REPUBLIC OF FIJI
WATER AUTHORITY OF FIJI (WAF)

REPUBLIC OF FIJI
PROJECT FOR FORMULATION OF WASTEWATER TREATMENT MASTER PLAN IN WESTERN DIVISION

FINAL REPORT
PART 1 : EXECUTIVE SUMMARY

OCTOBER 2024

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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Preface

The Final Report (F/R) of "the Project for formulation of Wastewater Treatment Master Plan in Western Division" is composed of the following four parts:

Part 1: Executive Summary

Part 2: Regional Wastewater Treatment Master Plan

Part 3: Municipal Sewerage Master Plan

Part 4: Pre-F/S of Priority Projects

This report is Part 1: Executive Summary of the F/R.

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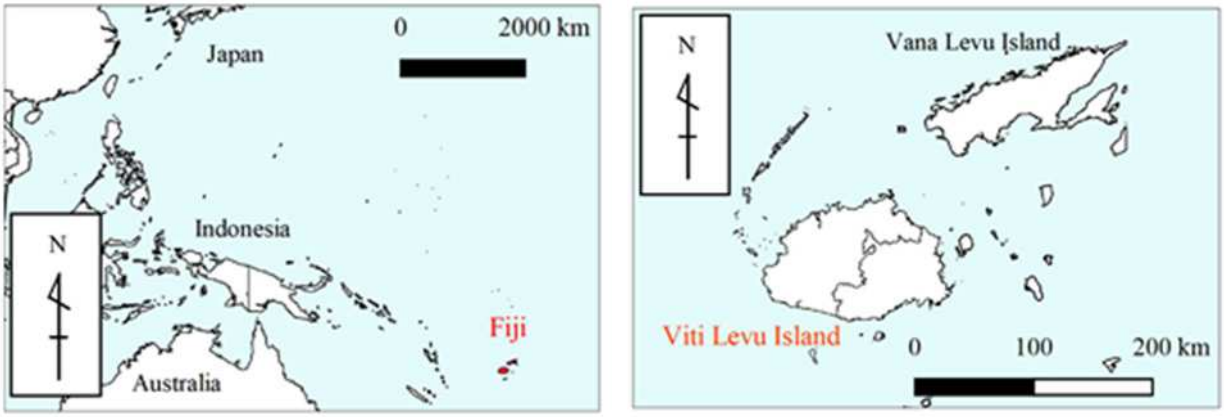
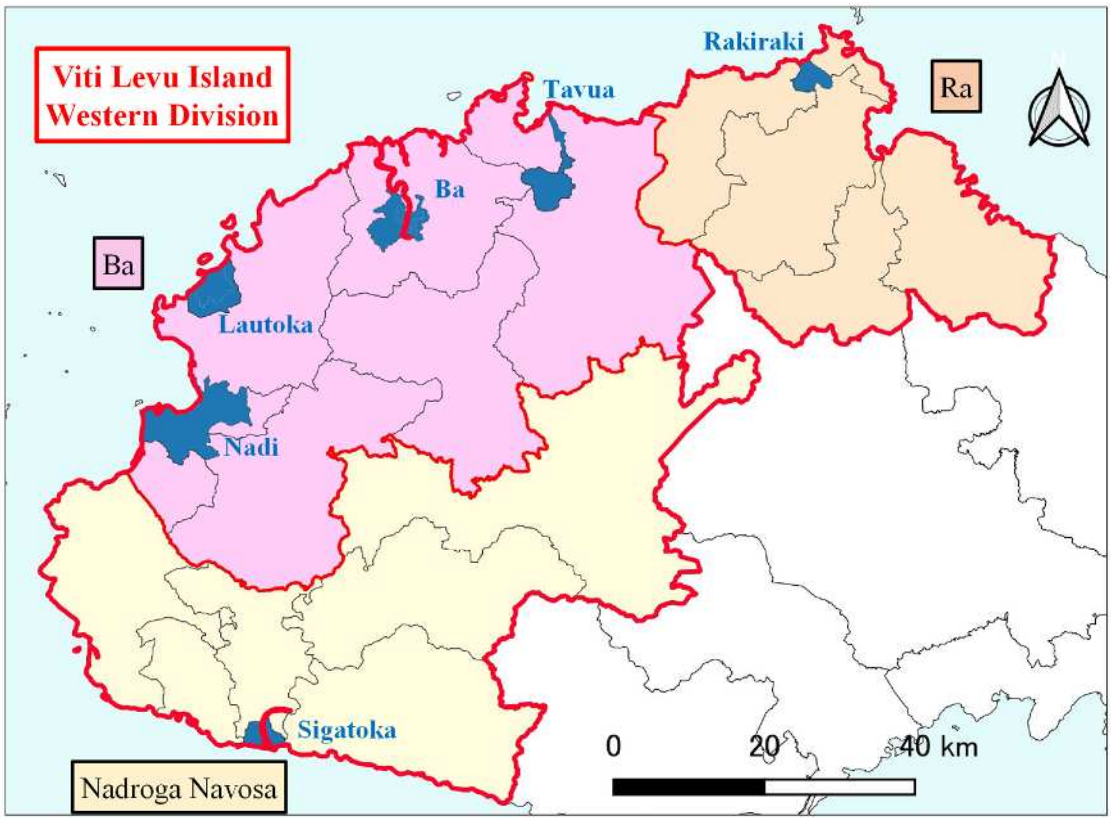
Location Map (Regional Wastewater Master Plan)



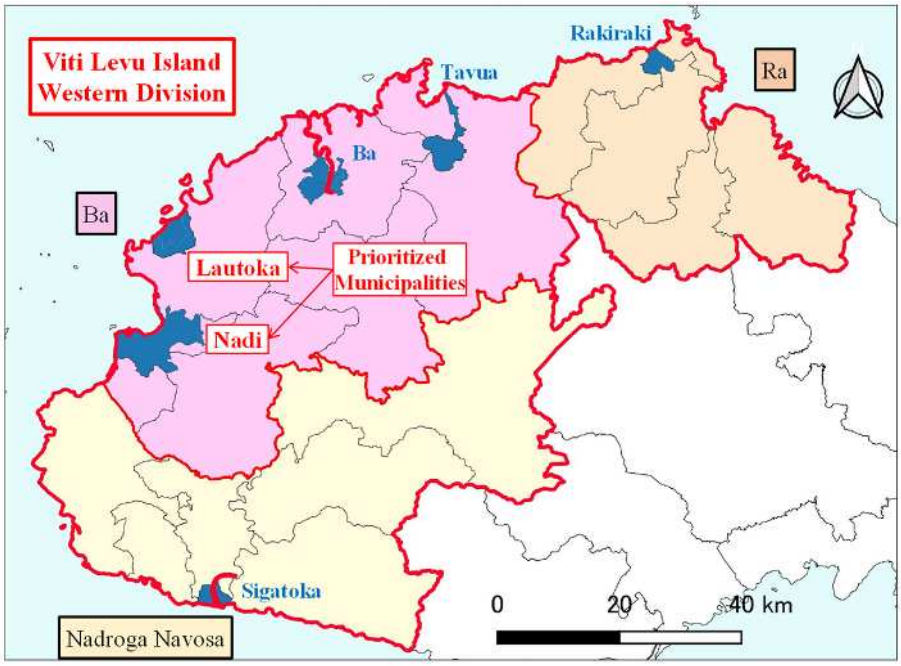


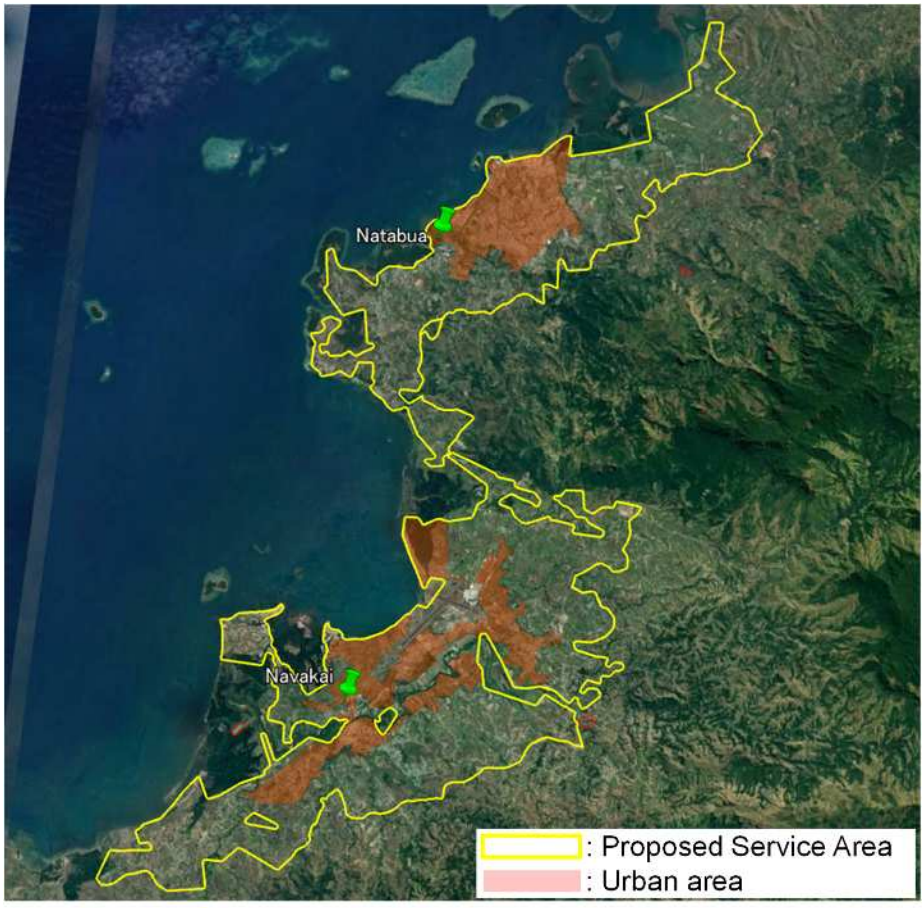
Province	Population		
	Urban	Rural	Total
Ba	165,411	82,297	247,708
Ra	5,987	24,445	30,432
Nadroga Navosa	10,293	48,638	58,931
Sub-total: Western Division	181,691	155,380	337,071
Entire Fiji	494,252	390,635	884,887

Source: Fiji Population & Housing Census 2017

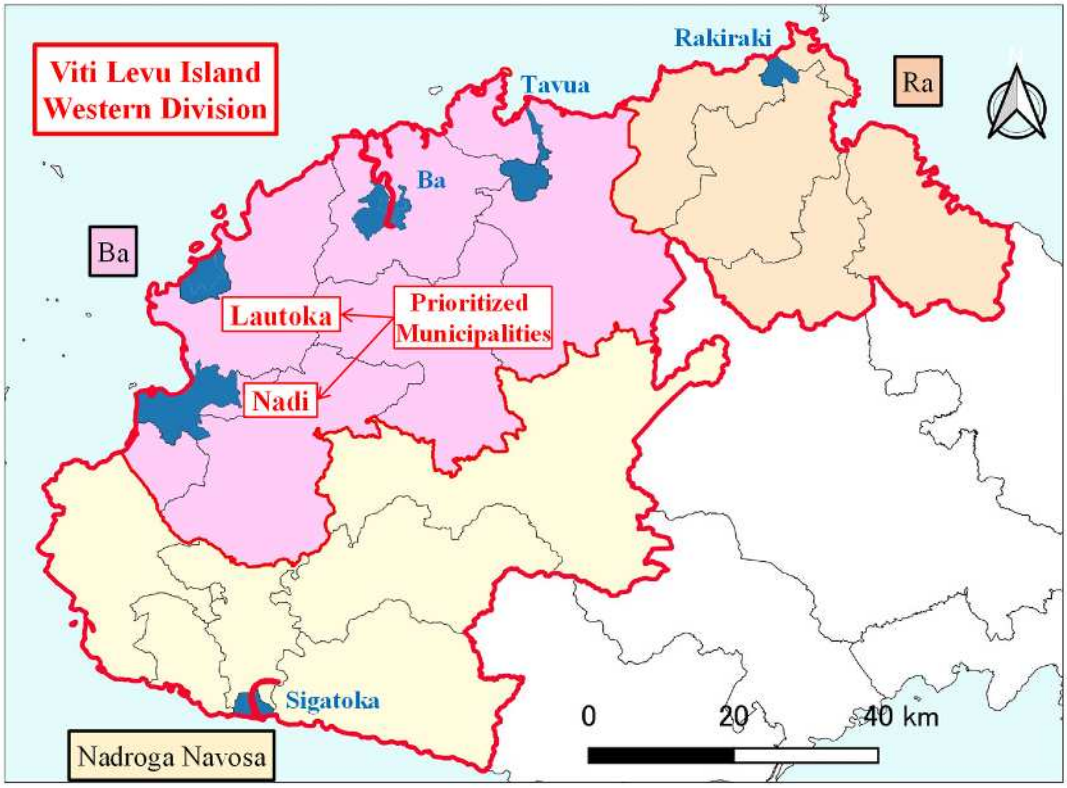
Municipalty	Name of WWTP
Nadi	Navakai
Lautoka	Natabua
Ba	Votua
Sigatoka	Olosara

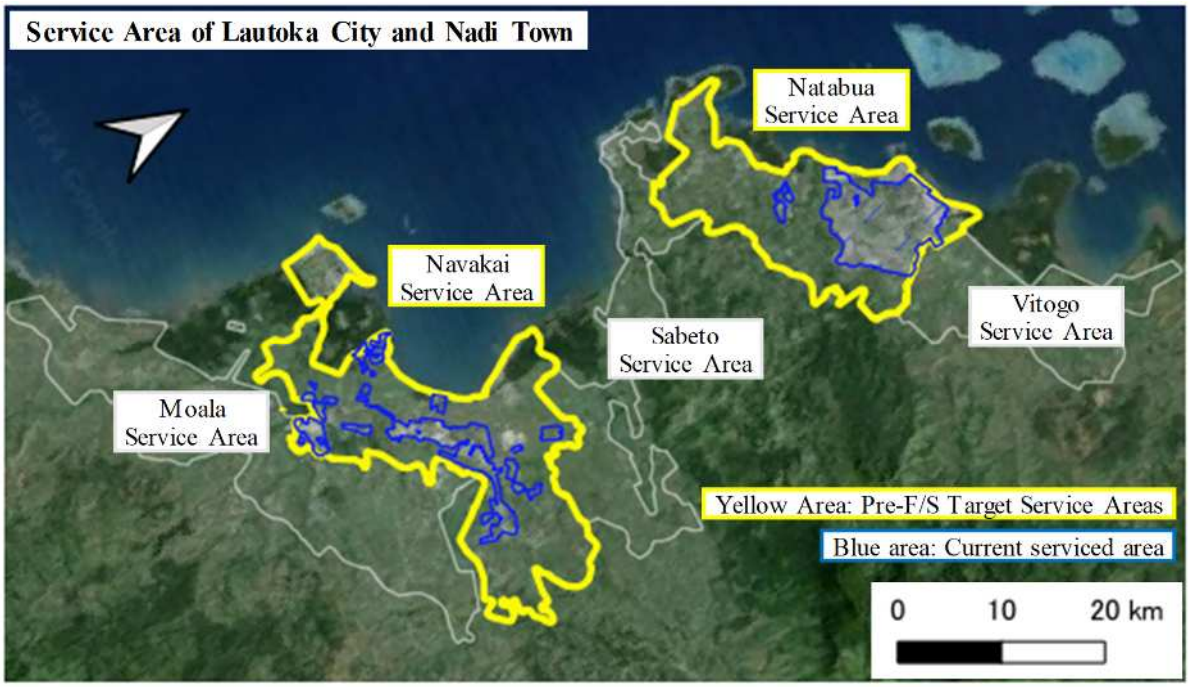
Location Map (Municipal Sewerage Master Plan)





Location Map (Pre-F/S for Priority Project)





Abbreviation

ADB	Asian Development Bank
ADWF	Average Dry Weather Flow
AHP	Analytic Hierarch Process
AL	Aerated Lagoon
AS	Australian Standards
ATP	Affordable To Pay
BOD	Biochemical Oxygen Demand
CAPEX	Capital Expenditure
CD	Capacity Development
CBH	Central Bureau of Health
COD	Chemical Oxygen Demand
C/P	Counter Part
CWIS	Citywide Inclusive Sanitation
DBOM	Design Build Operation Maintain
DD	Detailed Design
DF/R	Draft Final Report
DOE	Department of Environment
DOL	Department of Land
DTCP	Department of Town and Country Planning
DWS	Department of Water and Sewerage
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EIRR	Economic Internal Rate of Return
ESC	Environmental and Social Considerations
FIRR	Financial Internal Rate of Return
FOG	Fats, Oil, Grease
FRA	Fiji Roads Authority
F/S	Feasibility Study
F/R	Final Report
GCF	Green Climate Fund
GHG	Green House Gas
GIS	Geographic Information System
HQ	Headquarters
IC/R	Inception Report
IDEA	Intermittent Decant Extended Aeration
IEE	Initial Environmental Examination
JCC	Joint Coordination Committee
JET	JICA Expert Team
JICA	Japan International Cooperation Agency
JPP	JICA Partnership Programs
KCCP	Knowledge Co-Creation Program (JICA)
LCC	Life Cycle Cost
LEDS	Fiji Low Emission Development Strategy 2018-2050
L&D	Lecture & Discussions
LMMA	Locally Managed Marine Area
MBBR	Moving Bed Biofilm Reactor
ME	Mechanical/Electrical
MHCD	Ministry of Housing and Community Development
MHMS	Ministry of Health and Medical Services
MIMS	Ministry of Infrastructure and Meteorological Service (before organizational restructuring: current MPW)

MLIT	Ministry of Land, Infrastructure, Transport and Tourism (Japan)
MLMR	Ministry of Lands and Mineral Resources
MOA	Ministry of Agriculture
MOE	Ministry of Economy (before organizational restructuring: current MOF)
MOL	Ministry of Land
MOF	Ministry of Finance (after organizational restructuring: former MOE)
MoU	Memorandum of Understanding
MOWE	Ministry of Waterways and Environment
M/P	Master Plan
MPW	Ministry of Public Works, Meteorological Services and Transport (after organizational restructuring: former MIMS)
MWCPA	Ministry of Women, Children and Poverty Alleviation
NPO	Non-Profit Organization
OD	Oxidation Ditch
ODA	Official Development Assistance
OJT	On the Job Training
O&M	Operation and Maintenance
PDWF	Peak Dry Weather Flow
PG/R	Progress Report
PI/R	Project Implementation Report
Pre-F/S	Pre-Feasibility Studies
R/D	Record of Discussion
SCF	Standard Conversion Factor
SDGs	Sustainable Development Goals
SEA	Strategic Environmental Assessment
SEZ	Significant Ecological Zone
SOP	Standard Operation Procedure
SP	Stabilization Pond
SS	Suspended Solids
TC	Technical Committee
TF	Trickling Filter
TLTB	iTaukei Land Trust Board
T-N	Total Nitrogen
TOR	Terms of Reference
T-P	Total phosphorus
TSS	Total Suspended Solids
UNDP	United Nation Development Program
WAF	Water Authority of Fiji
WWTP	Wastewater Treatment Plant

Section 1 REGIONAL WASTEWATER MASTER PLAN

1. INTRODUCTION

(1) Outline of the Project

The Western Division of the Republic of Fiji (hereinafter referred to as "Fiji"), which includes Lautoka and Nadi (the second and third largest cities of Fiji, respectively) as well as Nadi International Airport, is an important location for tourism and other major Fijian industries. Despite robust growth in recent years, wastewater treatment capacity has not kept up with increases in resident and tourist populations. Development of this essential infrastructure corresponding to the increasing demand is urgently needed.

