

3.3. Fauna and flora survey

The objective of the study is to confirm the present condition of rare precious species, fauna and vegetation, by means of existing data assessment, and a field survey to determine the present status of the fauna and flora. The Red List Categories under IUCN on December 1994 were adopted for threatened species.

3.3.1. Fauna study

Terrestrial vertebrates in the Fiji Islands were listed from existing data. The field survey about fauna was carried out in the tropical rain forest (Lowland rain forest) at Waivaka South in Namosi Province. A Scholar of Environmental consultants (FIJI) Ltd. was entrusted with the field survey.

(1). Overview of Fiji's Fauna

(The Fiji Islands)

Origin of animals in the Fiji Islands is presumed to derive from overseas. It is presumed that many animals were settled from the west through Papua New Guinea, Australia, New Caledonia, Vanuatu and Solomon Islands etc. The animal migrations were against the southeast trade wind. Birds have succeeded in propagation in comparison with other animals because of their flight ability. Representative birds in Fiji are Rails, Pigeons, Parrots, Flycatchers and Honey eaters.

About 150 species of Birds were recorded and native species counts 57 including 26 endemic species.

Native Mammals consist of six species of bats, including one endemic species. Feral pigs, cats, mice and mongooses are all introduced animals.

Native Reptiles counts 27 species, including eight endemic species, and consists of 2 iguanas, 12 skinks, 10 geckos, and 3 snakes.

Native Amphibians consist of only two frogs, and they are endemic species.

In general, introduced species have been brought around villages and reclaimed hills accompanied with human activities. On the other hand, native species tend to be preserved in a tropical rain forest that is widely distributed in the study area.

(Viti Levu South Area)

The vertebrates in the South East Viti Levu area (mainly tropical rain forest) have been recorded 84 species: 51 species of Birds, 11 species of Mammals, 19 species of Reptiles and 3 species of Amphibians. Endemic species are 2 Birds: Masked Shining Parrot and Pink-billed Parrotfinch. The list is shown in Table 3-3-1.

(2). Field survey

The field survey of fauna at the native tropical rain forest (Lowland rain forest) of Waivaka South in Namosi province was carried out from December 9, 2002 to December 13, 2002. In regard to Birds and Bats, visual inspection was done along roads and paths. Small mammals were caught using traps. Reptiles and Amphibians were caught during daytime search. The result is shown in Table 3-3-1.

1) Birds

A preliminary analysis of the transect surveys revealed 34 land and freshwater birds. Of major significance was the observation on eleven occasions of the Pink-billed Parrotfinch *Erythrura kleinschmidti*, a globally 'Endangered' species, and endemic to Viti Levu. Two threatened categories

Table 3-3-1. Terrestrial vertebrates of south east Viti Levu (1)

No.	Scientific Names	English Names	Fijian Names	Introduced, Endemic, Threat Status	Field observation and Remarks
Birds					
1	<i>Egretta sacra</i>	Eastern Reef Heron	Belo		Not recorded. But doubtless a visitor along the creeks from time to time.
2	<i>Ardea novaehollandiae</i>	White-faced Heron	Belo matavula		Not recorded. But this recently-arrived bird on Viti Levu has been seen in the Rewa delta area and along the Navua River and so may well occur in the area.
3	<i>Anas superciliosa</i>	Pacific Black Duck	Ganiviti		Singletons or pairs seen several times on the Wainikatama and Waivaka Rivers
4	<i>Accipiter rufigitorques</i>	Fiji Goshawk	Reba	Fiji Endemic	Uncommon, only three seen.
5	<i>Circus approximans</i>	Pacific Harrier	Manu levu		Uncommon several seen over both forest and secondary habitats
6	<i>Falco peregrinus</i>	Peregrine Falcon	Ganivatu	At Risk in Fiji	Not recorded. A very rare species in Fiji which is known to nest on the cliff faces of the Korobasabasaga range from where they could hunt over the study area. No suitable rock faces were noted in the Waivaka area. Not a globally threatened species.
7	<i>Porzana cinereus</i>	White-browed Crake		Conservation Concern in Fiji	Not recorded. There would appear to be no suitable habitat in the Waivaka area for this species, which inhabits freshwater swamps and ponds. Although threatened in Fiji this is not a globally threatened species.
8	<i>Porzana tabuensis</i>	Spotless Crake	Mo	Data Deficient in Fiji	Not recorded. There would appear to be no suitable habitat in the Waivaka area for this species, which inhabits freshwater swamps ponds and thick wet vegetation. Although probably threatened in Fiji this is not a globally threatened species.
9	<i>Columba vitiensis</i>	White-throated Pigeon	Soqeloa		Uncommon, only one seen.
10	<i>Streptopelia chinensis</i>	Spotted Dove		Introduced	Not recorded. But could be present along roadsides
11	<i>Gallicolumba stairii</i>	Friendly Ground-dove	Qilu	Vulnerable Endemic to Fiji Samoa and Tonga	Not recorded. But may well occur. Uncommon on Viti Levu perhaps because of mongoose predation. Difficult to see but usually calls frequently. The forest appeared to be suitable for this species.
12	<i>Ducula latrans</i>	Barking Pigeon	Soqe	Endemic to Fiji	Commonly seen and more commonly heard because of its loud and distinctive call.
13	<i>Ptilinopus perousii</i>	Many-coloured Fruit-dove	Kuluvotu		Uncommon heard twice.
14	<i>Chrysoenas luteovirens</i>	Golden Dove	Bunako	Endemic to Viti Levu and offshore islands	Common although fewer than expected calling
15	<i>Phigys solitarius</i>	Collared Lory	Kula	Endemic to Fiji	Common seen or heard on several occasions every day
16	<i>Chamosyna amabilis</i>	Red-throated Lorikeet	Kulawai	Endangered Endemic to Fiji	Not recorded. A very rare species: none were seen in a dedicated 3-month survey in 2001/2. May be nomadic in response to flowering trees ? there were very few suitable trees (eg vuga) in flower during the survey - and it may occur at different times at Waivaka even if not recorded.
17	<i>Prosopaea personata</i>	Masked Shining Parrot	Kaka	Vulnerable Endemic to Viti Levu	Uncommon one or two heard or seen most days and a group of four observed.
18	<i>Cacomantis flabelliformis</i>	Fan-tailed Cuckoo	Todi		Uncommon heard once or twice on most days
19	<i>Eudynamis taitensis</i>	Long-tailed Cuckoo	Migrant		Not recorded. Unlikely to be seen in the area, as it is a rare visitor to Viti Levu.
20	<i>Tyto alba</i>	Barn Owl	Belo		Not recorded. But doubtless present. No night surveys were undertaken.
21	<i>Tyto longimembris</i>	Eastern Grass Owl			Not recorded. This is known from only four specimens taken in the nineteenth century but all from southeast Viti Levu. It is presumed extinct but the comparatively extensive grasslands at the confluence of the Wainivuga and the Waivaka rivers could be suitable habitat. Further work would be required to confirm this.
22	<i>Collocalia spodiopygius</i>	White-rumped Swiftlet	Kakabace		Common seen flying over forest and secondary habitats at all times of the day.
23	<i>Todiramphus chloris</i>	White-collared Kingfisher	Lesi		Common seen or heard several times each day.
24	<i>Hirundo tahitica</i>	Pacific Swallow			Not recorded. May be found along the larger rivers.
25	<i>Artamus mentalis</i>	Fiji Woodswallow	Vukase	Endemic to Fiji	Locally fairly common in open areas and forest openings.
26	<i>Aplonis tabuensis</i>	Polynesian Starling	Vocea		Uncommon or rare seen on only three occasions.
27	<i>Acridotheres tristis</i>	House Mynah	Maina	Introduced	Not recorded.
28	<i>Acridotheres fuscus</i>	Jungle Mynah	Maina ni veikau	Introduced	Locally abundant especially near the camps and main road and where cattle were present.
29	<i>Pycnonotus cafer</i>	Red-vented Bulbul	Ulurua	Introduced	Abundant around the camps and fairly common along drilling access roads and the open area on the Waivaka River.
30	<i>Turdus poliocephalus</i>	Island Thrush	Tola		Uncommon. Only a few heard singing each day and so uncommonly encountered but more likely to have been revealed by more walks through the forest rather than on roads and drilling access tracks.
31	<i>Trichocichla rufa</i>	Long-legged Warbler		Data Deficient Endemic to Fiji	Not recorded. A rare species which is very difficult to see although it has a distinctive song. Its habitat requirements are poorly-known but there was some forest at Waivaka that was believed to be suitable. Areas of suitable habitat such as this should be surveyed at dawn ideally using tape-recordings of the species.
32	<i>Cettia ruficapilla</i>	Fiji Bush-warbler	Manu	Endemic to Fiji	Commonly heard but rarely seen.
33	<i>Petroica multicolor</i>	Scarlet Robin	Diriqwala		Common many fledglings recorded.
34	<i>Rhipidura spilodera</i>	Streaked Fantail	Sasaira		Common
35	<i>Mayornis lessoni</i>	Slaty Monarch	Sasaira	Endemic to Fiji	Common but less common than in many forest areas.
36	<i>Clytorhynchus vitiensis</i>	Lesser Shrikebill	Digisau		Common
37	<i>Clytorhynchus nigrogularis</i>	Black-faced Shrikebill	Kiro	Vulnerable Endemic to Fiji	Uncommon. A vociferous pair at the Wainikatama camp; two others heard calling and one seen.
38	<i>Myiagra vanikorensis</i>	Vanikoro Broadbill	Matayalo		Common more common than expected although mostly seen along roads and around openings
39	<i>Myiagra azureocapilla</i>	Blue-crested Broadbill	Batidamu	Endemic to Fiji	Common
40	<i>Pachycephala pectoralis</i>	Golden Whistler	Ketedromo		Common
41	<i>Lalage maculosa</i>	Polynesian Triller	Manusa		Common
42	<i>Zosterops explorer</i>	Fiji White-eye	Qiqi	Endemic to Fiji	Abundant throughout forest areas.

