the approvals of EIA Administrator.

The EIA process in Fiji proponent of EIA to hire a registered consultant for technical assistance (Environment Management (EIA Process - Regulations, part 4). Therefore, after the Study Team hands over the result of the study to GOF, registered consultant shall he hired to implement the EIA study for project.

(3) Countermeasures for Regulations of Town Planning Act

In case of major development in the area of planning scheme, approval from the administration is needed. In case of a development in the Nadi River Basin, approvals from Nadi Town Council (NTC) or Nadi Rural Council (NRC) and consent of Director of Town and Country Planning (DTCP) are needed.

In case of reformation of Nadi Town Planning Scheme, development plan and the Master Scheme and Rezoning Plan with consent of NTC or NRC shall be submitted to DTCP. The Master Scheme and Rezoning Plan will form an amendment to the Nadi Town Planning Scheme (approved in 1994 see below and amended in 2006) under the Town Planning Act.

(4) Relationship between Development Proposals which Approved EIA Study

Currently, there are two (2) major development proposals in the lower Nadi River Basin. Also, the Nadi River Basin and its vicinities have several development proposals. Therefore, it is important to consider the progress of these development projects. Especially, in case of development, not only the approval of the EIA report but also approvals from NTC through the procedure of public consultations is needed. The MOA will deliver its opinion on each development proposals, if required.

(5) Issues of Land Acquisition and Resettlement

The Fiji legal system does not allow trade of lands. Land acquisition with the exception of Free Hold Land (free for trade) and State Land (owned by GOF) needs to obtain the consent from land owners. The Department of Lands (DOL) has responsibilities for formation of agreements such as conditions of lease, compensations etc. DOL will negotiate with land owners through TLTB.

(6) Issues on Setting of Cut-Off Date

No cut-off date specified in the Fiji laws. The World Bank’s safeguard policy on the existing ADB project

is referred to as an example for setting a cut-off date.

(7) Issues on Environment and Social Surveys for Understanding of Baseline

To grasp the status of sites for priority projects, conducting a field survey is needed. Regarding social and economic conditions, detailed number of resettlement and current situation of local and house economy shall be surveyed.

The details of current situation and issues of environmental and social considerations are written in "Chapter11 Environmental and Social Considerations".