The "National Development Plan 2017-2036" formulated by the Fijian Government in 2017 targets to provide access to centralized treatment systems for 70% of the Fijian population by 2036, thorough the construction and expansion of public wastewater treatment systems in all urban centers. The "Data Collection Survey of Water Supply and Wastewater Sector in the Republic of Fiji" conducted by JICA in 2019 confirmed that the treatment performance of the four existing wastewater treatment plants (hereinafter referred to as "WWTP") located in the Western Division is insufficient. The main reasons were found to be over-capacity operation and lack of proper operation and maintenance (hereinafter referred to as "O&M"). The cause of the over-capacity operation was determined to be due to the existing sewerage master plan (hereinafter referred to as "M/P") being outdated and not reflecting current conditions. The causes of inadequate O&M were found to be a) O&M not being performed according to operational/water quality data, and b) lack of standardized O&M manuals.

To strategically improve the sewerage infrastructure of the Western Division of Fiji, JICA implemented "The Detailed Planning Survey for the Project for Formulation of Sewerage Master Plan in Western Region" to confirm roles of each agencies/department involved with sewerage works. The project contents were discussed and agreed to as the following:

- ✓ "Wastewater Treatment Master Plan in Western Division" (hereinafter referred to as "Regional Wastewater M/P") which considered centralized and decentralized collection methods for the Western Division,
- ✓ "Sewerage M/P for Priority Cities in the Western Division" (hereinafter referred to as "Municipal Sewerage M/P")
- ✓ Pre-Feasibility Studies for the Priority Projects (hereinafter referred to as "Pre-F/S").
- ✓ Strengthen O&M of sewerage facilities

This project, entitled "Project for Formulation of Wastewater Treatment Master Plan in Western Division," will carry out various activities necessary to achieve the four outputs summarized below. By achieving these outputs, the Project aims to improve the performance of sewerage facilities in the Western Division, promote projects for the expansion of facilities, and contribute to the protection and improvement of urban and public health and the water environment of the Western Division.

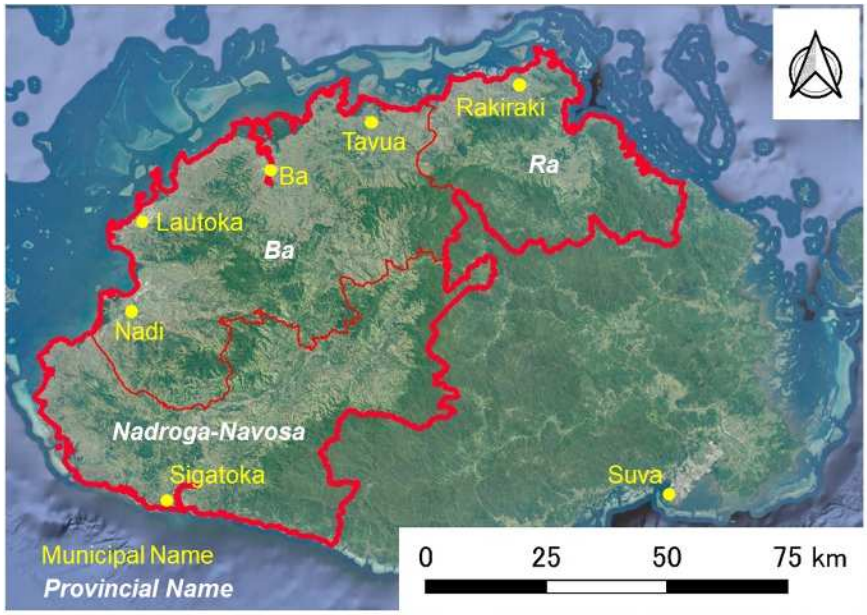
Output 1: A Regional Wastewater M/P that includes centralized and decentralized wastewater treatment systems for the Western Division of Viti Levu Island of Fiji will be formulated.

Output 2: A Municipal Sewerage M/P for priority cities and/or towns identified in the Regional Wastewater M/P will be formulated.

Output 3: A Pre-F/S for priority sewerage project(s) selected in the Municipal Sewerage M/P will be conducted.

Output 4: Capacity on sewerage management (Master Plan formulation, construction management (procurement), facility O&M, etc.) of Water Authority of Fiji (hereinafter referred to as "WAF") and MIMS[1] Department of Water and Sewerage (hereinafter referred as "DWS") will be strengthened.

The target area of the Regional Wastewater M/P is shown in **Figure S1. 1-1** the Ba, Ra, and Nadroga-Navosa Provinces located in the Western Division of Viti Levu Island.



Source: JET

Figure S1. 1-1 Target Area of Regional Wastewater Master Plan

(2) Project Implementation Structure

i. Joint Coordination Committee

The project implementation structure is shown in **Figure S1.1-2**, with the Joint Coordination Committee (hereinafter referred to as "JCC") at its nucleus. This project will use the JCC to ensure mutual communication between parties throughout the planning process, and to ensure prompt approval of the

[1] MIMS: Ministry of Infrastructure and Meteorological Service (before organizational restructuring). Current Ministry of Public Works, Meteorological Services and Transport (MPW)

formulated plans. The main role of the JCC is summarized as follows.

- Confirm and approve progress of Stage 1 Regional Wastewater M/P, Stage 2 Municipal Sewerage M/P and Pre-F/S
- Discuss overall direction of the project and build consensus between relevant authorities

*1: MIMS: before organizational restructuring; current MPW
*2: MOE: before organizational restructuring; current MOF
Source：Created by JET based on R/D

Figure S1. 1-2　Project Implementation Structure

ii. Advisor

Upon the formulation of the M/Ps and implementation of the Pre-F/S study in this project, the Road and Sewerage Bureau of Fukuoka City will be participating as an advisor to provide advice from a professional and technical standing point. In addition, Fukuoka City will also cooperate as the lecturer/instructor of the training program for WAF. Fukuoka City has a record over the years participating/cooperating with Fiji in its water and sewerage projects, holding connections with WAF and familiar with its institutional system; it is hoped that their knowledge will greatly support this project.

iii. Members of the JICA Expert Team

JICA officials and JICA Expert Team (hereinafter referred to as "JET") consists of the following members (see **Table S1.1-1**). In addition, JICA has asked the Fukuoka City to participate as an advisor, and the bureau provides advice on project activities and plans as appropriate.

Table S1. 1-1 Member of the JICA Expert Team

JICA	
NAME	**TITLE**
Hideaki MATSUOKA	Director, Environmental Management Group, Global Environment Department, JICA HQ
Kentaro YOSHIDA	Director, Environmental Management Group, Global Environment Department, JICA HQ
Yukiya HOSAKA	Officer, Environmental Management Group, Global Environment Department, JICA HQ
Shinichi WADA	Officer, Environmental Management Group, Global Environment Department, JICA HQ
Takashi OBA	Assistant Resident Representative, JICA FIJI Office
Shigeki NAMBA	Project Formulation Advisor, JICA FIJI Office
Hideaki IWASE	Project Formulation Advisor (Regional Infrastructure), JICA FIJI Office
Advisor: Fukuoka City	
NAME	**TITLE**
Hironori YASHIMA	Director, Policy Coordination Section, Road and Sewerage Bureau
Shingo MORIKAWA	Assistant Section Chief, Policy Coordination Section, Road and Sewerage Bureau
Shojiro HASHIZUME	Chief, Policy Coordination Section, Road and Sewerage Bureau
Mayumi ONO	Officer, Policy Coordination Section, Road and Sewerage Bureau
Makoto OHTA	Manager, Chubu Sewerage Treatment Center, Road and Sewerage Bureau

CONSULTANT TEAM		
NAME	**TITLE**	**OCCUPATION**
Yoshinobu NAKAJIMA	Team Leader/ Sewerage Works management	Nihon Suido Consultants Co., Ltd.
Kiyohiko HAYASHI	Deputy Team Leader/ Organization & Institutions	Nihon Suido Consultants Co., Ltd.
Tetsuo WADA	Sewerage planning	Nihon Suido Consultants Co., Ltd.
Hiroyuki KAWASHIMA	On-site wastewater treatment planning	Nihon Suido Consultants Co., Ltd.
Shinichi SASAKI / Yoko KOTEGAWA	WWTP planning and design	Nihon Suido Consultants Co., Ltd.
Hideyuki IGARASHI	Sewer network system and existing drainage survey	Yachiyo Engineering Co., Ltd.
Yasuaki MATSUMOTO	Mechanical engineering	Nihon Suido Consultants Co., Ltd.
Jyoji WAKAMOTO	Electrical engineering	Nihon Suido Consultants Co., Ltd.
Yuichiro KONNO	Implementation Plan and Cost estimation	Nihon Suido Consultants Co., Ltd.
Yoshiyuki CHOSO	Economic & Financial Analysis	Nihon Suido Consultants Co., Ltd.
Yuriko KUDO	Environmental & Social considerations/ Public Awareness	Yachiyo Engineering Co., Ltd.
Yasuo IIJIMA	Natural condition survey	Yachiyo Engineering Co., Ltd.
Koichi OKAZAKI	Water Supply Planning Adviser	Nihon Suido Consultants Co., Ltd.
Divesh SAMI	Sewerage Planner	NRW Macallan (Fiji) Ltd
Daiana BOLA	Sewerage Planner	NRW Macallan (Fiji) Ltd
Andrew BANNER	Civil Engineer	NRW Macallan (Fiji) Ltd
Aneshwar AMIT	Economic/Financial Analyst	NRW Macallan (Fiji) Ltd
Ashika SINGH	Secretary	NRW Macallan (Fiji) Ltd

Source: JET

2. PROJECT IMPLEMENTATION SCHEDULE

The project implementation schedule is shown in **Figure S1. 2-1**.

Main Contents	Phase 1				Phase 2							
	2021	2022			2023				2024			
	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q
Regional Wastewater M/P (Output 1)												
Municipal Sewerage M/P (Output 2)												
Pre-F/S (Output 3)												
Capacity Strengthening (Output 4)												

Source: Created by JET based on R/D

Figure S1. 2-1 Project Implementation Schedule

3. NATIONAL PLANS

The National Development Plan (hereinafter referred to as "NDP") was formulated under an initiative of the Ministry of Economy with the vision of "transformation of Fiji" and is a plan that lays out the path to the future of Fiji and all Fijians. The plan includes a 20-Year Development Plan (2017-2036) and a comprehensive 5-Year Development Plan (2017-2021). Detailed action plans as well as specific goals and policies that are in line with the 20-Year Development Plan are provided in the 5-Year Development Plan.

One goal of the 20-Year Development Plan related to wastewater is to increase the connection rate to centralized treatment to 70% of the population by 2036. In addition, although no specific figures have been set, the plan states that measures to improve and expand access to centralized treatment systems for all urban centers, as well as on-site processing and public health protection measures in rural areas will be considered.

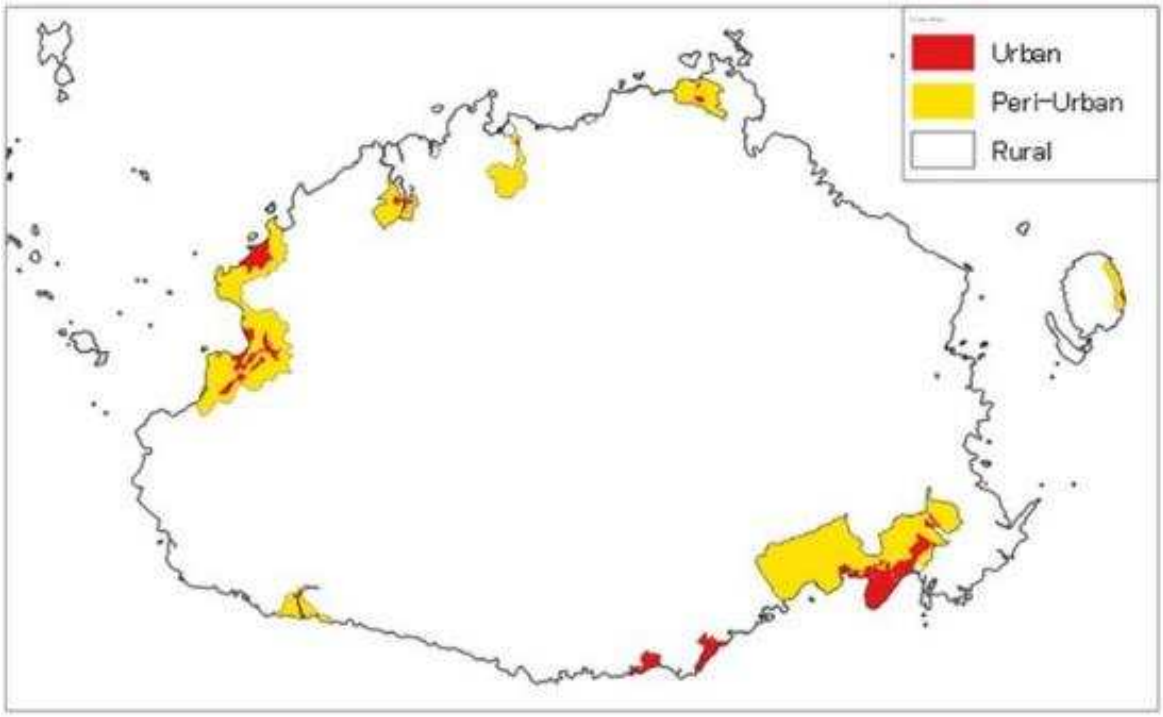
Specifics of some of the goals are shown in **Table S1. 3-1**. The goal for access to centralized sewerage is 70% for both urban and rural areas. The NDP follows the definitions of "urban" and "rural" defined by the Fiji Bureau of Statistics and refers to the urban and peri-urban areas shown in **Figure S1. 3-1** as urban areas, and all other areas as rural.

Table S1. 3-1 National Development Targets (20-Year Development Plan)

Table 1: National Development Targets

	2015	2021	2026	2031	2036
Inclusive Socio-economic Development					
Access to clean and safe water in adequate quantities (% of population) (SDG 6.1)	78	90	95	100	100
Access to clean and safe water in adequate quantities, rural (%of population) (SDG 6.1)	58	85	90	100	100
Access to clean and safe water in adequate quantities, urban (% of population) (SDG 6.1)	98	100	100	100	100
Access to central sewerage system (% of population) (SDG 6.2)	25	40	50	60	70
Access to central sewerage system, urban (% of population) (SDG 6.2)	25	40	50	60	70
Access to central sewerage system, rural (% of population) (SDG 6.2)	0	40	50	60	70

Source: : NDP



Source: Fiji Bureau of Statistics

Figure S1. 3-1 Urban Areas Defined by the Fiji Bureau of Statistics

4. CURRENT STATUS OF WASTEWATER SECTOR IN THE WESTERN DIVISION

4.1 Centralized Treatment System

(1) Outline of Centralized Treatment System

Currently, sewerage works in the Western Division are implemented in Lautoka, Nadi, Ba, and Sigatoka. The outline is summarized as **Table S1. 4-1.**

Table S1. 4-1 Outlines of Sewerage Works in Western Division Municipalities

Contents		Nadi	Lautoka	Ba	Sigatoka
Sewer networks	Total length (km)	129	80.5	26	16
	Pipe material	Concrete PVC, AC, Clay	DIP, AC, Concrete, PVC	AC, PVC	DIP, AC, PVC
	Bore size (mm)	100~550	150~750	150~375	100~300
Pumping station	Number	42	12	8	6
	No. of pumps (per station)	2~3	2~3	2	2~3
WWTP	Name	Navakai	Natabua	Votua	Olosara
	Started operation	1974	1983	1996	1986
	Capacity (estimation)	35,000EP ($7,000m^3$/day)	43,000EP ($8,600m^3$/day)	10,000EP ($2,000m^3$/day)	4,000EP ($800m^3$/day)
	Treatment process	IDEA	Stabilization pond	Stabilization pond	Stabilization pond
	Discharge to	Nadi River	Ocean outfall	Water channel	Sigatoka River

Source : JET

(2) Condition of Effluent Quality

The quality of treated wastewater from the four existing WWTPs is shown **Table S1. 4-2**. The general category of Fiji's effluent standards (described in detail later) requires that treated water have less than BOD of 40 mg/L, but all WWTP plants discharge water with a BOD greater than 40 mg/L (shown in red in the table).