Table 3-3-1. Terrestrial vertebrates of south east Viti Levu (2)

No.	Scientific Names	English Names	Fijian Names	Introduced, Endemic, Threat Status	Field observation and Remarks
43	<i>Zosterops lateralis</i>	Silvereye	Qiqi		Uncommon except in more open habitats - roadsides and along the Waivaka River.
44	<i>Erythrura pealii</i>	Fiji Parrotfinch	Qiqikula	Endemic to Fiji	Common
45	<i>Erythrura kleinschmidti</i>	Pink-billed Parrotfinch	Sitibatibua	Endangered Endemic to Viti Levu	Uncommon One or two seen on three occasions and singles heard or seen flying overhead on eight occasions; all within 500m of camp. More research is needed to clarify its habitat preferences: birds were seen both in old-growth forest and roadside bushes.
46	<i>Amandava amandava</i>	Red Avadavat	Siti	Introduced	Not recorded. Inhabits grasslands and not likely to be present.
47	<i>Padda oryzivora</i>	Java Rice Sparrow	Manumanu ni Raisi	Vulnerable Introduced	Not recorded. Inhabits grasslands and not likely to be present.
48	<i>Myzomela jugularis</i>	Orange-breasted Myzomela	Delakula	Endemic to Fiji	Common
49	<i>Foulehaio carunculata</i>	Wattled Honeyeater	Kikau		Abundant
50	<i>Gymnomyza viridis</i>	Giant Forest Honeyeater	Sovau	Vulnerable Endemic to Fiji	Commonly heard although overall density difficult to assess because of the strength of their call.

Reptiles

1	<i>Brachylophus fasciatus</i>	Banded Iguana	Vokai	Endangered	Not encountered or reported but probably occurs at very low density because of predation by the Mongoose and feral cats.
2	<i>Candoia bibronii</i>	Pacific Boa	Gata		Not encountered but reported by landowners. As elsewhere on Viti Levu probably occurs at a low density because of predation by the Mongoose and feral cats.
3	<i>Ogmodon vitiensis</i>	Fiji Burrowing Snake	Bolo	Endemic to Viti Levu Vulnerable	Not encountered but reported by landowners. The Namosi area is the only place where this species appears to persist at a reasonable density.
4	<i>Gehyra vorax</i>	Giant Forest Gecko			Not encountered. A very secretive species and difficult to find.
5	<i>Gehyra oceanica</i>	Oceanic Gecko		?Introduced	Not encountered but almost certainly occurs. Usually a common forest gecko.
6	<i>Gehyra mutilata</i>	Stump-toed Gecko		Introduced	Not encountered. A recently introduced species confined to buildings or their near vicinity.
7	<i>Lepidodactylus lugubris</i>	Mourning or Pacific Gecko		Introduced	Not encountered. An introduced species confined to buildings or their near vicinity.
8	<i>Lepidodactylus manni</i>	Mann's Forest Gecko		Endemic	Not encountered but probably occurs. Usually a rare forest gecko.
9	<i>Hemiphyllodactylus typus</i>	Tree Gecko			Not encountered. A rare introduced species.
10	<i>Hemidactylus frenatus</i>	House Gecko		Introduced	Not encountered. An introduced species confined to buildings or their near vicinity.
11	<i>Hemidactylus garnotti</i>	Fox Gecko			Not encountered but probably occurs. An apparently declining gecko but not confined to forest.
12	<i>Nactus pelagicus</i>	Slender-toed Gecko			Recorded
13	<i>Emoia mokosariniveikau</i>	Turquoise Forest Skink		Endemic	Unidentified Skink - Recorded. This tree skink was seen on three occasions a voucher specimen was collected. Currently <i>Emoia mokosariniveikau</i> is known only from Vanua Levu and so if the identification is confirmed it will be a new record for Viti Levu. If this is not <i>Emoia mokosariniveikau</i> then it will be a new species.
14	<i>Emoia campbelli</i>	Campbell's Skink		Endemic to Viti Levu	Not encountered. Currently only known from higher altitudes (Monasavu) and not yet recorded in the Namosi area.
15	<i>Emoia concolor</i>	Green tree Skink		Endemic	Not encountered. Usually a common tree skink but found mainly in disturbed habitats.
16	<i>Emoia impar</i>	Blue-tailed Copper-striped Skink			Not encountered a ground skink which is unlikely to occur in upland forested areas.
17	<i>Emoia cyanura</i>	Brown-tailed Copper-striped Skink			Not encountered. A ground skink which is unlikely to survive in upland forest areas because of predation by the Mongoose and feral cats.
18	<i>Emoia parkeri</i>	Bronze-headed Skink		Endemic	Recorded. An arboreal skink which was comparatively commonly recorded.
19	<i>Lipinia noctua</i>	Moth Skink			Not encountered but probably occurs. A secretive but usually quite common skink which is not confined to forest.
20	<i>Cryptoblepharus eximius</i>	Pacific Snake-eyed Skink		Endemic	Not encountered a ground skink of coastal areas but one which has been found way inland up along major rivers and so may occur.

Amphibians

	<i>Bufo marinus</i>	Cane Toad	Boto	introduced	Common around the camp
	<i>Platymantis vitiensis</i>	Fiji Tree Frog	Ula	Endemic	Opportunistic searching revealed the presence on three occasions

Mammals:Native

	<i>Pteropus tonganus</i>	Pacific Flying Fox	Beka		No day time roosting camps were encountered in the limited area surveyed. This bat was surprisingly uncommon only 10-20 being seen flying around each evening.
	<i>Pteropus samoensis</i>	Samoan Flying Fox	Beka ni Siga	Vulnerable	A few seen flying around the forest each day
	<i>Notopteris macdonaldi</i>	Long-tailed Fruit Bat			Not recorded. This is a nocturnal cave-roosting species. No caves were visited during this preliminary survey and no landowner discussions were held to locate the whereabouts of any caves.
	<i>Emballonura semicaudata</i>	Sheath-tailed Bat	Bekabeka		Not recorded. This is a nocturnal cave-roosting species. No caves were visited during this preliminary survey and no landowner discussions were held to locate the whereabouts of any caves.

Mammals:Introduced

	<i>Rattus rattus</i>	Black Rat			6 rats were caught on 146 'corrected trap-nights', providing a standard index of 4.1. This is a relatively low index.
	<i>Herpestes auropunctatus</i>	Mongoose			Observed
	<i>Felis domesticus</i>	Feral cat			Not captured in the live traps used.
		Feral pigs			Sign of feral pigs was observed in the forest.

birds: Friendly Ground Dove and Peregrine Falcon were not recorded.

2) Reptiles

Only three species were recorded on herpetological survey. Of major significance was the finding (and collection) of an arboreal tree, and it looks like *Emoia mokosariniveikau* that is only known from Vanua Levu. Local informants indicate that the Viti Levu endemic, Bolo *Ogmodon vitiensis*, a small burrowing snake, is found at the site. This is a threatened species classified as 'Vulnerable'.

3) Amphibians

Two species were recorded. The introduced Cane Toad, Boto, *Bufo marinus* was common around the camp but was not seen in the forest. Opportunistic searching revealed the presence on three occasions of the small and very little seen Fiji Tree Frog, Ula, *Platymantis vitiensis* (endemic).

4) Mammals

Two native species of fruit bat or flying fox were recorded including the rare Samoan Flying Fox *Pteropus samoensis*. As for introduced mammals, the Black Rats *Rattus rattus* were caught by traps. The mongoose *Herpestes auro punctatus* was observed, but as with the feral cat *Felis domesticus* was not captured in the live traps. Sign of feral pigs was observed in the forest.

3.3.2. Flora study

The flora study described key vegetation types such as montane cloud forest, upland forest, lowland forest and wetlands, and common plants found in each vegetation type. It also confirmed the present condition of rare precious species. The ground truth survey was carried out at a selected site – Waivaka South. A Scholar of the University of the South Pacific was entrusted with the field survey.

(1). Overview of Fiji's Flora

The flora of Fiji was assembled from propagules that were transferred across an ocean barrier. Of the 476 plant genera native to Fiji, 90% are shared with Papua New Guinea, and 65 to 75% of these area present in North Queensland, New Caledonia and the islands of western Melanesia: Vanuatu, Solomon Islands. The remains 10% of the Fijian genera are either endemic or restricted to the Pacific.

About 10% Fijian seed plants were probably transferred to the island by cyclonic storms, and 3% dispersed by ocean. The remaining 87% were either bird or bat dispersed.

Though endemism of vascular plants species has been estimated by 23% or 35% in Fiji, recent studies indicated that endemism for the natural forests in the province of Serua and Namosi could be as high as 60%. Speciation for some group of plants is very high: for the native palm flora has 100% endemism.