Table S1. 4-2 Water Quality Test Results from 4 Existing WWTPs

WWTP	Year	Influent (mg/L)					Effluent (mg/L)				
		T-SS	BOD	COD	T-N	T-P	T-SS	BOD	COD	T-N	T-P
Navakai	2014	970.0	500	930	9.2	3.5	80	55	140.0	5.4	2.8
	2015	930.0	360	880	9.2	2.8	44	41	91.0	5.6	2.3
	2016	590.0	450	1300	-	2.3	54	49	120.0	-	1.6
	2017	510.0	320	650	58.0	3.3	160	85	230.0	32.0	1.5
	2018	450.0	240	590	47.0	3.2	120	68	180.0	29.0	2.4
	2019	250.0	190	440	33.0	6.5	43	29	77.0	27.0	5.9
	2020	200.0	140	430	20.0	7.6	24	20	100.0	15.0	2.8
	2021	200.0	130	290	21.0	9.0	29	31	54.0	20.0	4.3
	Avg.	510.0	290	690	26.0	4.8	69	47	120.0	18.0	3.0
Natabua	2014	530.0	320	590	8.4	4.6	82	64	170.0	4.4	3.4
	2015	480.0	300	580	11.0	3.7	44	65	130.0	4.9	2.2
	2016	440.0	390	830	-	0.6	52	44	120.0	-	0.8
	2017	850.0	330	600	51.0	3.6	110	69	190.0	26.0	2.3
	2018	300.0	210	520	41.0	2.3	55	51	140.0	22.0	1.2
	2019	370.0	220	410	28.0	5.8	53	39	110.0	20.0	4.0
	2020	870.0	220	530	20.0	8.1	58	36	120.0	15.0	5.7
	2021	430.0	170	480	22.0	7.0	57	83	210.0	1.9	3.9
	Avg.	530.0	270	570	26.0	4.4	65	57	150.0	14.0	2.9
Votua	2014	470.0	290	750	8.5	4.6	86	41	140.0	5.1	3.4
	2015	540.0	310	800	7.8	2.5	78	53	160.0	3.9	1.9
	2016	590.0	270	910	11.0	2.6	42	49	130.0	9.8	1.7
	2017	2200.0	290	660	32.0	3.1	70	50	140.0	17.0	2.0
	2018	950.0	270	670	36.0	2.8	54	53	140.0	15.0	1.9
	2019	130.0	120	200	25.0	4.8	47	32	95.0	11.0	3.0
	2020	180.0	130	320	23.0	9.1	47	46	160.0	9.9	9.0
	2021	130.0	130	260	20.0	8.9	70	47	120.0	8.8	6.4
	Avg.	700.0	230	590	20.0	4.7	62	47	130.0	10.0	3.6
Olosara	2014	740.0	410	1200	9.1	3.4	78	57	120.0	4.3	1.7
	2015	350.0	240	530	9.1	3.0	45	55	160.0	5.1	2.4
	2016	440.0	260	550	30.0	2.5	42	41	140.0	24.0	1.0
	2017	410.0	290	580	48.0	4.2	60	40	130.0	18.0	1.5
	2018	510.0	370	870	46.0	3.3	49	55	140.0	20.0	1.0
	2019	130.0	120	200	25.0	4.8	42	32	92.0	7.8	1.6
	2020	200.0	650	380	78.0	110.0	32	33	140.0	6.5	26.0
	2021	6.2	380	19	150.0	430.0	3.9	57	1.9	83.0	210.0
	Avg.	360.0	340	570	47.0	64.0	45	47	120.0	20.0	28.0

Source：JET based on WAF's data

4.2 Decentralized Treatment System

(1) Installation Status of Septic Tanks

Table S1. 4-3 show the types of sanitation facilities (toilets) and their connection types in Western Division of Fiji based on data from the 2017 Census. Since 18.7% of sanitation facilities "flush to piped sewerage system," currently about 20% of the population is connected to centralized treatment systems. 80% of the population utilizes decentralized treatment systems, in which septic tanks are the most widely used facility.

Table S1. 4-3 Current Status of Installation (Connection) of Sanitation Facilities

Toilet Facility (Province Total)	Ba		Nadroga-Navosa		Ra		Western Division	
	Number	%	Number	%	Number	%	Number	%
Flush to piped sewer system	13,712	24.4	499	3.8	81	1.2	14,292	18.7
Flush to septic tank	35,857	63.9	9,284	70.9	4,497	63.9	49,638	65.1
Flush to pit latrine	936	1.7	348	2.7	457	6.5	1,741	2.3
Pit latrine with slab	1,818	3.2	1,333	10.2	786	11.2	3,937	5.2
Pit latrine without slab (open pit)	986	1.8	610	4.7	455	6.5	2,051	2.7
Water sealed	2,365	4.2	913	7.0	565	8.0	3,843	5.0
Shared toiled	388	0.7	69	0.5	178	2.5	635	0.8
Other	50	0.1	33	0.3	15	0.2	98	0.1
Total	56,112	100	13,089	100	7,034	100	76,235	100

Source: JET based on Fiji 2017 Population & Housing Census

(2) O&M Situation of Septic Tank

In the interview survey about desludging frequency. When asked how often sludge was removed from their septic tanks, about half of respondents answered "never" followed by "uncertain" and "more than 10 years." Less than 10% of those surveyed responded that they bail their septic tanks once every 10 years or less. Of those that responded "once every 10 years or more" most admitted they called the bailer only because of problems such as leaks or overflows. It is suspected that desludging is almost never done in general households.

(3) Disposal of Septage

The septage collected by private companies is transported to a WWTP operated by WAF for treatment. Of the four WWTPs operated by WAF in the Western Division, the three shown in the **Table S1. 4-4** accept septage. These facilities use the stabilization pond method for treatment. At Votua and Olosara WWTPs, septage is introduced directly into the anerobic ponds. At Natabua WWTP, the sludge is discharged directly into wetlands adjacent to the WWTP. The sludge input point is a natural wetland with two dumping pits. However, there is no constructed discharge point. The sludge either soaks into the ground or flows out to the ocean.

Table S1. 4-4 Current Status of Septage Treatment

Facilities that accept septage	Treatment process
Natabua WWTP (Lautoka)	Sludge dumping pit
Votua WWTP (Ba)	Dump to treatment system (stabilization pond)
Olosara WWTP (Sigatoka)	Dump to treatment system (stabilization pond)

Source: JET

5. FINANCIAL STATUS OF WAF

(1) Income Statement

The WAF financial statements up to 2017 are shown below. Financial statements from 2018 onwards will be provided after the audit is completed. Audited income statement is shown in the **Table S1. 5-1** below.

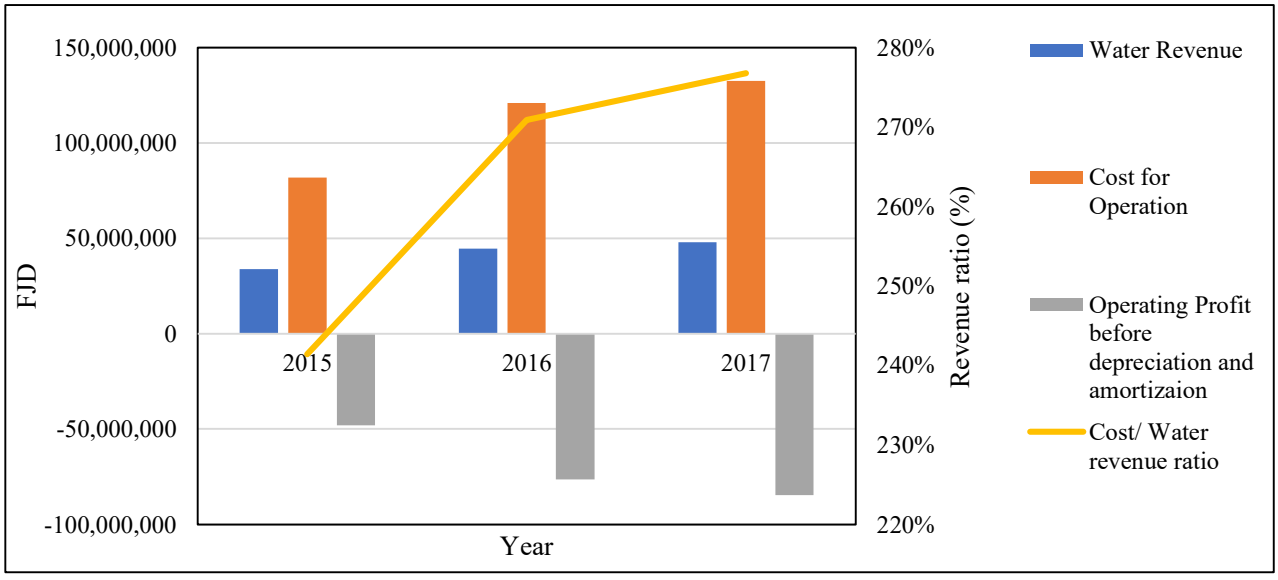
Table S1. 5-1 WAF Income Statement

(Units: FJD)

Year	2015	2016	2017
Revenue	87,329,457	72,071,657	78,899,685
Other Income	22,497,780	49,326,460	48,747,566
Total Revenue	109,827,237	121,398,117	127,647,251
Personnel expenses	(19,515,199)	(26,026,267)	(33,950,443)
Operating expenses	(62,452,610)	(94,936,223)	(98,732,047)
Operating Profit before depreciation and amortization	27,859,428	435,627	(5,035,239)
Depreciation & amortization	(58,300,576)	(59,288,328)	(56,892,377)
Finance Income	50,315	103,454	154,410
Loss for the period	(30,390,833)	(58,749,247)	(61,773,206)
Total comprehensive (loss) for the year	(30,390,833)	(58,749,247)	(61,773,206)

Source: WAF Annual Report 2017

Sales revenue do not cover operation and maintenance costs. Expenses in 2017 far exceeded sales, with an expense ratio of over 250% to sales (**Figure S1. 5-1**).



Source: JET

Figure S1. 5-1 Operating Income, Expenses, Operating Loss, and Operating Expense Ratio

(2) Balance Sheet

The Audited Balance Sheet is shown in the **Table S1. 5-2** below.

Table S1. 5-2 WAF Balance Sheet

(Units: FJD)

Year	2015	2016	2017
Non-current assets			
Property, plant and equipment	1,761,711,340	1,746,069,527	1,769,830,071
Intangible asset	823,273	967,501	825,440
Total non-current assets	1,762,534,613	1,747,037,028	1,770,655,511
Current assets			
Cash and cash equivalents	35,464,433	34,241,532	62,578,916
Trade and other receivables	12,235,959	6,818,766	22,246,585
Inventories	16,565,503	28,939,985	31,273,648
Held-to-maturity investments	50,000,193	1,323,742	1,326,710
Other assets and prepayments	1,513,407	887,838	922,430
Total current assets	70,779,495	72,211,863	118,348,289
Total assets	1,833,314,108	1,819,248,891	1,889,003,800
Equity			
Contributed equity	1,747,699,848	1,746,452,278	1,746,440,815
Accumulated losses	(232,852,610)	(301,827,102)	(363,600,308)
Total equity	1,514,847,238	1,444,625,176	1,382,840,507
Current liabilities			
Obligations under finance lease	422,551	91,458	
Trade and other payables	15,268,669	18,820,909	28,938,966
Provision for employee entitlements	683,010	775,140	405,078
Deferred revenue - capital grant		47,512,310	43,891,010
ADB funded grant		1,613,149	3,807,243
Total current liabilities	16,374,230	68,812,966	77,042,297
Non-current liabilities			
Obligations under finance lease	88,350		
Deferred revenue – capex grant	231,992,329	239,025,086	365,701,621
ADB funded grant	70,011,961	66,785,663	63,419,376
Total non-current liabilities	302,092,640	305,810,749	429,120,997
Total liabilities	318,466,870	374,623,715	506,163,294
Total equity and liabilities	1,833,314,108	1,819,248,891	1,889,003,800

Source: WAF Annual Report 2017

- Sales of water supply and wastewater management do not cover O&M expenses. Since the collection rate of sales is as high as 95% (2017), the low-price setting is the reason why the income cannot cover the expenses, and the loss is recorded every year. The production cost of water is about 1.00 FJD/m^3 according to WAF's finance dept, the operating loss increases as the sales volume increases since the current water and sewerage tariffs are much lower than the production cost. Even if the current non-revenue water rate of 30% improves to zero, the operating loss will continue.
- Subsidies for WAF from the government budget are the cornerstone of capital investment and operating funds. Since the current policy of the Fijian government is to operate the water and sewerage business with a subsidy budget, it is necessary for the Ministry of Economy to continue its commitment to support WAF.

- The financial statements obtained up to 2017 do not show the impact of COVID-19 on WAF management yet. Since the current business situation cannot be grasped from this data set, WAF needs to provide the latest financial data (2018～up to date). According to WAF management, this is due to the delay in auditing by the Office of the Auditor General, and not due to a WAF issue, such as problems in the accounting processing method.
- According to the Ministry of Economy, one of WAF's supervisory body, WAF will continue to be a government-owned business entity. However, it aims for WAF to eventually become a financially independent organization based on its water use sales to customers, rather than relying on government budgets. To that end, raising water tariffs is recognized as an important option for WAF to improve profitability.

6. CENTRALIZED AND DECENTRALIZED TREATMENT SYSTEM

6.1 Summary of Planning Factors

(1) Target Year

The target year of this Regional Wastewater M/P is 2036, in line with the National Development Plan.

(2) Future Population

The forecasted population of Fiji in 2036 was estimated to be about 1 million considering the declining population growth rate based on the Census population and forecasted population by United Nation.

The population of the Western Division and each of the provinces (Ba, Ra, and Nadroga-Navosa) was estimated based on the past census population trends, with Ba at 288,800, Ra at 32,300, and Nandoroga-Navosa at 58,900. The total population of the Western Division is 380,000.

The population by district in each province was allocated to urban, peri-urban and rural areas in each district based on future population estimates from the Fiji Bureau of Statistics, and the allocated future population are shown in **Table S1. 6-1**.

Table S1. 6-1 Population Forecast by District (2036)

Province	District (Tikina)	Population 2017				Population 2036			
		Total	Urban	Peri-Urban	Rural	Total	Urban	Peri-Urban	Rural
Ba	Ba	39,372	6,405	9,441	23,526	36,020	8,930	19,900	7,190
	Magodro	4,806			4,806	4,810			4,810
	Nadi	59,717	29,016	29,422	1,279	86,380	40,440	45,550	390
	Naviti *	2,910			2,910	2,910			2,910
	Nawaka	16,121		8,406	7,715	16,510		14,160	2,350
	Tavua	23,269	1,194	7,616	14,459	18,900	1,660	12,830	4,410
	Vuda	99,264	45,047	30,259	23,958	121,040	62,770	50,960	7,310
	Yasawa *	2,226			2,226	2,230			2,230
	sub-total	247,685	81,662	85,145	80,878	288,800	113,800	143,400	31,600
Ra	Nakorotubu	4,392			4,392	4,240			4,240
	Nalawa	4,932			4,932	4,760			4,760
	Rakiraki	13,908	1,672	3,949	8,287	16,170	2,100	6,070	8,000
	Saivou	7,184		343	6,841	7,130		530	6,600
	sub-total	30,416	1,672	4,292	24,452	32,300	2,100	6,600	23,600
Nadroga-Navosa	Barava	8,332		628	7,704	7,880		940	6,940
	Cuvu	7,264			7,264	6,540			6,540
	Malolo *	3,211			3,211	2,890			2,890
	Malomalo	15,484			15,484	13,930			13,930
	Nasigatoka	14,338	1,533	8,348	4,457	18,370	1,900	12,460	4,010
	Navosa	5,106			5,106	4,600			4,600
	Ruwailevu	4,430			4,430	3,990			3,990
	Vatulele *	775			775	700			700
	sub-total	58,940	1,533	8,976	48,431	58,900	1,900	13,400	43,600
Western Division		337,041	84,867	98,413	153,761	380,000	117,800	163,400	98,800

*Italics**: Located on islands other than Viti Levu.
Source: Fiji Bureau of Statistics, JET

(3) Unit Water Consumption

The unit wastewater flows to be used in the Regional Wastewater M/P are summarized in **Table S1. 6-2** based on the actual data of WAF's revenue water. Infiltration ratio was set as 10% considering the applied value in the Rakiraki M/P.

Table S1. 6-2 Summary of Unit Wastewater Flow

Item	Unit	Nadi	Lautoka	Ba	Tavua	Rakiraki	Sigatoka
Domestic water usage (Uniform)	L/day/capita	220	220	220	220	220	220
Return Ratio	%	90	90	90	90	90	90
Domestic wastewater unit flow (Uniform)	L/day/capita	200	200	200	200	200	200
Non-domestic ratio	%	40	45	30	20	30	60
Infiltration ratio	%	10	10	10	10	10	10

Source: JET

6.2 Examination of the Centralized Treatment Service Area

The target area needs to be selected so that 70% of the population will have access to centralized sewerage treatment by the target year. The population of the Western Division in 2036 is expected to be 380,000. Therefore, 266,000 people will need to have access to centralized treatment. The remaining 114,000 people will need to have access to on-site methods of wastewater treatment.

Due to the extensive expansion of service area required to meet these goals, the target area needs to be selected so that priority of project implementation is clear and so that the project can be executed efficiently and economically.

Considerations when selecting the centralized treatment service area are listed below, in order of importance.

a) City/town boundaries set by municipalities which denote the city centers ("Urban" areas as defined by the Bureau of Statistics).
b) Densely populated areas in the Peri-Urban area.
c) Areas already receiving water supply services.
d) Areas planned to receive water supply service.

6.3 Determination of the Centralized Treatment Service Area

The population of areas under consideration that meet all of the requirements previously outlined in Section 6.2 exceeds 70%. **Table S1. 6-3** shows the population targeted for centralized treatment in each district. **Figure S1. 6-1** to **Figure S1. 6-3** show the areas.