A review of the current state of knowledge about Fiji's flora recorded approximately 2530 species of vascular plants. The plants consist of 301 pteridophyte species (310 taxa) and 2225 seed plant species. Of these, 63% (1592 species) are considered native, of which 56% (892 species) are endemic to Fiji. The remaining 37% (936 species) consist of introduced exotics, of which 34% (319 species) have become naturalised. However, estimates since 1980 in excess of 1500 undocumented cases where plant species have been introduced deliberately or accidentally into Fiji, including more than 100 palm species, a large number of orchids, ornamental plants and various weeds.

There are approximately 1028 vascular plant genera in Fiji, 53% of which contain at least one native species, and of those genera containing native species, 49% have species endemic to Fiji.

(2). The Rare and Endangered Flora of South Viti Levu

A total of 80 vascular plant species (Table 3-3-2) considered rare and endangered have been recorded from the Viti Levu South Area. The species list was extracted from a list of vascular plant species submitted for the Fiji National Biodiversity Strategy and Action Plan (BSAP) as a list of potentially rare and threatened plants that need immediate conservation measures by the national government to ensure their protection. All (80 species) are native with 69% (56 species) endemic. For Waivaka South and Waisoi, 31 species are recorded.

(3). Principal Vegetation Types

Nine principal vegetation types are recognized for Fiji. Eight of these vegetation types are present in the area. The vegetation types include:

- 1) Smaller Island Vegetation
- 2) Mangrove forest and shrubs (on large Islands)
- 3) Coastal vegetation
- 4) Freshwater wetland Vegetation
- 5) Lowland rain forest
- 6) Upland rain forest
- 7) Cloud forest
- 8) Grassland vegetation

The Lowland rain forest (tropical rain forest) predominates in the area, and the Upland rain forest and the Cloud forest are found in the inland. These vegetation types are important because the biological diversity is well conserved.

(4). Field survey

The field survey of the native forest of Waivaka South in Namosi province was carried out from December 9, 2002 to December 13, 2002. The survey involved the documentation of plants found in the area. For vascular plants, a preliminary annotated checklist was compiled based on field observations whilst trekking through the area, and the detailed assessment of the vegetation's growth status and plant distribution in the identified natural forest. In assessing plant distribution patterns a 6m X 60m Belt Transect was used. The name, relative position, bole height, crown height and width of shrubs and trees with heights > 3m and diameter at breast height (dbh) >10 cm within the transect were recorded.

The flora is compiled from the assessment of the forest that is relatively intact from the four forest types identified for detailed quantitative vegetation study. The total number of species is 173 except 12 invasive species. The composition of the vascular flora of Waivaka South is summarized in Table 3-3-3. The largest family, Orchidaceae, comprises 10% of the flora. Rubiaceae is the next largest family and contributes 6% to the flora. With regards to the origin, distribution and establishment of the taxa plants that are native to Fiji represent 100 % (i.e., 173 species) of the flora with 60 % (i.e., 104 species) endemic and 40% (i.e., 69 species) indigenous.

In Waivaka South nine species are considered Rare, Critically Endangered, Endangered, Vulnerable and threatened (Table 3-3-4).

Table 3-3-2. Rare and endangered plants of the Viti Levu South Area

Checklist Legend:

Distribution Status (Dist/St): E=endemic; I=indigenous

Conservation Status and its Basis (CSB): CE=critically endangered; EN=endangered; TH=threatened; DD=data deficient.

TC=plant known from type collection, holotype collection and type locality only; 1L= one locality; 2L= two localities; 3L three localities; 1C=a single collection; 2C=two collections; 3C=three collections; *= inadequately known.

Location - Province: Cak= Cakaudrove; Lom=Lomaiviti; Mac=Macuata; Nad=Nadroga; Nai= Naitasiri; Nam=Namosi; Nav=Navosa; Rew=Rewa; Ser=Serua

Species	Dist/St	CSB		Locality	Province
<i>Acmopyle sahniana</i> Buchh. & N. E. Gray	E	CE		Mt. Vakarogasau, Waisoi – Korobasabasaga range	Nam
<i>Agathis macrophylla</i>	I	E		Threatened from Logging	
<i>Agrostophyllum megalurum</i> Reichenb.	I	TH	1C	Namosi Village vicinity	Nam
<i>Alyxia erythrosperma</i> Gillespie	E	DD	TC	Between Naqarawai and Saliadrau- Wainikoroluva	Nam
<i>Angiopteris opaca</i> Copel.	E	TH	TC	Nadarivatu	Ba
<i>Appendicula bracteosa</i> Reichenb.	I	DD	TC	Namosi Village vicinity	Nam
<i>Asplenium induratum</i> Hook.	E	DD	1L	Mt. Voma	Nam
<i>Astronidium floribundum</i> A. C. Sm.	E	DD	TC	Mt. Korobaba upper south east slopes	Rew
<i>Astronidium pallidiflorum</i> A. C. Sm.	E	DD	TC	Hills west Waivunu creek between Galoa & Korovou	Ser
<i>Astronidium saulae</i> A. C. Sm.	E	DD	1L	Mt. Korababa south slopes	Rew
<i>Atuna elliptica</i> (Kostermans) Kostermans	E	TH	2L	Saru vicinity, Tamanua creek, Vatukarasa, Viria	Nad-Nav, Nai
<i>Balaka macrocarpa</i> Burret	E	CE	4L	Along the Nabukavesi - Namosi road.	Ser, Nam, Cak, Mac
<i>Balaka microcarpa</i> Burret	E	E	1L	Wailoku water catchment, Savura reserved forest	Nai
<i>Blechnum gibbum</i> (Labill.) Mett.	I	DD	1L	Maybe grown as an ornamental	
<i>Bulbophyllum polypodioides</i> Schltr.	I	TH	1C		
<i>Bulbophyllum samoanum</i> Schltr.	I	TH	2C	Nadarivatu vicinity & Namosi village, waisoi	Ba, Nam
<i>Bulbophyllum sessile</i> (Koen) J.J. Sm.	I	TH		Near Suva, waisoi	Rew, Nam
<i>Calophyllum amblyphyllum</i>	E	E		Waisoi	Nam
<i>Carruthersia macrantha</i> A. C. Sm.	E	TH	2C	Waisoi, Lomaivuna	Nam, Nai
<i>Casearia fissistipula</i> A. C. Sm.	E	TH	TC	Naivucini, Waisale creek junction with Wainimala river	Nai
<i>Cleistanthus micranthus</i> Croizat	E	TH	3C	Hills between Wainigere & Waisese	Ser
<i>Cleistocalyx seemanii</i> (A. Gray) Merr. & Perry var. <i>punctatus</i> Merr. & Perry	E	DD	TC	vicinity of Namosi,	Nam
<i>Coelogyne lycastoides</i>	I	DD		Waisoi	Nam
<i>Cryptocarya laucifolia</i> A. C. Sm.	E	TH	2C	Nasinu	Nai
<i>Ctenopteris vodonaivalui</i> Brownlie	E	DD	TC		Nam
<i>Ctenopteris vomaensis</i> Brownlie	E	DD	TC	Mt. Voma track	Nam
<i>Cyathea affinis</i>	I	E		Waisoi	Nam
<i>Cyathea plagiostegia</i> Copel.	E	DD	TC	Mt. Naitaradamu	Nam
<i>Cyphosperma "naboutini"</i>	E	CE		North of Naboutini village in Mahogany forest	Ser
<i>Cyrtandra cyathibracteata</i> Gillet	E	TH	TC	Matawailevu, Wainano crk- Wainimala river	Nai
<i>Dennaetia flaccida</i>	I	E		Waisoi	Nam
<i>Diospyros elliptica</i> var. <i>opaca</i> A. C. Sm.	E	DD	TC	Upper Navua River	Ser
<i>Discocalyx amplifolia</i> A. C. Sm.	E	TH		Upper Wainimala	Nai
<i>Discocalyx crinita</i> A. C. Sm.	E	TH	1L	Tawavulu creek, inland from Naboutini, Galoa	Ser
<i>Eleocharis ampliflorus</i> A. C. Sm.	E	TH	TC	Waibu creek, upper Wainanu river	Rew
<i>Eleocharis pittosporoides</i> A. C. Sm.	E	DD	TC	Hills east of Navua river	Nam
<i>Elaphoglossum bastruncatum</i> Brownlie	E	DD	TC		Nam
<i>Eleocharis chionanthus</i> A. C. Sm.	E	DD	TC	Hills west of Waivunu creek between Galoa & Korovou	Ser
<i>Flacourtia mollipila</i> Sleumer	E	TH	TC	Lami quarry	Rewa
<i>Flickingeria comata</i> (Bl.) A. Hawkes	I	TH	1C	Lami quarry, Suva, Waisoi	Rew, Nam
<i>Freycinetia vitiensis</i> Seem.	E	TH	4C	Mt. Voma	Nam
<i>Garmoti villosa</i> Swallen	E	DD	TC	Korobasabasaga range rock cliffs	Nam
<i>Glochidion atalotrichum</i>	E	CE	1L	Waisoi	nam
<i>Grammitis vitiensis</i> Brownlie	E	DD	TC	Mt. Voma	Nam
<i>Gulubia microcarpa</i> Essig	E	V	2L	Galoa road to Namuamua village, Raciba rd to Mt Sorolevu	Nam, Mac
<i>Heterospathe phillipsii</i> Sp. Nov. Fuller & Dowe	E	E	1L	Nakavu forest (NFMPP Reserve)	Nam
<i>Lindsaea gueriniana</i> (Gaud.) Desv.	I	DD	1L	Mt. Korobaba	Rew
<i>Lindsaea moorei</i> (Hook.) Fourn.	I	DD	1L	Mt. Korobaba	Rew
<i>Lunathyrium gillespiei</i> (Copel.) Brownlie	E	DD	1C; 1L	Stream banks in dense forest	Nam
<i>Lycopodium serratum</i> Thunb.	I	TH	1L	Waisoi – Korobasabasaga Range	Nam
<i>Malaisia scandens</i> (Lour.) Planch.	I	TH		Waidina river above Naqali	Nai
<i>Malaxis platyphila</i>	E	DD		Waisoi	Nam,
<i>Mapania parvibractea</i> (C. B. Clarke) T. Koyama	I	TH	1C	Wainadodo river	Nam
<i>Memecylon inseparatum</i> A. C. Sm.	E	DD	TC	Near Nabua Village	Nai
<i>Metroxylon vitiense</i> (H.A. Wendl.) H.A. Wendl. ex Hook.	E	V	5L	Naduruloulou, Deuba, Galoa swamps.	Nai, Ser, Nam, Cak
<i>Neovitchii storckii</i> (H.A. Wendl.) Becc.	E	E	2L	Naduna near Waidradra crk., Near Nagali village	Rew, Nai
<i>Octarrhena oberonioides</i> (Schltr.) Schltr.	I	DD	1C	Mt. Korobalevu slopes, near the Naitasiri-Rewa boundary	Nai-Rew
<i>Pandanus sonicola</i> A. C. Sm.	E	DD	TC	Bay of Islands	Rew
<i>Parkia parri</i> Horne ex Baker	E	DD	Ex	Parri's coffee plantation;	Rew, Bua
<i>Passiflora barclayi</i> (Seem) Mast.	I	TH		Nukulua Is, Levuka	Rew, Lom
<i>Peperomia namosiana</i> Yuncker	E	DD	TC	Wainabua creek near Mt. Naitaradamu	Nam
<i>Pleocnemia elagans</i> (Copel.) Holtt.	E	TH	1L	Wet lowland forest of Vanua Levu & eastern Viti Levu	Nam, Cak
<i>Pleocnemia leuzeana</i> (Gaud.) Presl	I	TH	1L		Nai
<i>Podocarpus affinis</i> Seem.	E	EN	1L	Mt. Tuvutau., Mt. Voma, Mt. Naitaradamu, near its summit, Korobasabasaga, Monasavu	Nam, Ser, Ba
<i>Pomatocalpa vaupelii</i> (Schltr.) J. J. Sm.	I	TH		Veinuqa creek, Navua tributary	Nam
<i>Psychotria bullata</i> A. C. Sm.	E	TH	3L	Veinuqa creek, Galoa	Nam, Ser
<i>Psychotria magnifica</i> (Gillespie) Forsberg	E	TH	3C	Mt. Naitaradamu; Hills north of Wainavidrau creek.;	Nam
<i>Psychotria scitula</i> A. C. Sm.	E	DD	TC	Mt. Voma	Nam
<i>Psychotria valleculeata</i> A. C. Sm.	E	TH	TC	Nausori highland south slopes, Namosi creek drainage	Nad-Nam
<i>Psychotria vomensis</i> Gillespie	E	TH	3C; 1L	Mt. Voma; Mt. Naitaradamu	Nam
<i>eris vittata</i> L.	I	TH	1L	South east Viti Levu	Nam, Nai, Ser
<i>Schizaea fistulosa</i> Labill.	I	DD	1L	Mt. Vuimasia – Korobasabasaga range	Nam
<i>Schoenus achaetus</i> (T. Koyama) T. Koyama	I	CE	1C	Mt. Nabui track, Waisoi	Nam
<i>Serianthes melanesica</i> var. <i>meboldii</i> Fosberg	E	DD	*1L	Lami	Rew
<i>Syzygium simillimum</i> Merr. & Perry	E	TH	2C	Summit Mt. Korababa	Rew
<i>Tapelosperma babuscense</i> Mez.	E	TH	TC	Naboubuco creek headwaters, upper Wainimala	Nai
<i>Tarennia joskei</i> (Horne ex Baker) A. C. Sm.	E	TH	2C	Navesi, east of Naikorokoro creek	Rew
<i>Terminalia capitanea</i>	E	V		Waisoi	nam
<i>Tmesipteris truncata</i> (R. Br.) Desv.	I	TH	2L	Waisoi – Korobasabasaga range	Nam
<i>Zeuxine vieillardii</i> (Reichenb) Schltr.	I	TH		Veisari river	Rew

Table 3-3-3. Classification summary of the vascular plants identified in Waivaka South

Groups	Families	Genera	Species
Fern & allies	12	18	29
Gymnosperms	3	3	7
Dicots	41	68	106
Monocots	8	25	31
Total			173

Table 3-3-4. Origin and conservation status of Waivaka South

Species	Origin	Preservation Status	
		¹ IUCN 1997	² Others
<i>Agathis macrophylla</i>	Indigenous	Vulnerable	Vulnerable
<i>Appendicula bracteosa</i>	Indigenous		Rare , Data deficient
<i>Astronidium saulae</i>	Endemic		Rare , Data deficient
<i>Cyrtandra cyathibracteata</i>	Endemic	Threatened	Rare
<i>Elaeocarpus chionanthus</i>	Endemic		Rare , Data deficient
<i>Flickingeria comata</i>	Endemic		Rare , Data deficient
<i>Malaxisplatycheila</i>	Endemic		Rare , Data deficient
<i>Pandanus sonicola</i>	Endemic		Rare , Data deficient
<i>Podocarpus affinis</i>	Endemic	Endangered	Vulnerable

¹ species listed in the IUCN Red List of Threatened Plants and their conservation status.

² Plant species at risk as suggested by Brownlie (1977), Smith (1979-91), Doyle (1998), Tuiwawa (1999).

(Vegetation analysis)

The forest types selected, based on topographical features, included a high elevation (420m) ridge top (site 1); mid elevation (350m) slope forest (site 2) and ridge top (site 3) and; creek flat (site 4) at 250m asl. The ridge top forest is dominated by yaka (*Dacrydium nidulum* and *Dacrydium nausoriense*) and dakua (*Agathis macrophylla*); the slope forest (350 m) by damanu (*Calophyllum*), kaudamu (*Myristica*), yasiyasi (*Cleistocalyx*, *Syzygium*) and bau (*Palaquim fidjiense*, *Palaquim porphyreum*); the creek flat forest (250 m) by kauvula (*Endospermum macrophyllum*) and sa (*Parinari insularum*).

Characteristic of the Forest Type is as below:

Site 1. **Ridge Top Forest** – high elevation (420m asl)

The forest varies in height from 5 to 28 m. A sub-canopy layer was noticed between 9 to 15 m and canopy between 15 to 27 m. There are no gaps in the forest cover. The mean dbh of trees in the transect was 20.8 cm and this ranged from 10m to 56cm. A total of 61 trees (with dbh >10cm) was accounted for in the assessed area of 360 sq. m.

Site 2. **Slope Forest Type** – mid elevation (350m asl)

The forest varies in height from 9 to 25 m with occasional emergent attaining heights up to 38m. A sub-canopy layer was noticed between 8 to 15 m and canopy between 15 to 24 m. There were no gaps in the forest cover. The mean dbh of trees in the transect was 18.2 cm and this ranged from 10 to 40cm. A total of 37 trees (with dbh >10cm) was accounted for in the assessed area of 360 sq. m.

Site 3. **Ridge Top Forest Type** – mid elevation (265m asl)

The forest varies in height 5 to 32 m. The canopy was closed with a sub-canopy layer at c. 10 to 17 m and canopy layer between 17 to 30 m. The mean dbh of trees in the transect is 18.8 cm and

this ranged from 10m to 53cm. A total of 56 trees (with dbh >10cm) was accounted for in the assessed area of 360 sq. m.

Site 4. **Creek-flat Forest** (250m asl.)

The Creek flat forest varied in height from 25 to 32 m. There were three canopy layers occurring at 20m to 30 m, 15m to 20 m and between 10m to 15 m (under-storey with trees of dbh <10cm) with no breaks in the canopy cover. The mean dbh of trees in the transect is 29.3 cm and this ranged from 10m to 73cm. Some of the largest trees encountered in the survey were noticed in the forest type. A total of 23 trees (with dbh >10cm) was accounted for in the assessed area of 360 sq. m. The reason for the low density is there were lots of large trees in the area.

3.3.3. Chemical analyses of eels and clams

The eels (*Anguilla marmorata*) and freshwater clams (*Batissa violacea*) eaten sometime by inland people were captured, pulverized after dried, and then shipped the to ALS Environments in Australia for chemical analysis. The pulverized dry samples were the whole part of eels including the insides and the visceral mass of clams. The number of samples is 26 (eel: 5, clams: 21). The analyzed elements were Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Sr, Ti, V, W and Zn. Statistics values are shown in Table 3-3-5.

3.3.4. Vegetation map

A vegetation map was prepared by the data of the Optical sensor (VNIR) of ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) satellite. The validity of the vegetation map was examined by the ground truth.

(1). Image processing

Three satellite images: Natural Color Image (BGR= 321), False Color Image (BGR= 123) and Pseudo Color Image of band 2 were processed from ASTER data to distinguish vegetations. ASTER band 2 can observe spectrum in wavelength ranging from 0.63 μm to 0.69 μm . This wavelength is known to reflect the difference between vegetation types.

For a part of the study area, ASTER image could not be acquired, therefore JERS-1 /OPS data were interpolated and made mosaic patching. The Granule ID of ASTER data and Path/Row of JERS-1 /OPS data are shown in Table 3-3-6.