Table S1. 6-3 Population using Centralized and Decentralized Treatment Systems in each District

Province	District (Tikina)	Centralized System				Decentralized System			
		Total	Urban	Peri-Urban	Rural	Total	Urban	Peri-Urban	Rural
Ba	Ba	31,200	8,930	18,900	3,370	4,820	-	1,000	3,820
	Magodro	0	-	-	-	4,810	-	-	4,810
	Nadi	80,870	40,440	40,430	-	5,510	-	5,120	390
	Naviti *	0	-	-	-	2,910	-	-	2,910
	Nawaka	9,960	-	9,960	-	6,550	-	4,200	2,350
	Tavua	13,100	1,660	10,140	1,300	5,800	-	2,690	3,110
	Vuda	107,870	62,770	45,100	-	13,170	-	5,860	7,310
	Yasawa *	0	-	-	-	2,230	-	-	2,230
	sub-total	243,000	113,800	124,530	4,670	45,800	0	18,870	26,930
Ra	Nakorotubu	0	-	-	-	4,240	-	-	4,240
	Nalawa	0	-	-	-	4,760	-	-	4,760
	Rakiraki	7,100	2,100	4,620	380	9,070	-	1,450	7,620
	Saivou	0	-	-	-	7,130	-	530	6,600
	sub-total	7,100	2,100	4,620	380	25,200	0	1,980	23,220
Nadroga-Navosa	Barava	940	-	940	-	6,940	-	-	6,940
	Cuvu	430	-	-	430	6,110	-	-	6,110
	Malolo *	0	-	-	-	2,890	-	-	2,890
	Malomalo	0	-	-	-	13,930	-	-	13,930
	Nasigatoka	14,530	1,900	12,460	170	3,840	-	-	3,840
	Navosa	0	-	-	-	4,600	-	-	4,600
	Ruwailevu	0	-	-	-	3,990	-	-	3,990
	Vatulele *	0	-	-	-	700	-	-	700
	sub-total	15,900	1,900	13,400	600	43,000	0	0	43,000
Western	Division	266,000	117,800	142,550	5,650	114,000	0	20,850	93,150

*Italics**: Located on islands other than Viti Levu.
Source: Fiji Bureau of Statistics, JET

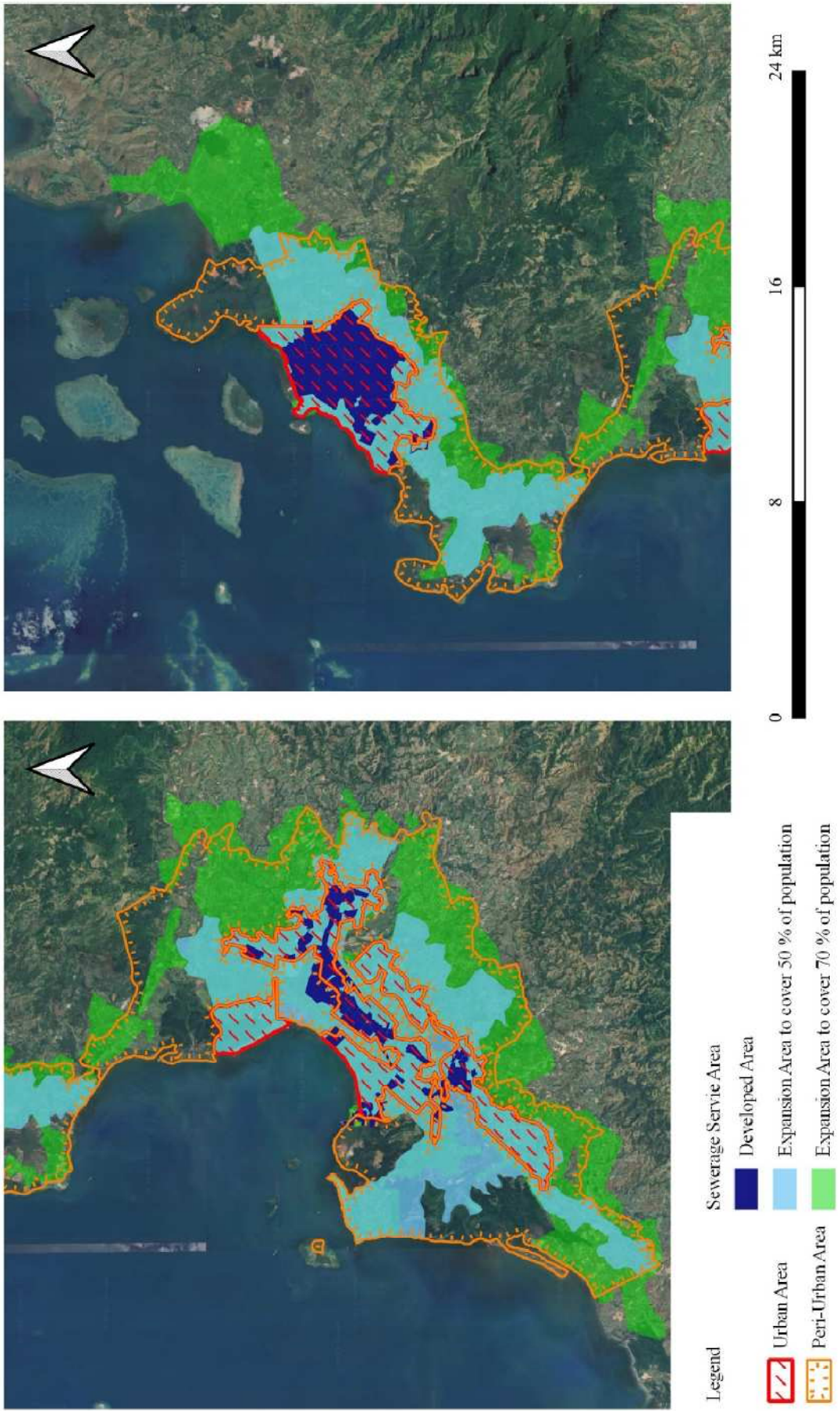
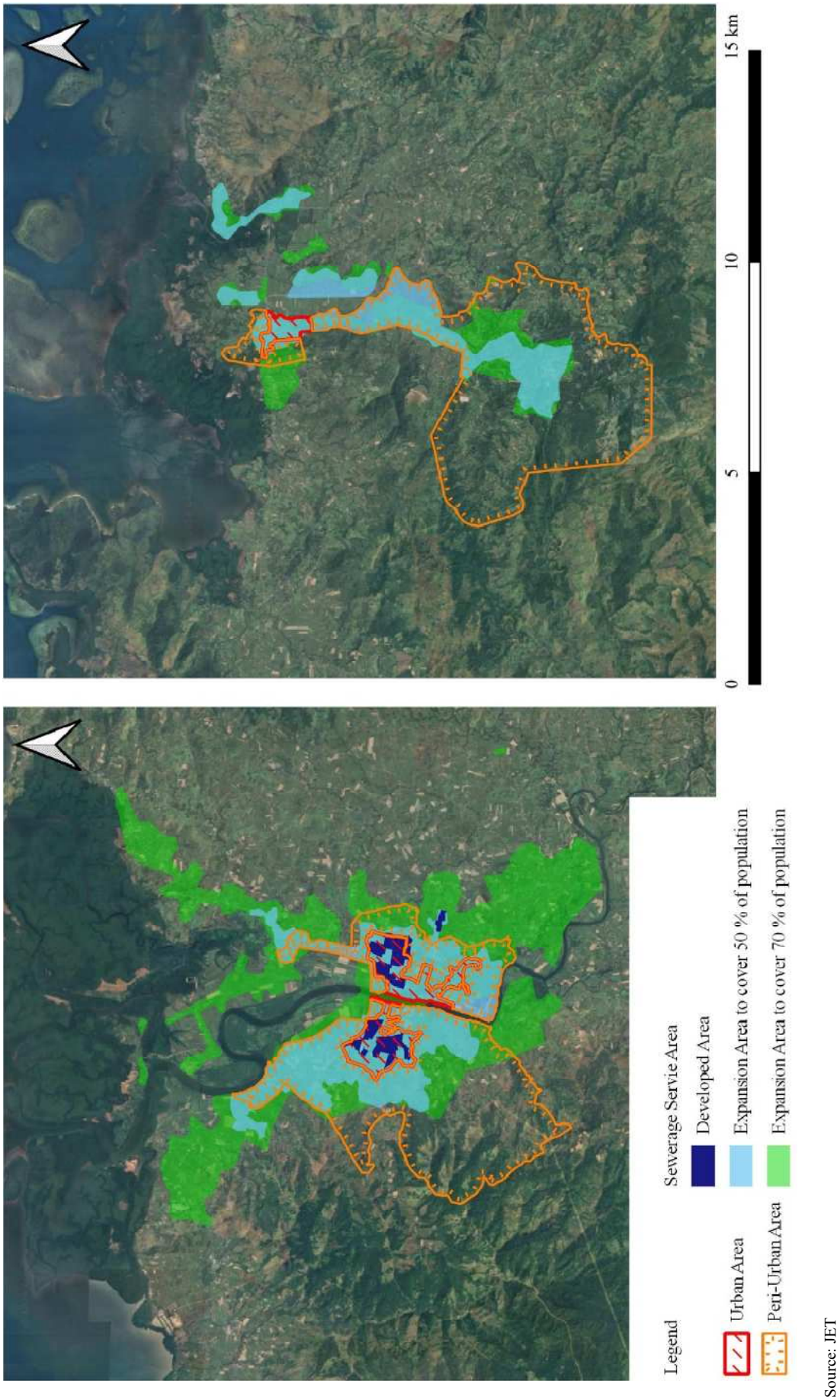


Figure S1. 6-1　Centralized Treatment Service Areas (Nadi, Lautoka)



Source: JET

Figure S1. 6-2　Centralized Treatment Service Areas (Ba, Tavua)

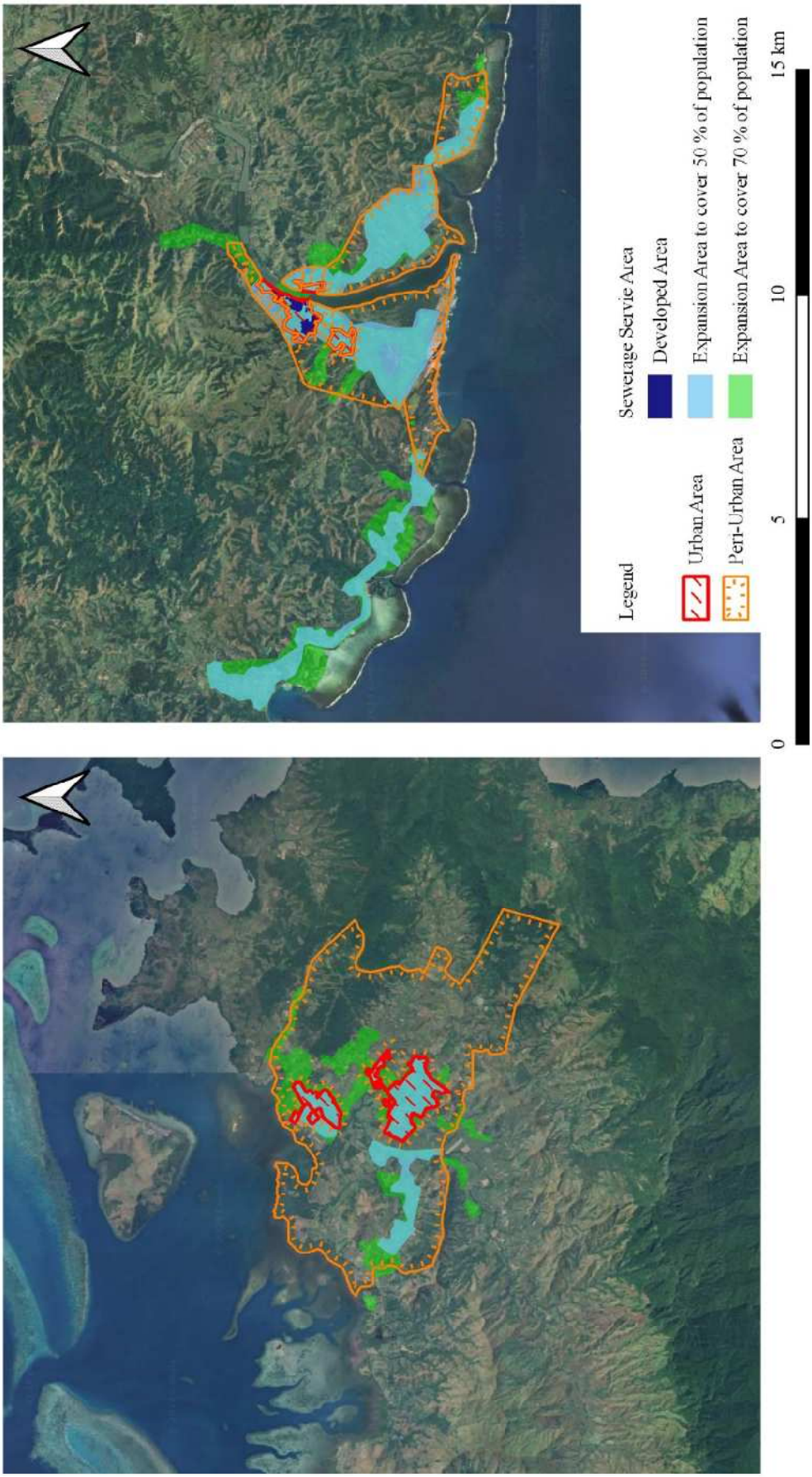


Figure S1. 6-3　Centralized Treatment Service Areas (Rakiraki, Sigatoka)

Source: JET

The amount of sewerage expected to be generated in the proposed service area is shown in **Table S1. 6-4**. If one treatment facility is constructed in each city, the scale of those facilities will be as shown in **Table S1. 6-4**. The daily average treatment volume ranges from 2,000 to 32,000 m^3/day.

Table S1. 6-4 Estimated Scale of WWTPs

No	Item	Unit	Nadi	Lautoka	Ba	Tavua	Rakiraki	Sigatoka
1	Population		101,600	97,100	31,200	13,100	7,100	15,900
2	Water Consumption	m^3/capita/day	0.220	0.220	0.220	0.220	0.220	0.220
3	Return Ratio	%	90	90	90	90	90	90
4	Unit wastewater Flow	m^3/capita/day	0.200	0.200	0.200	0.200	0.200	0.200
5	Domestic Flow	m^3/day	20,320	19,420	6,240	2,620	1,420	3,180
6	Non-Domestic Ratio	%	40	45	30	20	30	60
7	Non-Domestic Flow	m^3/day	8,128	8,739	1,872	524	426	1,908
8	Generated Wastewater	m^3/day	28,448	28,159	8,112	3,144	1,846	5,088
9	Infiltration ratio	%	10	10	10	10	10	10
10	Infiltration water	m^3/day	2,845	2,816	811	314	185	509
11	Total Inflow ADWF	m^3/day	31,293	30,975	8,923	3,458	2,031	5,597
12	Total Inflow PDWF	m^3/day	62,586	61,950	17,846	6,917	4,061	11,194
13	Total Inflow PWWF	m^3/day	156,464	154,875	44,616	17,292	10,153	27,984

Source: JET

6.4 Planning of Sewerage Facilities

(1) Wastewater Treatment Method

i. Effluent Water Quality

As listed in **Table S1. 6-5**, Fiji has two types of effluent water quality standards: General standards and Significant Ecological Zone (hereinafter referred to as "SEZ") standards, which has stricter conditions. The application of SEZ standards is not defined for specific water areas/water bodies but are designated by the Department of Environment (hereinafter referred to as “DOE”), which examines the topography and environmental characteristics around the discharge point of each proposed site.

Table S1. 6-5 Effluent Water Quality Standards

Parameter	Units	Concentration	
		General	Significant Ecological Zone
pH	pH	7-9	7-9
BOD5	mg/L	40	20
SS	mg/L	60	30
Fecal coliforms	CFU/100mL	400	200
TN	mg/L	25	10
Ammonia	mg/L	10	5
TP	mg/L	5	2

Source：Schedule 3 of the Waste Disposal and Recycling Regulations of Fiji (Environment Management (Waste Disposal and Recycling) Regulations, 2007).

Regarding the application of effluent water quality standards, DOE provided the below information in the meeting held on July 2022:

- SEZ standards are applied to effluents which discharge to coastal areas with delicate environmental characteristics.
- In the case of Lautoka's Natabua WWTP, General standards apply since the effluent is discharged 1.2 km away from the coast.

Therefore, in this report both the General and SEZ standards will be considered as the WWTP's target effluent water quality and organized into the below two cases.

(Case 1) Applies SEZ standards to all WWTP, perceiving the possibility of tightened environmental regulations (Strictest Case)

(Case 2) Apply General/SEZ standards based on the scale of outflow water bodies

Table S1. 6-6 Setting of Effluent Standards for Each WWTP

WWTP (Municipality)	Outflow Water body	Effluent Standard	
		Case 1	Case 2
Navakai (Nadi)	Nadi River	SEZ	SEZ
Natabua (Lautoka)	Ocean (1.2 km out to sea)	SEZ	General
Votua (Ba)	Waterway in mangrove thicket	SEZ	SEZ
Tavua	Undecided	SEZ	SEZ
Rakiraki	Undecided	SEZ	SEZ
Olosara (Sigatoka)	Mouth of Sigatoka River	SEZ	General

Source: JET

ii. Comparison of Treatment Process Options

The Regional Wastewater M/P considered the four processes in **Table S1. 6-7** as treatment processes capable of achieving each effluent quality standard.

Table S1. 6-7 Treatment Methods to be Examined in the Study

Treatment Method	Outline/Applicable Conditions	Effluent Quality
Stabilization Pond (SP)	・ Currently adopted at Natabua, Olosara, Votua WWTP ・ Requires large site area and application of General Standards for effluent water quality	General
Aerated Lagoon (AL)	・ Smaller land requirement compared to Stabilization Pond ・ Requires large site area and application of General Standards for effluent water quality	General
IDEA Process	・ Currently adopted at Kinoya WWTP. ・ Adopted in the detailed design project for Navakai WWTP ・ Apply if available site area is limited and/or if SEZ Standards apply for effluent water quality	General & SEZ
Oxidation Ditch Process (OD)	・ One of Japan's standard activated sludge (mechanical) treatment methods, and is highly applicable in Fiji ・ Apply if available site area is limited and/or if SEZ Standards apply for effluent water quality	General & SEZ

Source: JET

iii. Facility Layout Examination/Required Site Area

The approximate site area for each study case is organized in **Table S1. 6-8**. The site includes sludge storage areas for the sewerage sludge produced at WWTPs, since there are currently no outside disposal sites accepting sewerage sludge. The sludge storage space is assumed to store 20-years' worth of produced sewerage sludge.

The mechanical treatment process such as IDEA and Oxidation Ditch (hereinafter referred to as "OD") process provide smaller WWTP site footprints. In addition, the landfill site for the sludge produced at WWTP is quite large, so it will be necessary to formulate a plan for sludge disposal or effective reuse of the sewerage sludge.

Table S1. 6-8 Required Site Area Estimate of each WWTP/Treatment Process

WWTP (Municipality)	Acceptance of Septage	Treatment Method*	Target Effluent Quality Std.	Estimated Area (ha)	Area for Sludge Storage (ha)
Navakai (Nadi)	None	Stabilization Pond	General	73.3	4.2
		AL	General	49.8	4.2
		OD / IDEA	General/SEZ	20.5	11.5
Natabua (Lautoka)	Accept	Stabilization Pond	General	72.5	4.2
		AL	General	49.2	4.2
		OD / IDEA	General/SEZ	22.7	11.8
Votua (Ba)	None	Stabilization Pond	General	31.1	1.5
		AL	General	19.3	1.5
		OD / IDEA	General/SEZ	8.2	3.4
Tavua	Accept	Stabilization Pond	General	8.8	0.5
		AL	General	6.4	0.5
		OD / IDEA	General/SEZ	4.0	1.6
Rakiraki	Accept	Stabilization Pond	General	8.3	0.9
		AL	General	6.3	0.9
		OD / IDEA	General/SEZ	4.1	1.5
Olosara (Sigatoka)	None	Stabilization Pond	General	13.9	1.2
		AL	General	11.5	1.2
		OD / IDEA	General/SEZ	6.7	2.8

*The IDEA process footprint requirement is assumed to be almost the same as that of the OD process.
Source: JET

(2) Sewer Network (Pipeline)

The outline of the necessary sewer trunk lines and main branch lines in the service areas set out in Figures **S1. 6-1** to **S1. 6-3** is as shown in **Table S1. 6-9**.