Based on the pseudo color image of ASTER band 2, the vegetation distribution of the area are classified into 5 categories: Red purple area, Red purple-dark blue area, Blue area, Yellow-green area, and White area. Estimated vegetation types are shown in Table 3-3-7 and Fig. 3-3-1.

Red-Purple area was presumed to correspond to high mountain zone that distributes Upland rain forest and Cloud forest or a part of Lowland rain forest. Red-Purple to Dark blue area was presumed to correspond to mountain hillside that distributes Lowland rain forest. Blue area was presumed to correspond to slightly thin rain forest. Green-Yellow area was presumed to correspond to grassland vegetation of gentle hills, freshwater wetland vegetation and cultivated land. White saturated areas were presumed to correspond to clouds.

Table 3-3-5. Chemical composition of eels and fresh water clams (dried samples)

		unit: mg/kg																													
Item	population	stat.	Ca	Mg	Na	K	Fe	P	Ag	Al	As	Au	Ba	Be	Bi	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Sr	Ti	V	W	Zn	
Eel	5	Minimum	11,800	646	2,260	7,220	40	9,600	<0.05	51	0.27	<0.05	3.66	<0.05	<0.05	0.28	0.31	2.30	1.69	0.09	10.4	0.03	0.06	0.16	<0.05	17.00	28.1	1.25	<0.05	73.6	
		Maximum	22,500	1,180	3,030	11,100	2,890	15,500	0.06	1,250	1.39	<0.05	38.00	<0.05	<0.05	0.62	1.09	3.52	11.70	0.18	51.6	0.28	1.51	0.66	<0.05	62.70	147.0	11.00	<0.05	89.2	
		Median	20,200	1,020	2,590	9,780	475	13,700	<0.05	247	0.31	<0.05	10.50	<0.05	<0.05	0.33	0.39	2.73	3.69	0.12	14.3	0.03	0.28	0.21	<0.05	38.60	48.0	1.25	<0.05	81.1	
		Average	18,020	971	2,660	9,728	1,086	13,320	0.03	583	0.57	-	13.49	-	-	0.43	0.59	2.76	5.96	0.13	22.5	0.09	0.47	0.34	-	37.18	62.1	3.93	-	81.1	
Fresh water clam	Total	21	Minimum	1,140	430	606	777	522	5,500	<0.05	52	1.80	<0.05	1.64	<0.05	<0.05	0.71	0.89	2.41	7.75	<0.05	11.5	0.13	0.62	0.11	<0.05	3.32	17.6	1.25	<0.05	50.0
			Maximum	4,200	1,280	1,450	1,970	5,290	11,700	0.26	7,120	4.44	<0.05	15.90	<0.05	<0.05	3.55	3.57	6.67	22.20	0.15	165.0	0.40	3.51	0.58	<0.05	20.70	337.0	16.60	0.060	143.0
			Median	2,050	814	1,040	1,370	2,250	7,930	0.06	3,040	2.24	<0.05	6.16	<0.05	<0.05	1.62	1.69	3.65	11.30	0.06	87.6	0.20	1.16	0.29	<0.05	9.62	138.0	6.80	<0.05	84.8
			Average	2,099	795	1,028	1,421	2,326	8,208	0.07	2,916	2.58	-	7.22	-	-	1.78	1.91	3.92	12.49	0.07	80.9	0.22	1.51	0.29	-	9.17	130.3	6.66	0.031	85.3
	(Rewa)	7	Minimum	1,740	796	843	1,140	2,550	5,500	<0.05	3,040	1.80	<0.05	9.73	<0.05	<0.05	0.82	1.44	3.86	12.80	0.03	75.7	0.18	1.57	0.29	<0.05	8.29	128.0	7.20	<0.05	78.0
			Maximum	4,200	1,100	1,110	1,520	3,790	7,930	0.08	4,880	3.31	<0.05	15.90	0.05	<0.05	2.82	3.57	6.67	22.20	0.10	165.0	0.34	3.51	0.46	<0.05	20.70	194.0	10.90	0.060	108.0
			Median	2,430	953	1,040	1,250	2,980	6,720	0.07	4,120	2.22	<0.05	11.60	<0.05	<0.05	1.85	2.06	4.77	14.50	0.06	93.9	0.21	2.28	0.36	<0.05	11.30	152.0	9.10	<0.05	90.3
			Average	2,631	927	981	1,291	3,159	6,676	0.07	4,013	2.30	-	12.53	-	-	1.92	2.17	4.99	16.41	0.06	105.6	0.24	2.32	0.37	-	12.61	163.3	9.04	0.039	90.6
	(Coastal)	3	Minimum	1,460	430	941	874	522	7,370	0.06	52	2.22	<0.05	1.64	<0.05	<0.05	1.79	2.51	2.41	8.43	0.10	11.5	0.20	0.62	0.19	<0.05	3.32	17.6	1.25	<0.05	97.9
			Maximum	1,640	616	1,130	1,100	3,050	9,460	0.07	2,810	3.75	<0.05	3.78	<0.05	<0.05	3.44	2.88	3.42	11.30	0.13	53.7	0.21	0.72	0.33	<0.05	4.62	190.0	8.60	<0.05	124.0
			Median	1,610	443	1,000	1,090	1,310	8,910	0.06	494	2.81	<0.05	1.79	<0.05	<0.05	2.48	2.66	2.48	10.50	0.11	17.5	0.21	0.70	0.26	<0.05	3.75	45.2	1.25	<0.05	109.0
			Average	1,570	496	1,024	1,021	1,627	8,580	0.06	1,119	2.93	-	2.40	-	-	2.57	2.68	2.77	10.08	0.11	27.6	0.21	0.68	0.26	-	3.90	84.3	3.70	-	110.3
	(Navua)	2	Minimum	2,050	450	1,290	777	762	6,790	0.05	128	1.96	<0.05	2.59	<0.05	<0.05	3.01	2.83	2.52	10.40	0.13	30.8	0.30	0.79	0.11	<0.05	4.56	17.9	16.60	<0.05	107.0
			Maximum	2,160	1,280	1,450	1,620	5,290	7,280	0.07	7,120	2.57	<0.05	9.29	<0.05	<0.05	3.55	3.32	6.31	17.50	0.15	128.0	0.40	2.94	0.58	<0.05	9.84	337.0	16.60	<0.05	143.0
			Average	2,105	865	1,370	1,199	3,026	7,035	0.06	3,624	2.27	-	5.94	-	-	3.28	3.08	4.42	13.95	0.14	79.4	0.35	1.87	0.35	-	7.20	177.5	16.60	-	125.0
	(Sigatoka)	9	Minimum	1,140	620	606	1,310	1,140	7,600	<0.05	1,510	1.83	<0.05	3.46	<0.05	<0.05	0.71	0.89	2.73	7.75	<0.05	54.0	0.13	0.82	0.14	<0.05	5.41	70.6	3.40	<0.05	50.0
Maximum			2,720	955	1,320	1,970	2,580	11,700	0.26	3,730	4.44	<0.05	6.75	<0.05	<0.05	1.95	1.49	4.69	12.70	0.07	107.0	0.29	1.35	0.39	<0.05	12.10	157.0	7.90	0.060	78.8	
Median			1,820	790	1,070	1,660	1,890	9,710	<0.05	2,690	2.40	<0.05	5.39	<0.05	<0.05	0.98	1.15	3.17	10.40	0.06	66.7	0.16	1.10	0.21	<0.05	8.41	107.0	5.80	<0.05	63.1	
Average			1,859	777	989	1,704	1,756	9,537	0.07	2,504	2.76	-	4.97	-	-	1.08	1.18	3.36	9.92	0.05	79.7	0.18	1.07	0.23	-	8.69	109.6	5.30	0.029	63.9	

(LOR: Ca Mg Na K Fe:5mg/kg, P:50mg/kg, Al:2.5mg/kg, Ti:0.1mg/kg, V:2.5mg/kg, Other elements:0.05mg/kg)

(All Assay Results are shown by mg/kg)

Table 3-3-6. Satellite images for interpretation

Sensor	Granule ID	Level	Acquisition Date
ASTER	ASTL1A_0011072243420011230304B	Level 1B	2000.11.07
ASTER	ASTL1A_0101102242300101210621B	Level 1B	2001.01.10
ASTER	ASTL1A_0011072243510011230305B	Level 1B	2000.11.07
ASTER	ASTL1A_0101102242380101210622B	Level 1B	2001.01.10
JERS-1/OPS	Path632/ Row330	Level 2	1993.11.19
JERS-1/OPS	Path632/ Row330	Level 2	1993.11.19

Table 3-3-7. Interpretation of vegetation

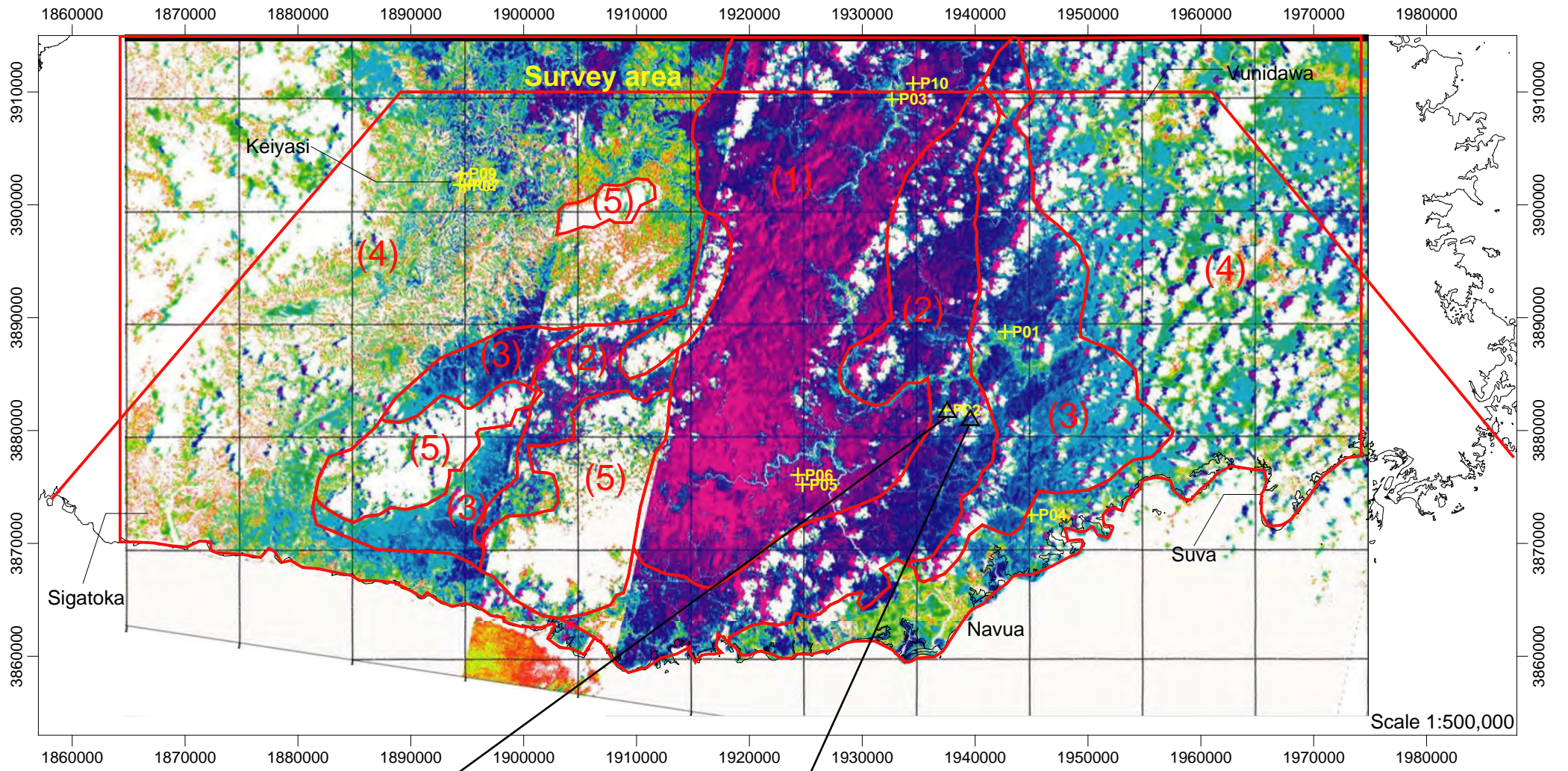
Area	Remarks
Red purple	Upland rain forest, cloud rain forest, lowland rain forest
Red purple -Dark blue	Lowland rain forest (dense)
Blue	Lowland rain forest (slightly thin)
Yellow -Green	Grassland vegetation, freshwater wet land vegetation, cultivated land
White	Cloud

(2). Ground truth

The result of the ground truth is shown in Table 3-3-8. The vegetation types estimated by the pseudo color image of the ASTER optical sensor were concordant with the result of the ground truth. It means that the vegetation map from the pseudo color image reflects the actual distributions of vegetation types of the area.

Table 3-3-8. Result of vegetation ground truth survey

Location	X(Easting)	Y(Northing)	Date	Aster image(pseudo)	Vegetation	Humidity	Soil or geology	Memo
P01	1942643	3888761	2002/10/8	blue, yellow ~ green	few	wet	laterite	Flat plain along a river, low grass and some woods, and farm
P02	1937387	3881807	2002/12/6	red, blue	thick	wet	laterite	Along a road, low grass and tropical rain forest beside Wainikatama Camp
P03	1932631	3909348	2002/10/4	blue (yellow ~ green)	middle	middle	?	From a road along a river, low grass and riverside bush
P04	1944990	3872515	2002/12/6	blue	middle	wet	laterite	Along Namosi Road, low grass and tropical rain forest
P05	1924700	3875215	2002/10/22	dark red	thick	middle	laterite	reclaimed area, tropical rain forest
P06	1924300	3876070	2002/10/22	red	thick	middle	laterite	Tropical rain forest along a road
P07	1894773	3901693	2002/11/18	yellow, white	few	dry	yellow-brown soil	Farm inside a village, farm plants and low grass and dried soil
P08	1894376	3901772	2002/11/18	blue	middle	dry	yellow-brown soil	Small woods beside a village, without short grass
P09	1894498	3902764	2002/11/18	white	few	dry	yellow-brown soil	Grass land, dried soil is exposed in some places
P10	1934511	3910748	2002/9/24	red	thick	wet	?	Tropical rain forest along a road



Pink-billed Parrotfinch
(*Enythrura kleinschmidti*)



Fotified skin
(*Emoia mokosariniveikan*)

- (1) Upland rain forest, Cloud forest
Lowland rain forest
- (2) Lowland rain forest (dense)
- (3) Lowland rain forest (slightly thin)
- (4) Grassland vegetation, Cultivated land
Fresh water wetland
- (5) Cloud

Fig.3-3-1. Satellite Image and vegetation distribution

Classified by Aster Band 2 satellite image

3.4. Soil bacteria survey

In order to examine the possibility of the application for a bacteria leaching and a biological wastewater treatment in the Namosi area, five soil samples were collected and screened for useful microbes.

Table 3-4-1. Characteristics of the soil samples for bacteria

Sampling point	Characteristics of soil	Note
A	Brown gray silt-clay (wet)	Waisoi-Wainitotoyeyeu river junction
B	Light brown silt-clay (dry)	Waisoi-Wainitotoyeyeu river junction
C	Brown gray silt-clay (wet)	Waivaka-Wainavuga river junction
D	Brown gray silt-clay (wet)	Near Wainavuga drilling site (in water)
E	Brown silt-clay (dry)	Near Wainavuga drilling site

Remark: Colors of the soil surfaces were changed into red-brown in sample A, CD.

Target microbes are as below:

- 1) Bacteria leaching applicable microbe
 - Iron oxidative bacteria (*Thiobacillus ferroxidans*)
 - Sulfur oxidative bacteria (*Thiobacillus thiooxidans*)
- 2) Mine wastewater treatment applicable microbe
 - Iron oxidative bacteria, Sulfate-reductive bacteria
 - Heavy-metal resistant filamentous fungi, Heavy-metal resistant yeast

(1). Microbial sampling and culture methods

Type of screening culture medium is shown in Table 3-4-2.

Table 3-4-2. Types of the culture mediums for screening

Target microorganisms	Name of the culture medium for screening	Culture medium	Culture temp. ()
Sulfate-reducing bacteria	B	High agar	20
Sulfur-oxidizing bacteria	Wakaman-Starkey	Liquid	30
Iron-oxidizing bacteria	9K	Liquid	30
Heavy-metal resistant filamentous fungi	Czapek-Dox	Semifluid agar	20
Heavy-metal resistant yeast	Czapek-Dox	Semifluid agar	20

Primary screening was done under the culture medium condition shown in Table 3-4-3 to examine pH and heavy-metal tolerance of microbe.

Table 3-4-3. Condition of the culture mediums

Culture condition	Items	Condition of pH and added heavy-metal						Number of sampling points	Total number of test samples
	pH	2.0	5.0	6.0	7.0				
	Heavy metal	-	-	-	-	Cu	Pb		
	Content of metal (mg/L)	-	-	-	-	1.0	1.0		
Target micro-organism	Sulfate-reducing bacteria		○		○	○	○	5	20
	Sulfur-oxidizing bacteria	○		○				5	10
	Iron-oxidizing bacteria	○		○				5	10
	Heavy-metal resistant filamentous fungi	○		○		○	○	5	20
	Heavy-metal resistant yeast	○		○		○	○	5	20

Remark1: "-" in the table means without adding heavy metal.

Remark2: Cu and Pb were added up to 1mg/L in consideration of background content.

Remark3: Screening were executed only under the condition of "○" in the table.

(2). Results

1) Sulfate-reducing bacteria

No propagation of Sulfate-reducing bacteria were recognized in the culture medium.

2) Sulfur-oxidizing bacteria (Table 3-4-4)

In the culture medium that discriminately cultivates sulfur oxidative bacteria, microbe cells were recognized from all samples. In addition, culture medium with pH2 has a tendency where more microbes were observed than that of pH6. Especially, the sample from point D indicated 10 times microbe as that of other points.

Usual bacteria leaching technology utilizes the microbe that produces sulfate ion with its propagation and can live under low pH condition (pH2) similarly to sulfur oxidative bacteria. The microbes that have above function were detected by primary screening from soil samples of the survey area. Therefore, there are possibilities of bacteria leaching using the microbes of the survey area.

Table 3-4-4. Result of screening sulfur-oxidizing bacteria

Condition of culture mediums	No. of culture mediums	Sampling point	Results of screening (unit: cell/ml) *	Note
pH2	25	A	1.70×10^6	
	26	B	1.91×10^6	
	27	C	1.27×10^6	
	28	D	3.19×10^7	
	29	E	2.10×10^5	
pH6	31	A	4.20×10^5	
	32	B	1.70×10^5	
	33	C	8.00×10^4	
	34	D	6.00×10^5	
	35	E	2.30×10^5	

*Remarks: The number of microorganisms multiplied in 1ml liquid culture mediums.