Table S1. 6-9 Length of Sewer Pipelines

Service Area	Units	Trunk Sewer Pipeline	Main Branch Sewer Pipeline
Nadi	km	37.1	113.3
Lautoka	km	27.3	86.9
Ba	km	27.0	56.7
Tavua	km	8.5	18.1
Rakiraki	km	12.6	14.7
Sigatoka	km	22.1	21.1

Source: JET

(3) Estimation of Construction Cost and O&M Cost

The construction costs required to install the WWTP and collection network in the six municipalities in the Western Division are shown in **Table S1. 6-10**. O&M costs are shown in **Table S1. 6-11**. The treatment process will be decided in future discussions with the DOE, so the WWTP costs are estimated separately for the General standards and the SEZ standards.

Table S1. 6-10 Construction Cost for Sewerage Systems

Item	Process	Nadi	Lautoka	Ba	Tavua	Rakiraki	Sigatoka
WWTP (mil. FJD)	IDEA/OD	20,856	20,328	7,194	3,300	2,508	4,884
	SP	14,982	14,784	5,478	1,980	1,584	2,772
Sewer Network (mil. FJD)		93,918	56,496	31,812	7,788	6,006	12,738
Pumping Station (mil. FJD)		3,168	1,914	1,056	330	264	462
Total (mil. FJD)	IDEA/OD	117,942	78,738	38,412	11,418	8,778	18,084
	SP	112,068	73,194	40,128	10,098	7,854	15,972

* 1 FJD = 67.55 JPY (April 2024 rate)
Source: JET

Table S1. 6-11 O&M Cost for Sewerage Systems

Item	Process	Nadi	Lautoka	Ba	Tavua	Rakiraki	Sigatoka
WWTP (mil. FJD/yr)	IDEA/OD	234	228	115	72	61	91
	SP	102	101	38	19	15	25
Sewer Network (mil. FJD/yr)		91	55	31	9	7	12
Pumping Station (mil. FJD/yr)		296	178	69	20	15	27
Total (mil. FJD/yr)	IDEA/OD	621	462	214	101	83	131
	SP	490	334	138	47	37	65

* 1 FJD = 67.55 JPY (April 2024 rate)
Source: JET

7. PRIORITIZATION OF SEWERAGE DEVELOPMENT

(1) Evaluation Items for Determining the Priority Cities

The evaluation criteria for selecting the priority city is composed of four main criterion and seven sub-criterions, considering two points listed below. The summarized criteria compilation for the six city and towns are shown in **Table S1. 7-1**. It should be noted that Sub-criteria No.1: Population is shown below for reference and is not used in the evaluation.

- Prioritization should be evaluated from multiple points of view.
- Data of each city/town can be used or can be collected.

Table S1. 7-1 Criteria for Prioritizing the 6 Target Municipalities

No.	Sub-Criteria	Nadi	Lautoka	Ba	Tavua	Rakiraki	Sigatoka
1	Population (persons)	71,048	71,573	15,846	8,810	5,964	10,509
1'	Non-sewered population (persons)	55,186	42,593	12,656	8,810	5,964	10,028
2	Population density (persons/ ha)	5.1	11.3	5.1	3.0	1.7	5.7
3	Ratio of waterborne disease (%)	2.34	0.81	0.47	0.65	0.52	1.47
4	No. of hotels (hotels)	76	19	0	1	2	18
5	Amount of water usage (Non-domestic) (1000 m^3/day)	9.2	8.5	2.0	0.4	0.6	2.8
7	Current river water quality (BOD mg/L)	2.6	8.6	3.2	4.5	3.2	2.5
8	Estimated future river water quality (BOD mg/L)	2.2	5.2	2.8	3.7	1.9	2.5

Data Source
1: Fiji Bureau of Statistics; Number of persons in "urban" & "peri-urban" area in Census 2017
1': above 1 - Number of customers connected to "Sewer" x 4.5
2: Fiji Bureau of Statistics; Area of "urban" & "peri-urban" in Census 2017
3: Central Board of Health: Health Status Report 2017"; Number of cases / populations
4: Fiji Bureau of Statistics; Number of hotels in "urban" & "peri-urban".
5: WAF; Categorized revenue water.
7: JET: Results from River flow measure and Water quality analysis
8: JET: Results of simulation calibrated based on result of River flow measure and Water quality analysis

Source: Created by JET based on the above

(2) Weighting of the Evaluation Criteria

The priority of project implementation is quantified and evaluated by weighting and scoring each evaluation item. The analytic hierarchy process (hereinafter referred to as “AHP”) is used to determine the weight of each criterion. AHP makes paired comparisons between each of the evaluation items (comparing the importance of each criterion to every other criterion one-by-one) to arrive at a weight of each criterion. The paired comparison survey was conducted by questionnaire and administered to WAF staff (10 general staff and six managerial staff).

Table S1. 7-2 shows the result of weighting for main criteria and sub criteria. The results reveal that “urbanization” and “population” are weighted highly.

Table S1. 7-2 List of Weights

Main Criteria	Weight	No.	Sub-criteria	Weight	Points
Population	0.269	1	Non sewered population	0.34	9.1
		2	Population density	0.66	17.8
Sanitation	0.201	3	Cases of waterborne disease	1.00	20.1
Urban Development	0.285	4	No. of hotels	0.45	12.7
		5	Non-domestic water usage	0.55	15.8
Water environment	0.245	6	Current water quality	0.40	9.8
		7	Estimated water quality	0.60	14.7
	1.000				100

Source: JET

(3) Project Implementation Prioritization

Table S1. 7-3 shows the prioritization of the six cities/towns in the Western Division for project implementation based on the prioritization criteria, weight of each criterion, and point allocation. Based on the above, Lautoka and Nadi were selected as the target cities for formulating the Municipal Sewerage M/P.

Table S1. 7-3 Points Allocated to Each City/Town and Prioritization

No.	Sub-Criteria	Nadi	Lautoka	Ba	Tavua	Rakiraki	Sigatoka
1'	Non-sewered population (persons)	9.1	9.1	2.7	2.7	2.7	2.7
2	Population density (persons/ ha)	11.6	17.8	11.6	5.3	5.3	11.6
3	Number of cases of waterborne disease	20.1	13.1	6.0	6.0	6.0	13.1
4	No. of hotels (hotels)	12.7	3.8	3.8	3.8	3.8	3.8
5	Amount of water usage (Non-domestic) (1000 m^3/day)	15.8	15.8	4.7	4.7	4.7	4.7
7	Current river water quality (BOD mg/L)	2.9	9.8	6.4	6.4	6.4	2.9
8	Estimated future river water quality (BOD mg/L)	4.4	14.7	9.6	9.6	14.7	4.4
	Total	76.6	84.1	44.8	38.6	43.7	43.3
	Rank	2	1	3	6	4	5

Source: JET

(4) Overall Implementation Schedule

Considering that only 20% of the population currently has access to centralized sewerage services, increasing this to 70% in the following 10 or so years until 2036, as stated in the National Development Plan, will be a significant challenge. In this light, two implementation schedules are proposed.

- Case 1: Complete construction of all facilities by 2036.
- Case 2: Implement the project city by city, based on implementation priority.

Taking into account the construction schedule, Case 2 was judged to be the most reasonable schedule. In Case 2, the construction periods of each municipality are not overlapped, so it is assumed that the construction works of all municipalities in the Western Division will be completed in 2053, 17 years later from 2036. In 2036, 34% of the population will have access to centralized treatment system.

Table S1. 7-4 Overall Implementation Schedule

Case 1: Achieving the target until 2036

Municipal	Priority	Outline	2020'						2030'										2040'										2050'			
			4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3
Lautoka	1	WWTP: 31,000 m3/day Population: 97,100																														
Nadi	2	WWTP: 32,000 m3/day Population: 101,600																														
Ba	3	WWTP: 9,000m3/day Population: 31,200																														
Rakiraki	4	WWTP: 2,100m3/day Population: 7,100																														
Sigatoka	5	WWTP: 5,600m3/day Population: 15,900																														
Tavua	6	WWTP: 3,500m3/day Population: 13,100																														
Access to Centralized (%)			19	19	19	19	19	19	19	19	19	24	41	58	70																	

F/S, Consultant selection, D/D, T/A Construction House Connection

Case 2: Developing the sewerage area one municipal by one

Municipal	Priority	Outline	2020'						2030'										2040'										2050'			
			4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3
Lautoka	1	WWTP: 31,000 m3/day Population: 97,100																														
Nadi	2	WWTP: 32,000 m3/day Population: 101,600																														
Ba	3	WWTP: 9,000m3/day Population: 31,200																														
Rakiraki	4	WWTP: 2,100m3/day Population: 7,100																														
Sigatoka	5	WWTP: 5,600m3/day Population: 15,900																														
Tavua	6	WWTP: 3,500m3/day Population: 13,100																														
Access to Centralized (%)			19	19	19	19	19	19	19	19	19	24	30	34	34	34	42	49	56	56	56	58	59	61	61	63	64	66	66	67	69	70

F/S, Consultant selection, D/D, T/A Construction House Connection

8. EXAMINATION OF DECENTRALIZED TREATMENT SYSTEMS

(1) Goals for Decentralized Treatment Systems

Based on a comprehensive development policy that includes both centralized and decentralized treatment objectives, the goal for decentralized domestic wastewater treatment are set as follows:

GOAL: Increase access to centralized or decentralized treatment systems to 70% of the Western Division population by 2036.

※ The coverage rate of centralized treatment systems is the ratio of population connected to centralized sewerage services to the total population.

※ The coverage rate of decentralized treatment is the "proportion of population using safely managed sanitation services" as defined in SDGs indicator 6.2.1a.

Since the population coverage ratio for centralized treatment system in 2036 is expected to be 34%, the coverage ratio for decentralized treatment system will be 36%.

(2) Target Collection Population

Based on the target population of decentralized treatment systems described above, the target population was set with the following considerations:

- The target population was set so that the population covered by "safely managed sanitation services" (sum of population serviced by "centralized treatment systems," and "regularly desludged septic tanks,") will reach 70% by 2036, and 90% by 2053
- A preparation period of five years from 2023 will be given and activities related to regular desludging of septic tanks will start from 2028.
- The target population of regular septic tank desludging will be determined per District, as listed in **Table S1. 8-1**. For the years between 2036 and 2053 the implementation percentage will be determined by linear interpolation.

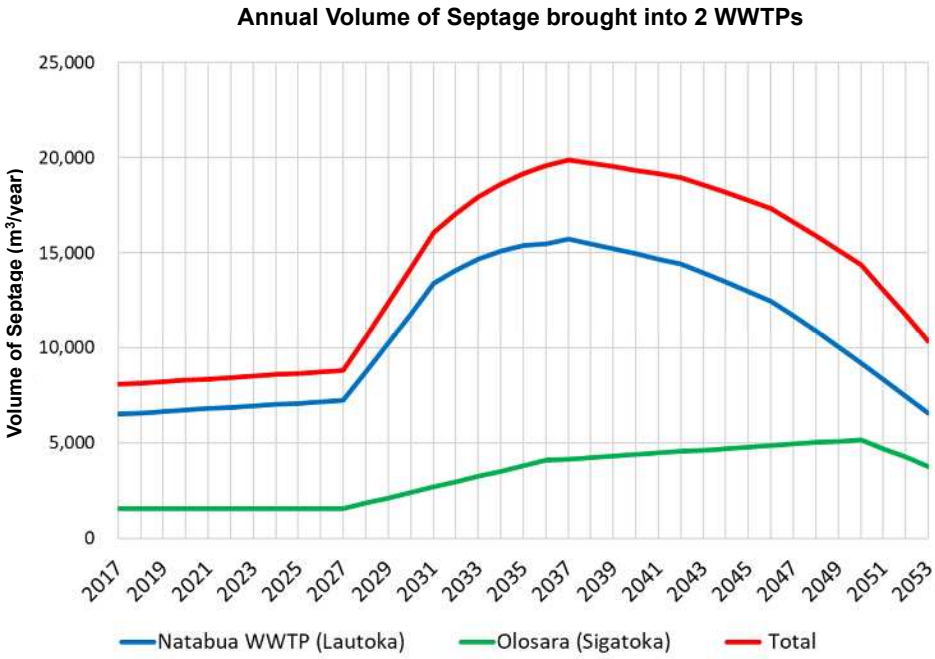
Table S1. 8-1 Target Population for Regular Desludging per District (Tikina)

District Category	Conditions	District (Tikina)	Target Population (%)	
			2036	2053
A	・ District has urban zone ・ Close by to WWTP and/or truck base of bailing company	Vuda, Nadi	65	80
B	・ Located along major highways (Kings Rd.、Queens Rd.) ・ District has urban zone and/or clustered villages	Ba, Nawaka, Tavua, Rakiraki, Saivou, Baravi, Cuvu, Malomalo, Nasigatoka	60	80
C	・ Area between District Category B and D	Ruwailevu	30	60
D	・ Located in Viti Levu Island ・ District with villages scattered in the mountainous area	Magodro, Nakorotubu, Nalawa、Navosa	0	30
E	・ Remote islands	Naviti, Yasawa, Malolo, Vatulele	0	0

Source: JET

(3) Septage Collection

The septage from Ra and Ba Provinces is transported to Natabua WWTP, and septage from Nadroga-Navosa is transported to Olosara WWTP. **Figure S1. 8-1** shows changes in the annual volumes of septage accepted by each WWTP, and **Table S1. 8-2** shows estimated mixed septage ratio at peak year for each WWTP.



Source: JET

Figure S1. 8-1 Annual Septage Volume Treated at WWTPs (Proposed)

Table S1. 8-2 Volume/Mixed Ratio of Septage brought to WWTPs (Proposed)

WWTP	Treatment Capacity	Volume of Septage	Mixed Septage Ratio (Septage/Treatment Cap.)
Natabua	8,200 m^3/day	~15,700m^3/year (63 m^3/day), 2037	0.8%
Olosara	2,600 m^3/day	~5,200m^3 year (21 m^3/ day), 2050	0.8%

※The daily septage volume is calculated based on 250 operation days per year
Source: JET

9. STRATEGIC ENVIRONMENTAL ASSESSMENT

The Strategic Environmental Assessment (hereinafter referred to as "SEA") for the Regional Wastewater M/P was conducted:

- To identify potential environmental and social impacts of wastewater treatment improvements in the six municipals (Nadi, Lautoka, Ba, Tavua, Rakiraki and Sigatoka) and recommend key environmental and social considerations and proposed study methodologies.
- To compare environmental and social alternatives for the sewerage development scenarios considered in the M/P to enable decision making, impact avoidance/minimization and facility design to ensure environmental and social considerations are implemented.
- To support and prepare plans for public consultation and meetings with relevant authorities and stakeholders on the findings and recommendations.

The key findings of the SEA are as follows:

- There is no legislation in Fiji that requires the application of SEA. The DOE is also in the process of developing mangrove conservation and management regulations.
- As a result of the scoping, it is expected that the implementation of the currently proposed project will have both positive and negative environmental and social impacts. In particular, given the environmental and social baseline conditions, future planning will require attention to land acquisition, resettlement, the lives and livelihoods of surrounding communities (especially iTaukei), flooding, mangrove forests, and the poor (especially informal settlements).
- As a result of comparing development scenarios from an environmental and social perspective, focusing on the expansion and construction of new treatment plants in each city and town, the optimal scenario was the expansion of existing facilities in Nadi and Lautoka, which already have treatment plants, and the construction of new facilities avoiding mangrove forests in other towns.
- A total of three stakeholder consultations were held, and participants at each meeting made many positive comments about the Regional Wastewater M/P. In addition, participants shared their opinions and information from a variety of perspectives on issues at specific sites and future facility construction and expansion.

10. ECONOMIC AND FINANCIAL ANALYSIS IN REGIONAL WASTEWATER M/P

An economic and financial analysis were conducted for the development of centralized treatment for the six municipals that are the target of the Regional Wastewater M/P, and the following results were obtained. From the point of view of economic and financial analysis using FIRR and EIRR as evaluation indicators, the implementation of the M/P will not achieve the target for the project owner from the financial and economic point of view. However, FIRR and EIRR are just one of evaluation methods. It should not be simplified for policy maker to judge the validity of project implementation based on the results of these indicators only.

(1) Economic Analysis

The economic evaluation of the implementation of M/P facilities showed an EIRR of 2.4%, which is below the EIRR target of 9% for the implementation of development projects.

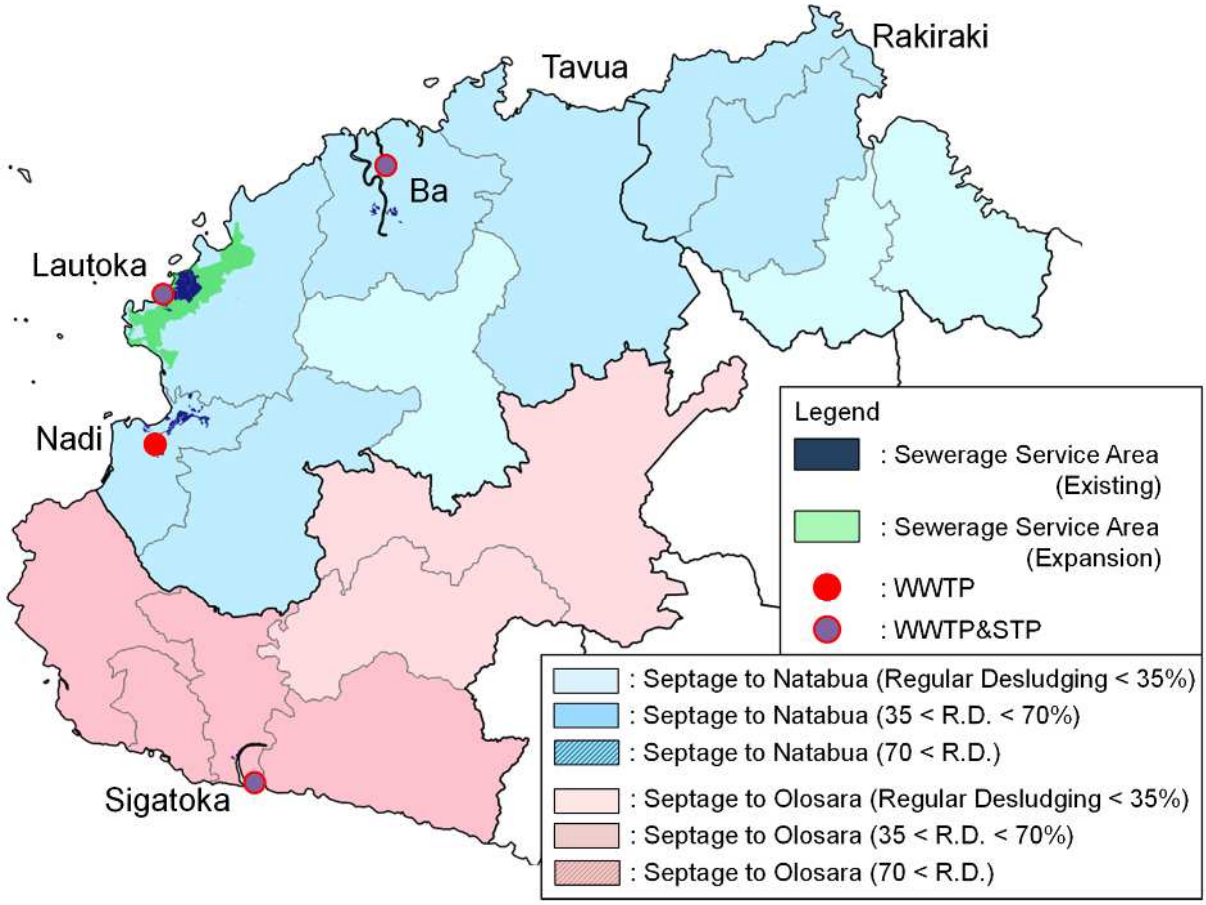
(2) Financial Analysis

The financial evaluation showed a FIRR of -2.1%. In addition, the results of the estimation of sewerage tariffs to cover OM costs showed that the sewerage tariff would need to be set at 0.71 FJD/m^3 or higher.