3) Iron-oxidizing bacteria (Table 3-4-5)

As a result of primary screening for iron oxidative bacteria, $2 \sim 8 \times 10^4$ of microbe cells per 1 ml culture medium were recognized in the samples of point A, C and D under the condition of pH2. In addition, these culture media indicated color changing to yellow-brown. This yellow-brown color suggests iron hydroxide owing to propagation of iron oxidative bacteria. The microbes that have the same function as iron oxidative bacteria were detected by primary screening from soil samples of the survey area. Therefore, there are possibilities of mine wastewater treatment using the microbes of the survey area.

Table 3-4-5. Result of screening iron-oxidizing bacteria

Condition of culture mediums	No. of culture mediums	Sampling point	Results of screening (unit: cell/ml) *1	Color of the culture mediums (precipitation, (ml))
PH2	37	A	2.00×10^4	Weak yellowish-brown (0.1)
	38	B	-	No change (0.2)
	39	C	4.00×10^4	Light yellowish-brown (0.5)
	40	D	8.00×10^4	Light yellowish-brown (0.6)
	41	E	-	Weak yellowish-brown (0.2)
PH6	43	A	-	Strong yellowish-brown (1.2)
	44	B	-	Strong yellowish-brown (0.9)
	45	C	-	Strong yellowish-brown (1.4)
	46	D	-	Strong yellowish-brown (1.3)
	47	E	-	Strong yellowish-brown (1.3)

Remark*1: The number of microorganisms identified in 1ml liquid culture mediums.

Remark 2: “-” in the table means no detected microorganism cells.

4) Heavy-metal-resistant filamentous fungi and yeast (Table 3-4-6, Table 3-4-7))

Propagation of filamentous fungi and yeasts were detected in the culture media with Cu and Pb. The metal adsorption abilities of these microbes are not clarified. However, it is certain that heavy metal resistant microbes inhabit the survey area.

It is not uncertain whether these microbes can be used for actual bacteria leaching or mine wastewater treatment without detailed examination concerning pH tolerance, heavy-metal tolerance, heavy-metal absorbability and propagation ability under the low nutritional condition. However, there is potential of microbes applicable to these technologies in the survey area.

Table 3-4-6. Result of screening heavy-metal-resistant filamentous fungi

Condition of culture mediums	No. of culture mediums	Sampling point	Results of screening	Note
pH2	51	A	-	
	52	B	-	
	53	C	-	
	54	D	-	
	55	E	-	
pH6	57	A	+++	
	58	B	+	Many bacteria mixing
	59	C	-	
	60	D	-	
	61	E	+	
Add Cu (pH7)	63	A	+	
	64	B	+	
	65	C	-	
	66	D	-	
	67	E	+	
Add Pb (pH7)	69	A	-	
	70	B	++	Many bacteria mixing
	71	C	-	
	72	D	-	
	73	E	++	Many bacteria mixing

Remark1: +: Few hyphas of filamentous fungi ++ : Some hyphas of filamentous fungi

+++ : Many hyphas of filamentous fungi

Remark2: “-“ in the table means no detected filamentous fungi.

Table 3-4-7. Result of screening heavy-metal-resistant yeast

Condition of culture mediums	No. of culture mediums	Sampling point	Results of screening (unit: cells/ml)*1	Note
pH2	Y51	A	-	
	Y52	B	-	
	Y53	C	-	
	Y54	D	-	
	Y55	E	1.34×10^7	
pH6	Y57	A	4.00×10^4	
	Y58	B	-	
	Y59	C	-	
	Y60	D	-	
	Y61	E	-	
Add Cu (pH7)	Y63	A	-	
	Y64	B	-	
	Y65	C	4.00×10^4	
	Y66	D	-	
	Y67	E	-	
Add Pb (pH7)	Y69	A	-	
	Y70	B	-	
	Y71	C	-	
	Y72	D	-	
	Y73	E	2.00×10^4	

Remark*1: The number of cells multiplied in 5ml semi-fluid high culture mediums.

Remark2: “-“ in the table means no detected yeast cells.

3.5. Archeological survey

There are two laws that relate to the identification, research and protection of Cultural Heritage in Fiji:

Preservation of Objects of Archaeological and Palaeontological Interest Act,

National Trust of Fiji Act and Amendment ACT.

The Fiji Museum with its Preservation of Object of Archaeological and Palaeontological Act is actively involved in the research, protection and management of archaeological sites of both historic and prehistoric nature.

The analysis of the Literature, Database and Oral History survey in the study area was entrusted by the Department Archaeology, Fiji Museum, and have revealed that there is significant cultural history and remnant archaeological sites and oral history of the Viti Levu South Area.

There are 213 of archaeological sites in the Viti Levu South Area, and range from the earliest occupation of Fiji (Lapita sites- human settlement relics before approximately 3000 years) to sites from late prehistory (hill and ring ditch fortifications) to fairly recent to current occupation. These sites can be classified into 12 types on their characteristics.

Stratified site - stratified relics distributed in sandy beach and dune along coast.

Stone flaking floor site - house floor relics which utilizes flint pieces from mine mark.

Grave

Lapita site

Naga site - stonewall formation (enclosure)

Yavu - old house mound

Cave/rock shelter

Agricultural relics

Koromakawa - old Fijian village relics

Complex - compound relics of rock shelters and other relics

Hill fort - fortification common in mountainous or hilly ridges.

Ring ditch - fortification built in low lying areas using a ring formation. This is particularly prevalent in damp, marshy areas.

Unknown - unclear relics as for details

The known archaeological sites are summarized in Table 3-5-1. The following information will provide a general description and a summary of the types of sites that have been identified in the area so far in the area of Topographic Quadrangle Maps 1:50,000.

1) Sigatoka

Sigatoka has a range of physical features from river valleys to flat areas to rugged areas. Sigatoka's records show prolonged occupation by humans. There are prehistorical Lapita site in Sigatoka dune, hill fort and ring ditch (fortification) on hills. Several cave/rock shelters exist in a limestone area, and plenty earthenwares and shellfishes have been unearthed from caves.

2) Korolevu

Cultural sites at Korolevu are found both on the coastal lands and the higher mountain ranges, while five ring ditches are concentrated mainly on the coastal lands.

3) Navua

Navua comprises of flat areas and rugged terrain. The known cultural sites in the Navua area are concentrated mainly on the flat areas and near the water sources (rivers). The sites are mainly ring ditch fortifications. The recorded sites from Navua include 2 cave/rock shelters, 3 hill forts, 3 ring ditches, 1 stratified site and 10 unknown sites.

4) Suva

The Suva area is a range of flat and hilly coastal area. There is a large concentration of 11 ring ditches and 13 World War II sites. The World War II sites range from bunker sites to seaplane breakwater, hospital, pile light for the Eastern Reef of the Suva Harbour and underground tunnels.

5) Keiyasi

Keiyasi is a mostly mountainous area with mainly prehistoric sites that consist of prehistoric settlement sites (Naga site , Koromakawa , stone flaking floor site), and fortifications (hill fort , ring ditch) .

6) Namosi

Namosi is an area that has extremely rugged terrain with very steep mountain ranges and is covered by tropical forest. There is dense vegetation cover and this makes it difficult to traverse the site or locate sites. Recorded sites include 1 cave/rock shelter, 2 hill forts, 3 ring ditches, 3 complex sites, 2 yavu, 5 agricultural sites and 25 unknown sites.

7) Nausori

Nausori is a mixture of flat and hilly areas and has been agriculturally extensively developed in the recent times. Within the flat areas of Nausori, there is a high concentration of ring ditches.

Table 3-5-1 Summary of archaeological sites

Site Type	Sigatoka	Korolevu	Navua	Suva	Keiyasi	Namosi	Nausori	Total
Stratified site			1					1
Stone flaking floor site					1			1
Grave		1						1
Lapita	2							2
Naga site					4			4
Yavu				3		2	1	6
Cave/rock shelter	3		2	1		1	1	8
Agricultural site	1					5	2	8
Koromakawa	3	3			5			11
Complex				3	8	3	2	16
Hill fort	4	1	3		3	2	4	17
Ring ditch	2	5	3	11	5	3	23	52
Unknown	4	4	10	7	20	25	16	86
Total	19	14	19	25	46	41	49	213