11. OVERALL PLAN OF WASTEWATER TREATMENT

As a summary of the study of the centralized and decentralized treatment system, the development status in 2036 and 2053 and each major index are shown in this section.

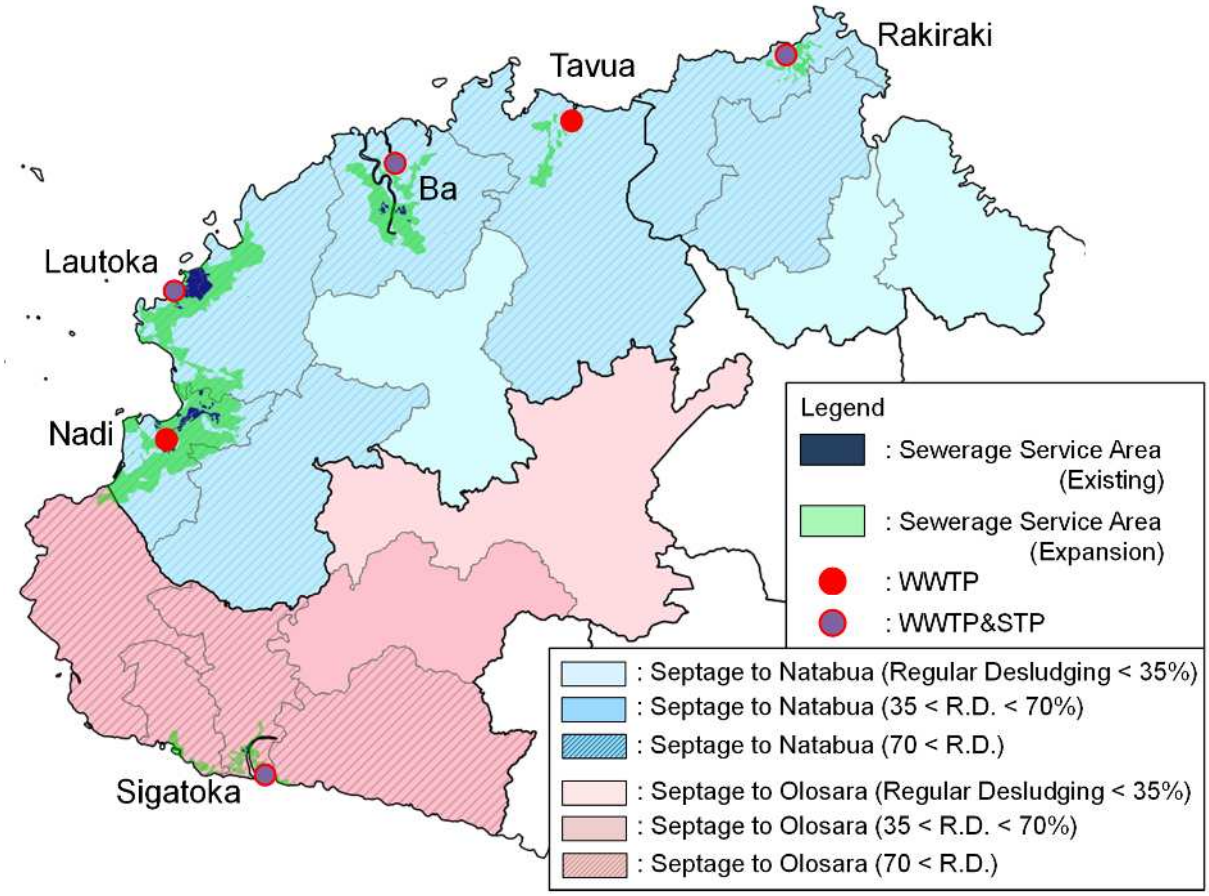
As for the situation in 2036, as shown in **Figure S1. 11-1**, the expansion of the Lautoka sewerage system will be completed, and the access ratio to the centralized treatment system will improve to 34%. In line with this, as a leveling up of decentralized treatment, the rate of regular septic tank desludging will be increased to 36%, and the access ratio of safely managed sanitation services will reach 70%. Septage generated in Ba and Ra provinces will be collectively treated at the new treatment facility at Natabua WWTP (Lautoka).



Source: JET

Figure S1. 11-1 Wastewater Treatment Status in 2036

Figure S1. 11-2 shows the situation in 2053 when sewerage development is expected to be completed. With the completion of sewerage development in the 6 municipalities in the western division, the access ratio to the centralized treatment system will reach 70%, achieving the national development goal.



Source: JET

Figure S1. 11-2　Wastewater Treatment Status in 2053

12. RECOMMENDATION

The main recommendation to achieve the NDP are as follows.

(1) Improve the Organization and Capacity of WAF Sewerage Department

As technical training is not systematically implemented in WAF, it is necessary to implement technical training so that the employees can fully utilize their skills. It is important that this project provides technical training in various areas and that WAF continues to train its staff even after the project is completed. Therefore, a human resources unit in charge of staff training should be established within WAF, and a system for continuous improvement of training materials should be established.

(2) Sewerage Tariff Plan

Currently, sales do not cover operating costs, so the sewerage tariffs need to be increased. A minimum of 0.71 FJD/m^3 is needed to cover maintenance costs, which will require a significant increase from the current rate of 0.20 FJD/m^3. A higher tariff is needed to cover the depreciation of capital investments, but the tariff should be increased gradually, starting with 0.71 FJD/m^3 as a guideline.

(3) Possibility of Introducing Private Funds

Water supply and sewerage services can be outsourced to the private sector, but since it is difficult to make profits under the current tariffs, it is necessary to increase tariffs significantly and provide preferential treatment such as investment grants, tax exemptions, and free land rent to encourage private investment.

(4) Measures to Promote Individual Household Connections

Since new connection fees are borne by users, which is an obstacle to increasing the connection rate, the government must subsidize connection fees and conduct publicity. Residents should be encouraged to connect by subsidizing connection fees for the first three years after the construction of the sewerage system.

(5) Issues Related to Decentralized Treatment Systems

i. Setting SDG targets and indicators related to decentralized treatment systems

The SDGs are useful as a tool for recognizing issues and setting goals, and "safely managed sanitation" is particularly important for sanitation services. Fiji does not have statistical data on this item, and no numerical targets have been set for SDGs goal 6.2. There is a need to set targets and indicators for decentralized treatment systems, and to establish a monitoring system to achieve the SDGs goal for 2030.

ii. Establish an inspection and guidance system for the maintenance of decentralized treatment systems

Currently, the installation of sanitation facilities in buildings is subject to inspection, but maintenance is inadequate. A system similar to Japan's septic tank law needs to be established, and local authorities also need to develop human resources and secure budgets.

iii. Correcting disparities in bailing (desludging) fees

The disparity in fees among private companies is a problem, and public involvement is needed. Financial support and the establishment of service centers in high-load areas are possible, but securing financial resources and cooperation from private enterprises is necessary.

iv. Eliminate mixed transport and treatment of industrial waste and septage

At present, industrial waste and septage are treated indiscriminately, which requires legislation and the introduction of an industrial waste manifest.

v. Public awareness

The understanding and cooperation of residents is essential to improve decentralized treatment systems. Since the understanding and interest of the population is low, public awareness activities in conjunction with WASH[2] programs in schools and communities needs to be increased.

[2] WASH stands for Water, Sanitation and Hygiene. It is a rural water and sanitation improvement program that aims to ensure access to and sustainable management of water and sanitation for all.

Section 2 MUNICIPAL SEWERAGE MASTER PLAN

1. BACKGROUND AND CURRENT ISSUES

(1) Background

The Western Division of Viti Levu Island, Fiji, currently has four operating wastewater treatment plants. However, concerns have risen regarding water pollution caused by factors such as overloaded capacity caused by increased inflow, improper O&M, breakdowns/deterioration of equipment, resulting in the discharge of insufficiently treated wastewater.

In response to these issues, the “Project for Formulation of Wastewater Treatment Master Plan in Western Division” was implemented starting October 2021. The project’s goal is to formulate a Master Plan for wastewater treatment (including decentralized treatment systems), along with WAF staff capacity building programs/training sessions to improve sewerage facility O&M.

In the first year's Output 1 “Regional Wastewater M/P” six municipalities in the Western Division (Lautoka, Nadi, Ba, Tavua, Rakiraki, Sigatoka) were set as the service areas needed to achieve Fiji’s national development goal to "increase population’s access to centralized treatment systems to 70%." A priority assessment of the six municipalities concluded Lautoka City and Nadi Town to be the top two priority municipalities, which will be the target for Output 2 “Municipal Sewerage M/P.”

(2) Current Issues found through the Regional Wastewater M/P

Major issues relating to expansion of WWTP and sewerage collection network are listed in **Table S2. 1-1**

Table S2. 1-1 Challenge and Issues Relating to Sewerage Planning

No.	Item	Contents
WWTP-related Issues		
1)	Effluent Standards	In Fiji, two types of effluent standards are established: (1) General standards, and (2) Significant Ecological Zone standards (hereinafter referred to as “SEZ standards”) The SEZ standards are not pre-applied to certain waterbodies/coastal areas that have certain characteristics/conditions; instead, when a new effluent point is to be established, the DOE conducts site-specific examinations (studying the local geological and environmental characteristics) to determine its application. In meetings with the DOE, it was indicated that SEZ standards are applied to “Coastal areas and rivers with delicate environmental characteristics,” but no specific conditions for the standards’ application was given. The DOE also stated that by conducting environmental studies/assessments of effluent effects to the discharged water body, there is the possibility of applying General standards to effluents that are discharged offshore through ocean outfall pipes.
2)	Securing land for WWTP sites	Since the existing WWTPs in Natabua and Navakai are in the center of the municipalities, it is necessary to examine whether it is possible and appropriate to expand the site for the capacity expansion of WWTPs. If it is difficult to expand the site around the existing WWTPs, or if it is more efficient and economical to install multiple WWTPs, it is necessary to find another site.
3)	Securing land for sludge final disposal sites	WAF requests landfill disposal at municipal solid waste disposal sites, but due to concerns on heavy metal contamination in sewerage treated sludge, there are currently no waste disposal sites accepting sludge. Moreover, the standards for acceptance of sludge for final disposal have not yet been set by the DOE. Securing external sludge disposal sites and utilizing method of sludge are important issues.
4)	GHG reduction and biogas power generation	The "Climate Change Act 2021" enacted in 2021 set net zero emissions of greenhouse gases (hereinafter referred to as “GHG”) by 2050 as a long-term goal for global warming countermeasures. Concrete measures for the Kinoya WWTP in the Suva have been mentioned, and in the sewerage sector, digestion biogas power generation is expected to contribute to net zero. The Municipal Sewerage M/P for the western division should also include the consideration of the digestion biogas power generation as in the case of the Kinoya WWTP.
Sewerage Collection Network-related Issues		
5)	Construction of additional pipes in crowded area	In both Lautoka and Nadi, sewer pipes have already been installed in the city center. It is expected that it will be difficult to redevelop the sewers necessary for the expansion of the area in the city center because of traffic congestion and many other infrastructures buried under the existing roads.
6)	High initial cost for network expansion	Of the total project cost estimated in the Regional Wastewater M/P, the proportion of the cost related to sewerage collection network development is high. For the Kinoya service area, a long-distance pumping system is applied for collection, but it is expected to consider a multiple WWTP system.

Source: JET

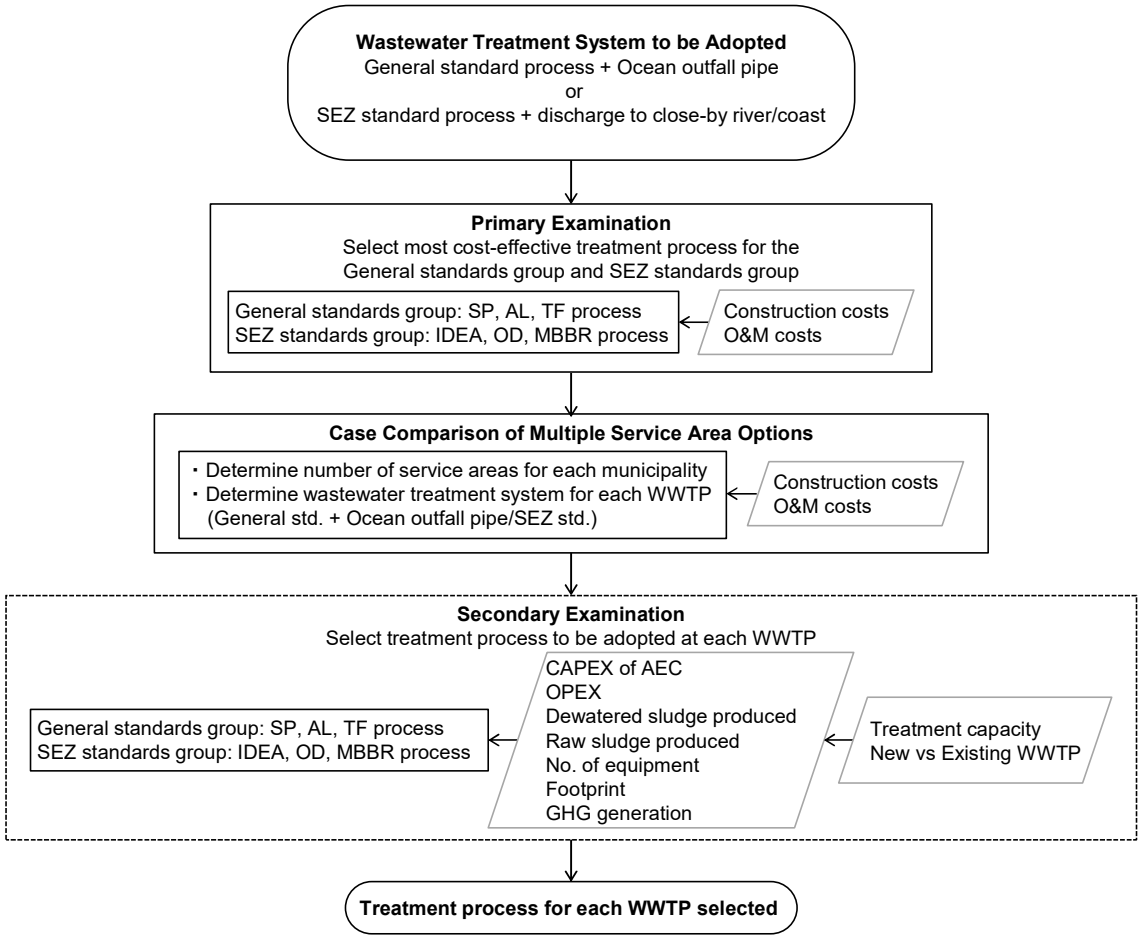
WAF has expressed their concern on Issues 5) and 6) since the formulation of the Regional Wastewater M/P, and has requested to consider the option of setting multiple WWTPs in each municipality, rather than centralizing the municipalities’ sewerage to a single WWTP

2. EXAMINATION OF SEWERAGE SYSTEM

(1) Examination of Sewerage Treatment Process and Multiple Service Areas

Discharge to the sea using ocean outfall pipes with a treatment process compatible to General standards has a possibility of being approved, as well as the use of a treatment process compatible with the SEZ standard. WAF recognizes that SEZ treatment processes will increase the O&M costs, and Kinoya WWTP is also considering the application of the combination of general treatment process and ocean outfall pipe, so it is necessary to consider the combination method based on the case in Kinoya.

Figure S2. 2-1 shows the workflow for selecting a treatment process and considering multiple WWTP systems. Each service area/ treatment process case was examined under this workflow, producing the results shown in **Table S2. 2-1**. The Oxidation Ditch process (hereinafter referred as "OD process") will be adopted at Navakai WWTP, and the Trickling Filter process (hereinafter referred as "TF process") will be applied for the remaining four WWTPs. Along with construction/O&M costs, assessment factors shown **Table S2. 2-2** were calculated and compared upon examination.