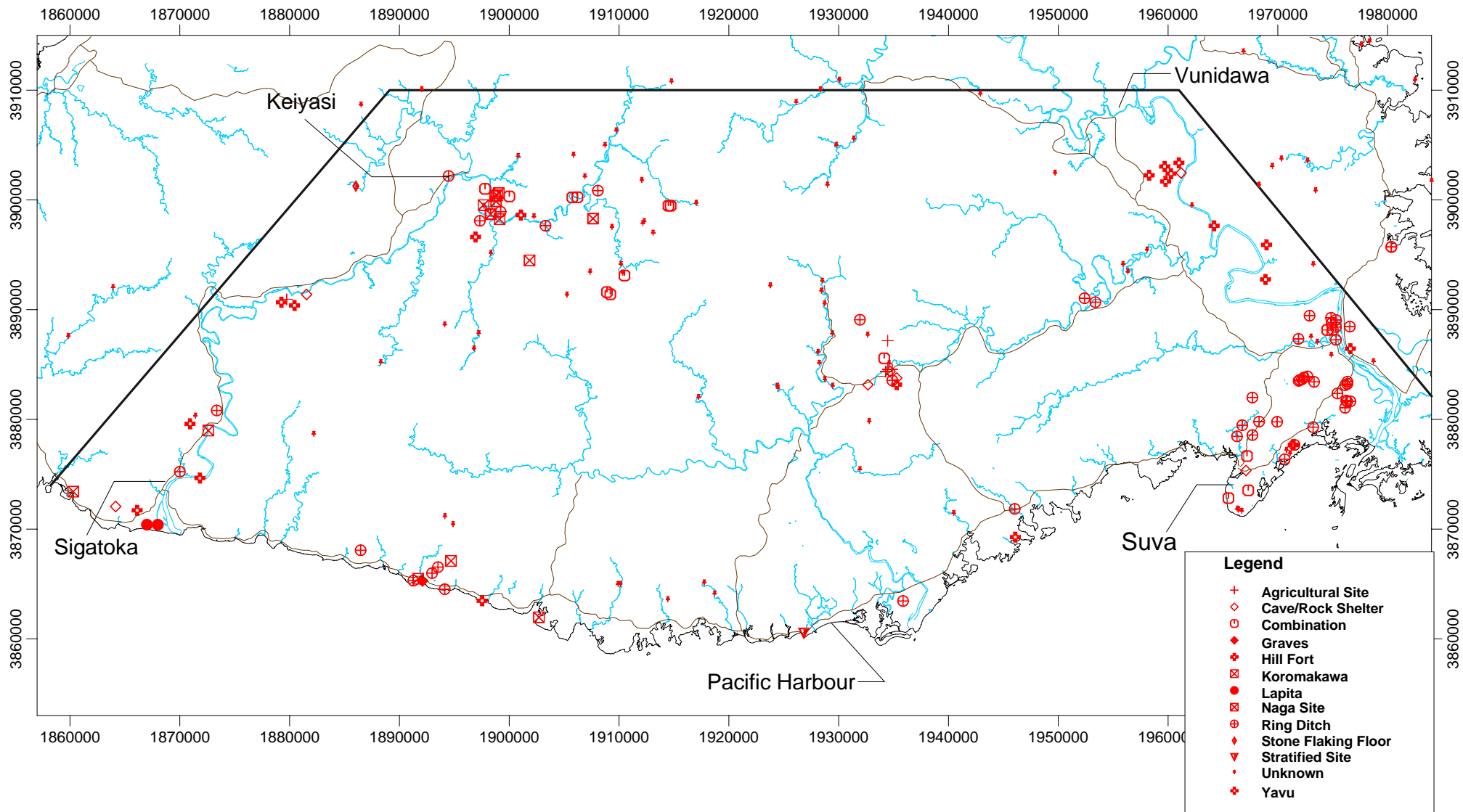


Fig.3-5-1. Location of the archaeological sites

(1:500,000)

Chapter 4. Conclusion and recommendation

4.1. Conclusion

(1). Hydrological survey

Surface water quality study was carried out both during the dry season and the rainy season. The measurement of flow rate and water quality was conducted at 80 sites and 186 samples were collected and analyzed chemically.

Surface water in the area shows generally neutral pH, Ca rich among major cation, and HCO_3 rich among major anions. The water in the area indicates carbonate hardness type. This composition is found mainly of free water, and is the underground water of circulating supply type.

The compositions of major components among drainage systems are slightly different. The water in the Sigatoka River shows the abundance of Ca, while the water in other three drainages (Rewa, Navua and Coastal) indicated almost the same values among these anions. The high Ca and HCO_3 values in the Sigatoka River could be influenced by the distribution of carbonate rocks.

The values of EC and major dissolved components (TDS, Na, Mg, HCO_3 , Cl) in the dry season showed lower than those in the rainy season. It means that major dissolved compositions were diluted by much water according as high precipitation in the rainy season. While, flow rate, turbidity, some of minor components (Al, As, Cr, Zn) in the rainy season shows higher values than those in the dry season. This means that these minor components were not diluted by much volume water in rainy season and it may be caused by other factor. For example, these elements might exist as small particulate form and pass through filter.

Compared with the values of Australian Drinking Water Guidelines, almost higher values above ADWG values were found in the Rewa River and the Navua River. The number of samples with high values increased in the rainy season.

A weather station was installed in the Namosi village secondary school, and two years meteorological data were observed. This data and surrounding other six observation stations data observed by the Department Meteorology of Fiji government were statistically compiled.

(2). Stream sediment survey

A total of 1,845 stream sediment samples (including 128 duplicated samples) was collected from 1,717 locations in the study area during 2002 and 2003. The geochemical map of multi-element analytical data revealed the outline of geochemical characteristic in the study area.

The concentrations of the constituents of major rock forming minerals such as Al, Ca, K, Na, Mg and P in the stream sediment samples were thought to be controlled by the background values of the local geology. For example, the high contents of Ca, Na and Mg were found in the northwest of the study area. In particular, the middle reaches of Sigatoka River indicated high Ca and Mg, where carbonate rocks are widely distributed. The elements of Ba, Cr and V were also controlled by the background values of the geologic units, while Cr content was especially high at the area covered by the Verata group.

The elements of Ag, As, Au, Cd, Cu, Hg, Mo, Pb, S, Sb and Zn were generally accompanied by the porphyry copper or hydrothermal mineralization. Among these elements, the anomalies of Ag, As and Hg

dispersed over the area. They indicate local hydrothermal mineralization. The gold anomalies overlapped with the area on a large scale mineral occurrences adjacent to Namosi and gold occurrences to the south of the Nomosi area, and subordinated Au anomalies also dispersed in all the area. The Cu anomalies concentrate on the big scale porphyry copper mineralization zone adjacent to Namosi in particular, where copper anomaly zone was surrounded by the anomalies of Mo, Pb and Zn. The anomaly of Mo was also detected to the east of the Wainaleka copper occurrence, where a porphyry type mineral occurrence at Echo Creek was located.

The result of principal components analysis summarizes the variability of analytical data. The first principal component may explain the ratio of major rock forming minerals in each geological units. The second principal component may explain the distribution of sedimentary rocks-volcaniclastic rocks-volcanic rocks, and intrusive rocks. The third principal component shows geochemical anomalies on porphyry type or hydrothermal mineral occurrences, and the areas with high scores overlap with the known copper or gold mineral indications.

(3). Fauna and flora survey

The fauna in the area consists of total 84 species of vertebrates, which are mainly of birds. During the fieldwork in tropical rain forest, 34 kinds of birds including a very rare species, Pink-billed parrotfinch, was recognized. A family of skink, *Emoia mokosariniveikau* that had been known only in Vanua Levu Island was possibly recognized.

The eels (*Anguilla marmorata*) and freshwater clams (*Batissa violacea*) were captured and chemically analyzed after drying the whole part of eels or the visceral mass of clams.

Eight of vegetation types based on climate, topography, critical substrate variation and human influences are present in the area: smaller Island Vegetation, mangrove forest and shrubs, coastal vegetation, freshwater wetland Vegetation, lowland rain forest, upland rain forest, cloud forest, and grassland vegetation. The Lowland rain forest (tropical rain forest) predominates in the area, and the Upland rain forest and the Cloud forest are found in the inland ravines. The Grassland vegetation is spread around the Sigatoka valley.

A total of 80 vascular plant species considered rare and endangered have been recorded from the Viti Levu South Area. The fieldwork in Waivaka south has revealed that the vascular plants that are native to Fiji represent almost 100 % (i.e., 173 species) of the flora with 60 % (i.e., 104 species) endemic. A high percentage of endemism and nine rare and threatened species for Waivaka South show a conserved area of high botanical diversity.

A vegetation map was prepared by use of the Optical sensor (VNIR) of ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) satellite data. The validity of the classified vegetation types was confirmed by the ground truthing.

(4). Soil bacteria survey

Five soil samples were collected and screened for useful microbes in the Namosi area. The microbes with the function similar to sulfur oxidative bacteria, iron oxidative bacteria, heavy-metal resistant filamentous fungi and yeast, were detected in the sample. This suggests the possibility of the microbes

application for a bacteria leaching and a biological wastewater treatment.

(5). Archeological survey

The 213 of historical relics and cultural assets are mainly concentrated on the flat areas, its adjacent hill and near the river. They consist of the early Lapita sites (earliest human settlement relics before approximately 3000 years), the late prehistoric sites (before approximately 1000 years) to sites from late prehistory to fairly recent to current sites. The principal ruins are ring structure and fortress ruins called Ring ditch and Hill fort, and old village and settlement ruins called Koromakawa, Naga site or Yavu.

4.2. Recommendation

Through this two years study, data regarding hydrology, meteorology, stream sediment geochemistry, flora and fauna, soil bacteria, and archaeology were obtained and systematically compiled throughout the Viti Levu South Area. The objective of this study was to acquire the environmental background data that will be applied for environmental assessment of future industrial developments. It is required that a continuously investigation shall be conducted to assess an increase of environmental load owing to mining activities, in addition to loggings, and discharge of the domestic waste and wastewater in this area. For this purpose, the following surveys are proposed.

(1). Hydrological survey

It is recommended to acquire water quality background data four times or more a year to clarify the relationship between the concentration of heavy metals elements, precipitation, and flow rate.

(2). Chemical analysis of fishes and benthos

More specimens of other species fishes and benthos should be analyzed chemically to compare with the data obtained by this study and to estimate an adequate intake.