Source: JET

Figure S2. 2-1 Flow for Selection of Treatment Process and Multiple-WWTP System

Table S2. 2-1 Service Area and Treatment Process

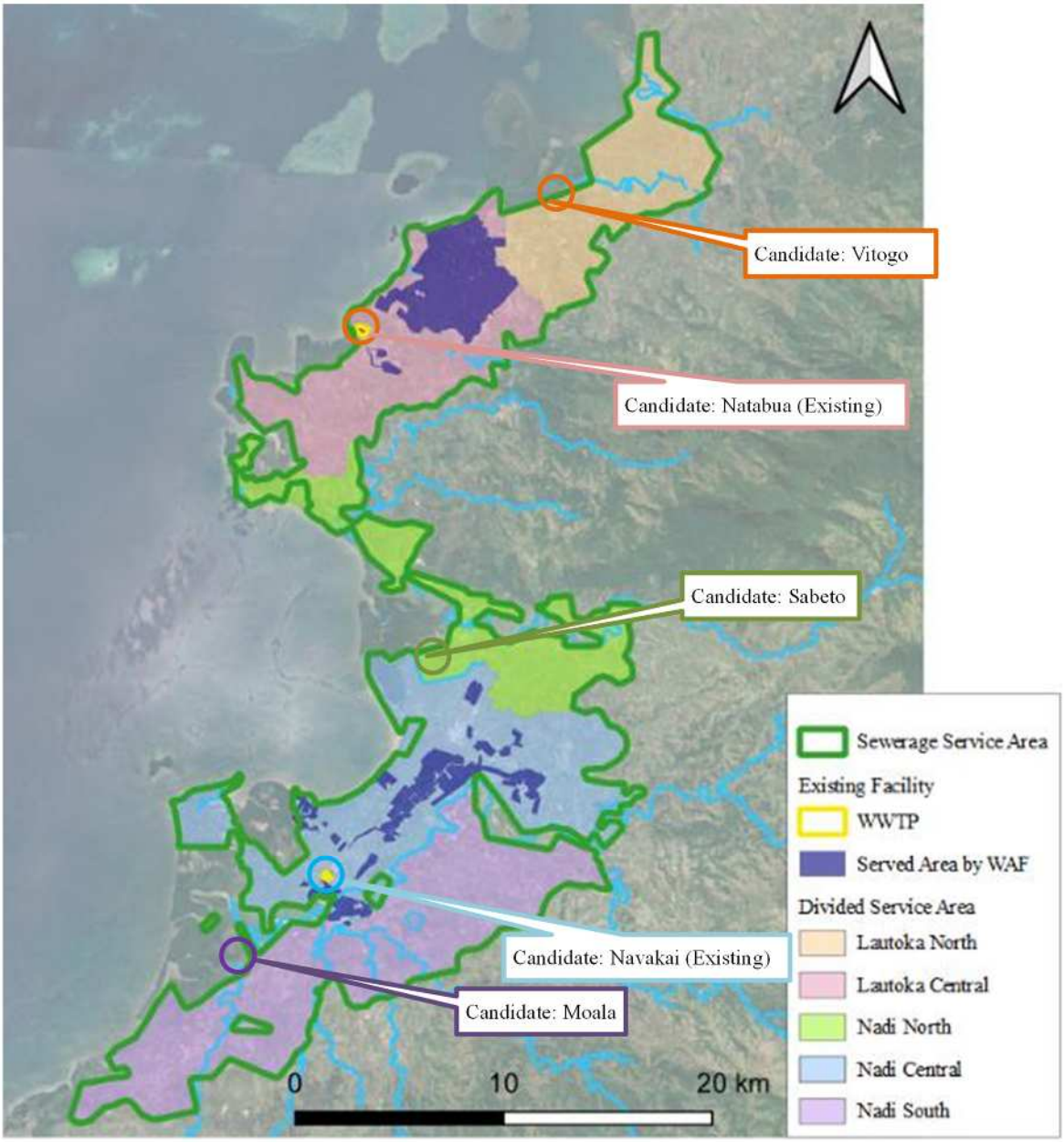
Municipal	Service Area	Standards/ Treatment Process	Remark
Lautoka	Vitogo	General/ Trickling Filter	Including ocean outfall pipe
	Natabua	General/ Trickling Filter	Including ocean outfall pipe
Nadi	Sabeto	General/ Trickling Filter	Including ocean outfall pipe
	Navakai	SEZ/ Oxidation ditch	Including ocean outfall pipe
	Moala	General/ Trickling Filter	Including ocean outfall pipe

Source: JET

Table S2. 2-2 Evaluation Criteria for the Wastewater Treatment Process Selection

Criterion	Units	Notes
Cost (CAPEX of AEC)	million FJD/yr	Parameter for economic efficiency
Cost (OPEX)	million FJD/yr	Parameter for economic efficiency
Dewatered Sludge Produced	t/yr	Site footprint for sludge disposal (in the Municipal Sewerage M/P, assumed to be onsite of WWTPs) increases in proportion to the dewatered sludge produced Smaller the amount of sludge, higher the score in the evaluation
Raw Sludge Produced	m^3/yr	Based on the above-mentioned sludge utilization policy, bioenergy production increases in proportion wo the raw sludge produced. Smaller the amount of sludge, higher the score in the evaluation
No. of Equipment	Units	Parameter for easiness of O&M
Footprint	ha	Parameter for economic efficiency (land acquisition costs)
GHG Generation	kt-CO_2/yr	Parameter for impact on global warming

Source: JET



Source: JET

Figure S2. 2-2 Proposed Service Areas and Candidate WWTP Sites

(2) Planned Treatment Flow of Each Service Area

The planned treatment flows of the five service areas are shown in **Table S2. 2-3** below.

Table S2. 2-3 Treatment Flow of Each Service area

No	Item	Unit	Lautoka		Nadi			Total
			Vitogo	Natabua	Sabeto	Navakai	Moala	
1	Population	capita	15,130	105,590	13,510	52,740	35,420	222,390
2	Water Consumption	m^3/capita/day	0.220	0.220	0.220	0.220	0.220	
3	Return Ratio	%	90	90	90	90	90	
4	Unit wastewater Flow	m^3/capita/day	0.200	0.200	0.200	0.200	0.200	
5	Domestic Flow	m^3/day	3,026	21,118	2,702	10,548	7,084	44,478
6	Non-Domestic Flow	m^3/day	2,760	15,640	3,110	14,000	8,810	44,320
7	Generated Wastewater	m^3/day	5,786	36,758	5,812	24,548	15,894	88,798
8	Infiltration ratio	%	10	10	10	10	10	
9	Infiltration water	m^3/day	579	3,676	581	2,455	1,589	8,880
10	Total Inflow ADWF	m^3/day	6,365	40,434	6,393	27,003	17,483	97,678
11	Total Inflow PDWF	m^3/day	7,001	44,477	7,033	29,703	19,232	107,446

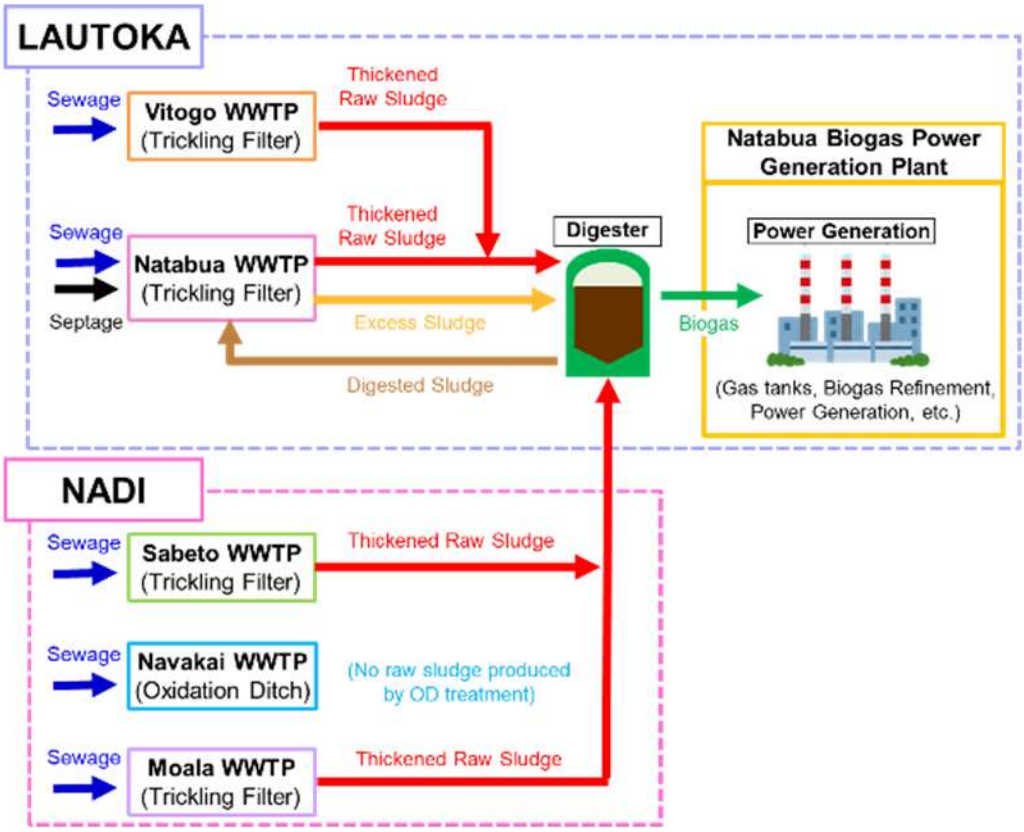
Source: JET

(3) Centralized Sludge Treatment and Biogas Utilization

Fiji has indicated global warming countermeasures for each sector in national policies such as the Climate Change Act 2021 and LEDS. For the sewerage sector, the utilization of recovered bioenergy from sludge (i.e. Power generation using biogas produced from anaerobic digestion of sewerage sludge)

Although the immediate implementation/realization of biogas power generation facilities is extremely difficult (mainly due to the requirement of high level expertise for the O&M of biogas power generation facilities), WAF intends to leave open the possibility of energy utilization in the sewerage sector; Responding to their request, the collection/utilization of sewerage sludge was incorporated into the M/P as shown in **Figure S2. 2-3**. Raw sludge produced from TF process WWTPs (Vitogo, Sabeto, Moala, Natabua) will be collected to Natabua WWTP and anaerobically digested; the biogas produced will be utilized as biofuel for energy production.

The energy production from biogas was estimated as shown in **Table S2. 2-4**, recovering nearly twice the electricity consumption of Natabua WWTP (4,500 MWh/yr).



Source: JET

Figure S2. 2-3 Sewerage Sludge Flow of Lautoka/Nadi WWTPs

Table S2. 2-4 Biogas Power Generation utilizing Sewerage Sludge

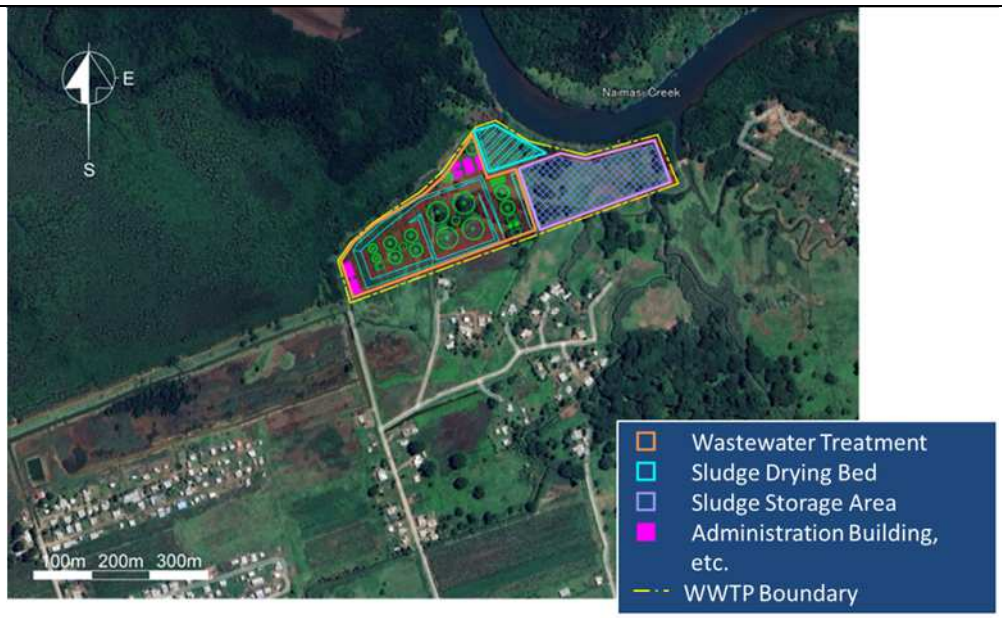
Parameter	Results
Biogas Production	4,607,240 m^3/yr
Methane Gas Production	2,764,344 m^3/yr
Generated Electricity	8,797 MWh/yr

Source: JET

3. OVERVIEW OF THE MUNICIPAL SEWERAGE M/P

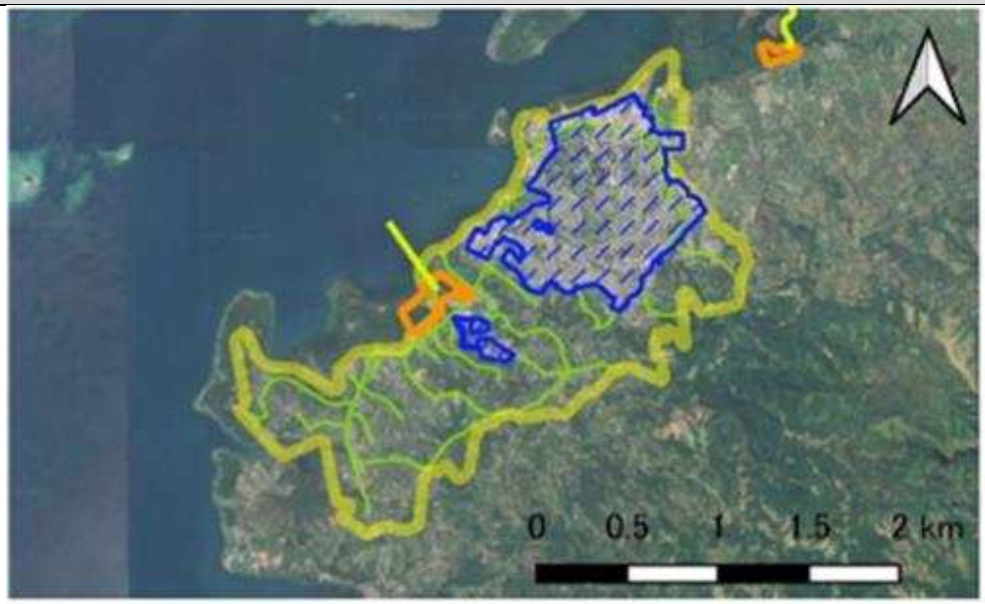
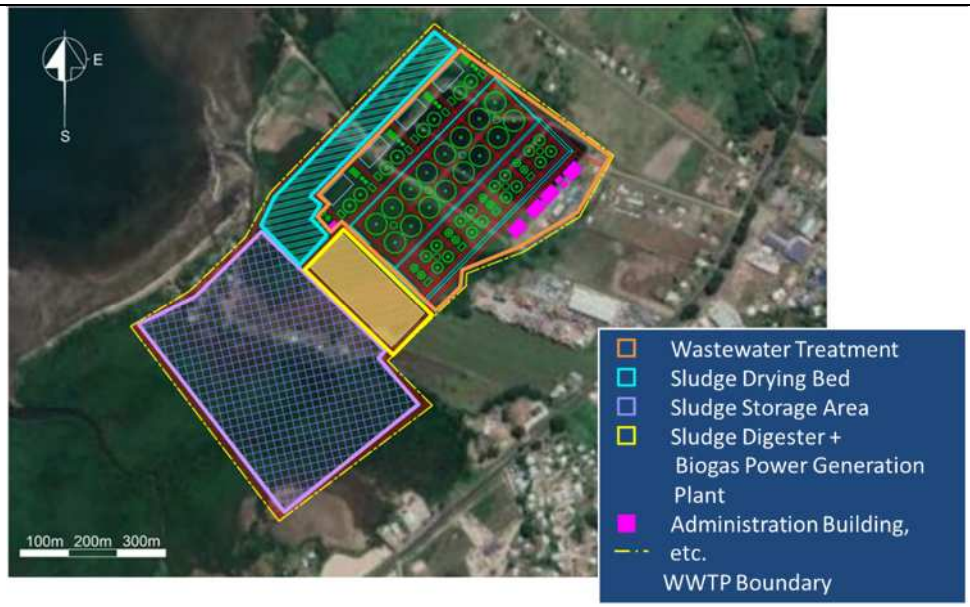
An overview of the Municipal Sewerage M/P for each service area in Lautoka/ Nadi are shown in **Table S2. 3-1** to **Table S2. 3-5**.

Table S2. 3-1　Overview of Vitogo Service Area (Lautoka)

Contents	Results
Plan View	
WWTP Facility Layout	
Target Year	2043
Population	15,130
Design Flow	6,365 m^3/day (Average Daily Flow), 7,001 m^3/day (Maximum Daily Flow)
Treatment Process	Trickling Filter
Treatment Capacity	7,100 m^3/day (Maximum Daily Flow)
Sludge Treatment	Raw sludge: Gravity thickener →Natabua WWTP Excess sludge: Dewatering → Sun drying → Storage
Discharge Destination	Ocean
Sewer Length	Main trunks/ Sub-trunk: Dia.100-750mm L = 41 km, Branch: Dia.100- 250mm L=71 km
Pumping Stations	12 stations

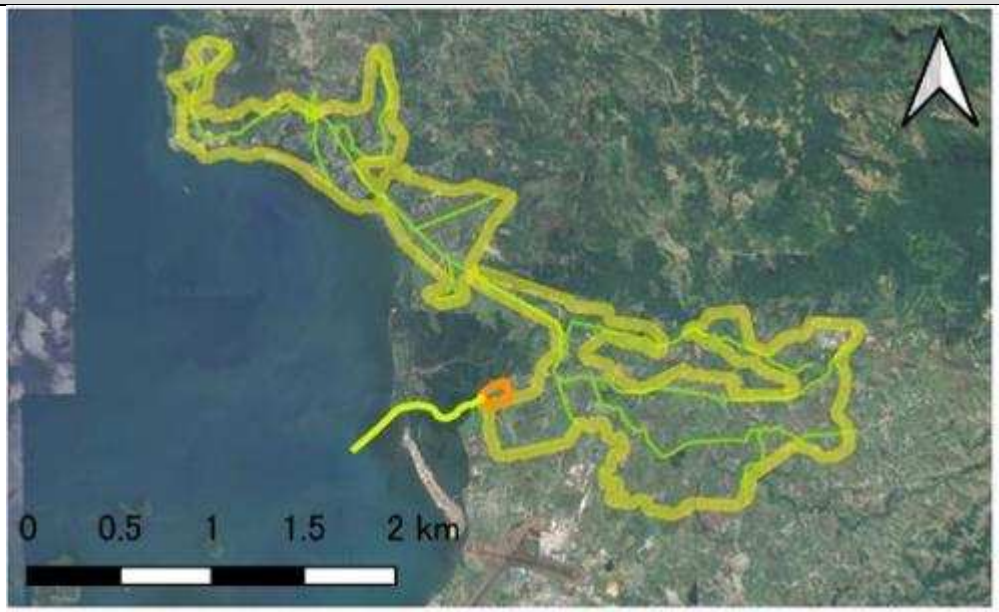
Source: JET

Table S2. 3-2 Overview of Natabua Service Area (Lautoka)

Contents	Results
Plan View	
WWTP Facility Layout	
Target Year	2043
Population	105,590
Design Flow	40,434 m^3/day (Average Daily Flow), 44,477 m^3/day (Maximum Daily Flow)
Treatment Process	Trickling Filter
Treatment Capacity	44,500 m^3/day (Daily Maximum)
Sludge Treatment	Raw/Excess sludge: Gravity concentration → Digestion → Dewatering → Sun drying → Storage Raw sludge (from other WWTPs): Digestion → Dewatering → Sun drying → Storage Septage: Dewatering → Sun drying → Storage
Discharge Destination	Ocean
Sewer Length	Main trunks/ Sub-trunk: Dia.100-600 mm L = 64 km, Branch: Dia.100- 600mm L=144 km
Pumping Stations	30 stations

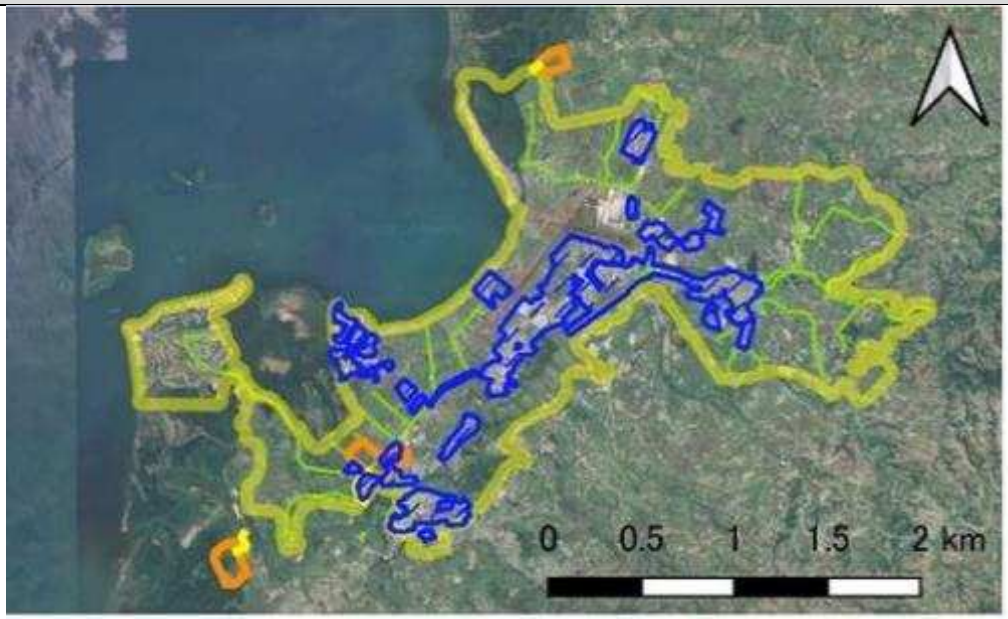
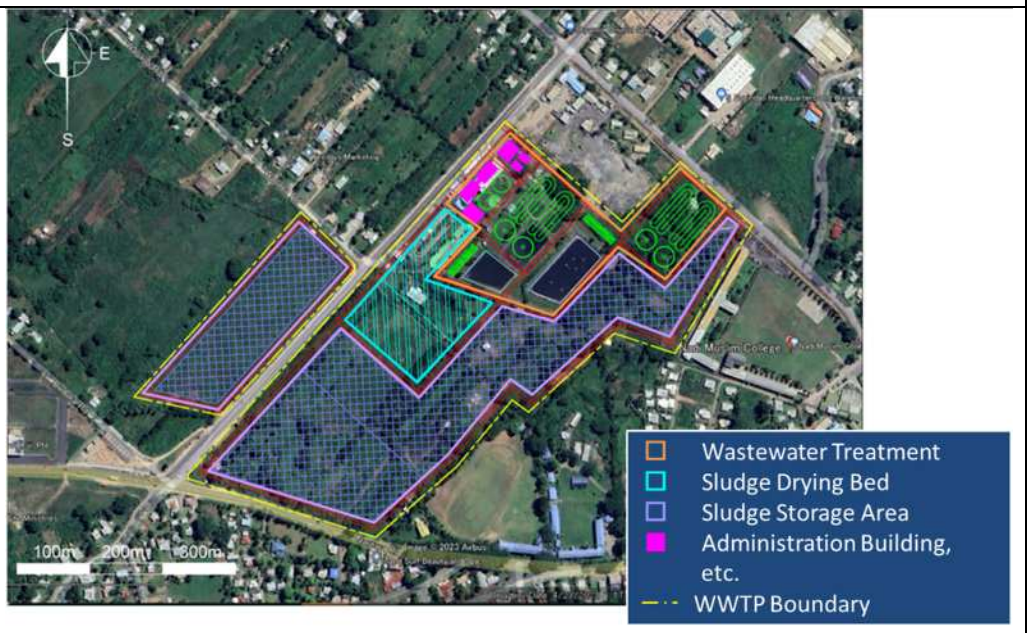
Source: JET

Table S2. 3-3 Overview of Sabeto Service Area (Nadi)

Contents	Results
Plan View	
WWTP Facility Layout	
Target Year	2043
Population	13,510
Design Flow	6,393 m^3/day (Average Daily Flow), 7,033 m^3/day (Maximum Daily Flow)
Treatment Process	Trickling Filter
Treatment Capacity	7,100 m^3/day (Maximum Daily Flow)
Sludge Treatment	Raw sludge: Gravity thickener → Natabua WWTP Excess sludge: Dewatering → Sun drying → Storage
Discharge Destination	Ocean
Sewer Length	Main trunks/ Sub-trunk: Dia.100-400 mm L=49 km, Branch: Dia.100-400mm L=78 km
Pumping Stations	35 stations

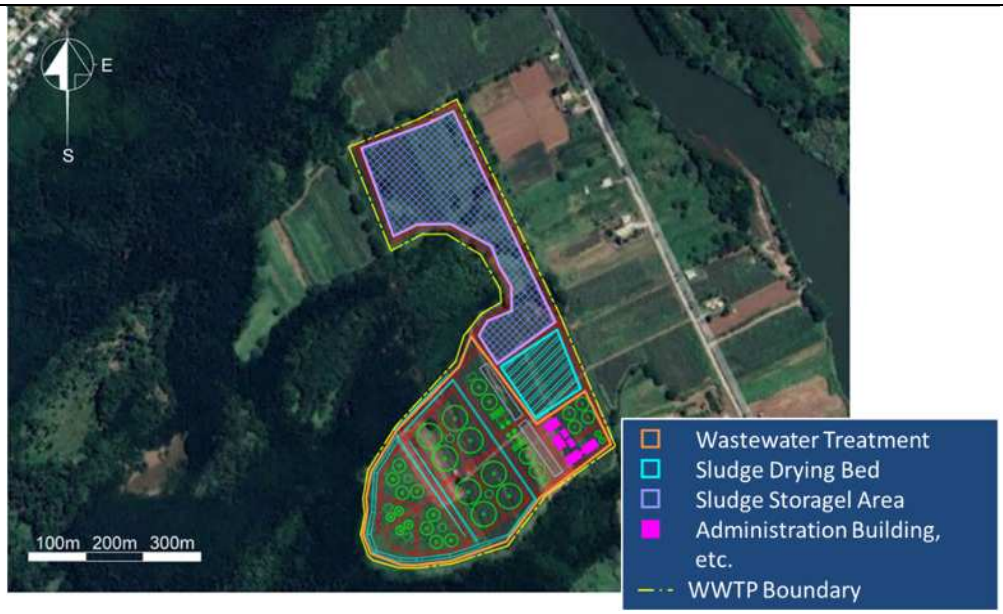
Source: JET

Table S2. 3-4 Overview of Navakai Service Area (Nadi)

Contents	Results
Plan View	
WWTP Facility Layout	
Target Year	2043
Population	52,740
Design Flow	27,003 m^3/day (Average Daily Flow), 29,703 m^3/day (Maximum Daily Flow)
Treatment Process	Oxidation Ditch
Treatment Capacity	29,800 m^3/day (Maximum Daily Flow)
Sludge Treatment	Excess Sludge: Dewatering → Sun drying → Storage
Discharge Destination	Nadi River
Sewer Length	Main trunks/ Sub-trunk: Dia.100-900 mm L = 58 km, Branch: Dia.100-300mm L=204 km
Pumping Stations	37 stations

Source: JET

Table S2. 3-5 Overview of Moala Service Area (Nadi)

Contents	Results
Plan View	
WWTP Facility Layout	
Target Year	2043
Population	35,420
Design Flow	17,483 m^3/day (Average Daily Flow), 19,232 m^3/day (Maximum Daily Flow)
Treatment Process	Trickling Filter
Treatment Capacity	19,300 m^3/day (Maximum Daily Flow)
Sludge Treatment	Raw sludge: Gravity thickener → Natabua WWTP Excess sludge: Dewatering → Sun drying → Storage
Discharge Destination	Ocean
Sewer Length	Main trunks/ Sub-trunk: Dia.100-900 mm L = 105 km, Branch: Dia.100-400mm L=161 km
Pumping Stations	54 stations

Source: JET

4. STAGED DEVELOPMENT OF THE SEWERAGE SYSTEM

(1) Staged Development and Proposed Projects

i. Lautoka

Table S2. 4-1 shows the proposed projects in Lautoka and outlines of their facilities. A two-staged expansion of the WWTP is proposed for Natabua WWTP. It is also proposed to develop the wastewater treatment plant (Ln-w3) as an independent component. The sewer network development has been divided into the trunk line/sub trunk line and branch.

Table S2. 4-1 Proposed Development Components for Vitogo, Natabua (Lautoka)

Area	Type	Outline of Facilities	
Vitogo	WWTP (Lv-w1)	TF process: Total Capacity	Q=7,100 m^3/day (PDWF)
	Sewer Network (Lv-s1)	Trunk/Sub-trunk line	Dia.100-600mm L=41 km
	Sewer Network (Lv-s2)	Branch sewer	Dia.100- 250mm L=71 km
Natabua	WWTP (Ln-w1)	TF process: Half of total capacity (1/2)	Q=23,000 m^3/day (PDWF)
	WWTP (Ln-w2)	TF process: Half of total capacity (2/2)	Q=22,000 m^3/day (PDWF)
	Septage Treatment Plant (Ln-w3)	Receiving facility, Mechanical dewatering	Q=76 m^3/day
	Sewer Network (Ln-s1)	Trunk/Sub-trunk line Half of total length (1/2)	Dia.100-750mm L=32 km
	Sewer Network (Ln-s2)	Trunk/Sub-trunk line (2/2) Branch sewer (1/2)	Dia.100-750mm L=32 km Dia.100- 600mm L=72 km
	Sewer Network (Ln-s3)	Branch sewer (2/2)	Dia.100- 600mm L=72 km

Source: JET

ii. Nadi

Table S2. 4-2 shows the proposed project components for the three service areas in Nadi. A two-staged expansion of the WWTP is proposed for Navakai WWTP. The sewer netowrk development has been divided into the trunk line/sub trunk line and branch.

Table S2. 4-2 Proposed Development Components for Sabeto, Navakai, Moala (Nadi)

Area	Type	Outline of Facilities	
Sabeto	WWTP (Ns-w1)	TF process: Total Capacity	Q=7,100 m^3/day (PDWF)
	Sewer Network (Ns-s1)	Trunk/Sub-trunk line	Dia.100-400mm L=49 km
	Sewer Network (Ns-s2)	Branch sewer	Dia.100-400mm L=78 km
Navakai	WWTP (Nn-w1)	OD process: Half of total capacity (1/2)	Q=15,000 m^3/day (PDWF)
	WWTP (Nn-w2)	OD process: Half of total capacity (2/2)	Q=15,000 m^3/day (PDWF)
	Sewer Network (Nn-s1)	Trunk/Sub-trunk line Half of total length (1/2)	Dia.100-900mm L=29 km
	Sewer Network (Nn-s2)	Trunk/Sub-trunk line Half of total length (1/2), Branch sewer (1/2)	Dia.100-900mm L=29 km Dia.100-310mm L=102 km
	Sewer Network (Nn-s3)	Branch sewer (2/2)	Dia.100-310mm L=102 km
Moala	WWTP (Nm-w1)	TF process: Half of total capacity (1/2)	Q=10,000 m^3/day (PDWF)
	WWTP (Nm-w2)	TF process: Half of total capacity (2/2)	Q=9,000 m^3/day (PDWF)
	Sewer Network (Nm-s1)	Trunk/Sub-trunk line Half of total length (1/2)	100-900mm L=53 km
	Sewer Network (Nm-s2)	Trunk/Sub-trunk line Half of total length (1/2), Branch sewer (1/2)	Dia.100-900mm L=52 km Dia.100-400mm L=80 km
	Sewer Network (Nm-s3)	Branch sewer (2/2)	Dia.100-400mm L=81 km

Source: JET

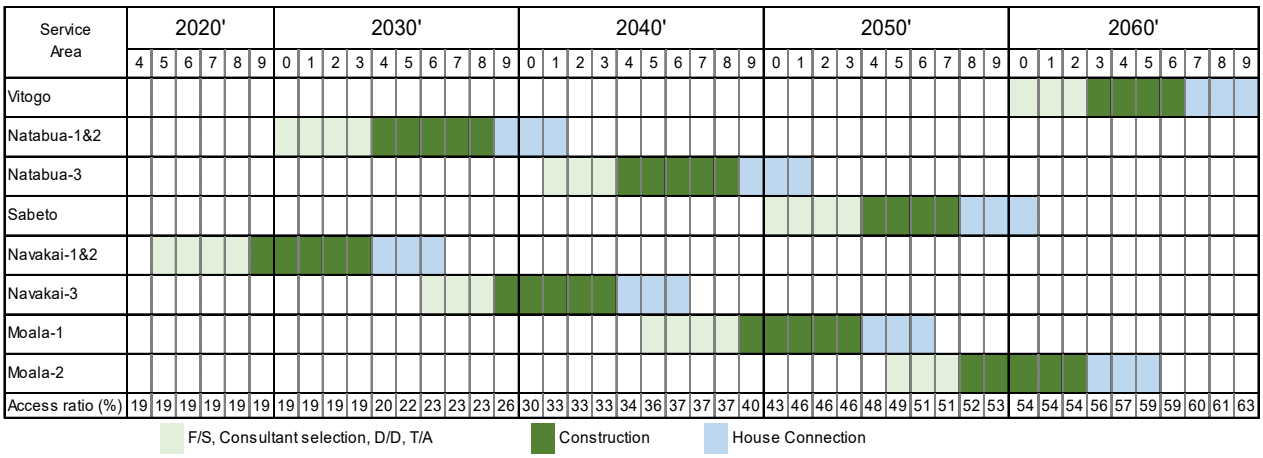
(2) Implementation Schedule

In consultation with the WAF, the development of the Navakai and Natabua service areas, which already have a high population and commercial facilities, should have a high priority in the Municipal Sewerage M/P. In addition, the WAF concept of priority for sewerage development is as follows.

- Legal compliance of the quality of treated wastewater from existing treatment plants.
- Upgrading and expansion of trunk and sub-trunk sewers to collect wastewater from private developments such as residential and commercial properties.
- Developing branch sewer system for increasing the served population. (Part of the sewerage system of private developers within residential complexes and commercial areas, as well as connecting pipes to trunk lines/sub trunk lines owned by WAF, will be installed by private contractors and are outside the scope of WAF).

The development schedule based on the results of the above discussion is shown in **Figure S2. 4-1**. The construction periods for each project are adjusted so that construction periods do not overlap. The sewerage

population development rate in 2036 is estimated to be 23%.



Source: JET

Figure S2. 4-1 Proposed Implementation Schedule

The proposed schedule shown in **Figure S2. 4-1** is based on the duration for each phase shown in **Table S2. 4-3**.

Table S2. 4-3 Assumed Duration for Each Phase

Phase	Duration
F/S study	1 year
Consultant Selection	1 year
Detailed Design	1 year
Bidding procedure for the contractor	1 year
Construction (Natabua, Navakai, Moala)	5 years
Construction (Vitogo, Sabeto)	4 years
House connection	3 year

Source: JET

5. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

(1) Summary of SEA Results

The findings from the Municipal Sewerage M/P stage SEA are summarized as below:

- No major differences were found between Fiji's national laws/regulations and JICA guidelines (April 2010 edition). Some small difference found include the methods of information disclosure and public consultation, etc. However, their basis is consistent with JICA guidelines
- In order to select important environmental and social items related to the sewerage system, scoping analyses were conducted for each project component. At the Municipal Sewerage M/P stage, there is a difficulty in evaluating impacts in detail because any project components together with spatial and temporal conditions have not been decided yet. Therefore, the impact levels are assumed based on the Regional Wastewater M/P, the local characteristics of the areas, and general information of each facility.
- As for the analysis of alternative options, each scenario had various advantages/disadvantages in terms of environmental and social aspects; in the end there were no significant gaps among the total scores. However, there was a general tendency that muti-service areas got a higher total score compared to single service areas. The same tendency was found for TF/mechanical treatment methods, compared to the AL method option.

(2) Stakeholder Meetings

Stakeholder meetings were held at the scoping stage and draft M/P stage, resulting in the following opinions and findings from participants:

- While no participants expressed concerns on the service area zoning and candidate sites for new WWTPs, it was suggested that WAF should closely consult with the local communities and landowners of the candidate sites at an early stage.
- No major concerns were expressed on the contents of the draft Municipal Sewerage M/P. Some comments were received concerning the necessity of considerations to be made at the implementation stage of each project, mainly for communities/tourism industries nearby the WWTPs.

(3) PR Activities

Since the Municipal Sewerage M/P is a plan that closely relates end-user to sewerage systems, PR activities publicizing the M/P were implemented under cooperation with the WAF PR team. Contents of the PR activities are summarized in the websites below.

- https://www.fbcnews.com.fj/news/wastewater-master-plan-is-a-proactive-step-waf/
- https://www.facebook.com/WaterAuthorityofFiji/posts/pfbid0bP4E17oqbokTf42PPW3B9fJwpfegqoSeT9hRZrtE7t8co327s678nTd54tqf4548l

6. OPERATION AND MAINTENANCE (O&M)

(1) Sewer Network (Pipelines)

Proper maintenance of sewer pipes is a very important task in the management of sewerage systems The maintenance of sewer pipes is divided into preventive maintenance through patrols, inspections, and surveys, and corrective maintenance such as removal of clogging.

A three-stage O&M development plan was proposed as shown in **Table S2. 6-1** , taking into consideration WAF's current manpower and outsourcing situation.

Table S2. 6-1 Introduction of Preventive and Corrective Maintenance for Sewer System

Stage 1	Preparation for preventive maintenance	Preventive maintenance	・ Staff training on preventive maintenance ・ Review of the sewer pipe ledger created by the GIS unit
		Corrective maintenance	・ Increase in the number of cases of pipe clogging response outsourced to the private sector ・ Preparation of construction records ・ Training of private sector
Stage 2	Stepwise introduction of preventive maintenance	Preventive maintenance	・ Commencement of patrols throughout the entire area based on the pipe ledger ・ Implementation of inspections for locations where pipe troubles have occurred
		Corrective maintenance	・ Implementation of preventive maintenance by large-scale outsourcing to the private sector
Stage 3	Full implementation of preventive maintenance	Preventive maintenance	・ Conducting detailed surveys using television cameras, etc., for areas where damages were found during patrols and inspections ・ Prioritize repair/replacement based on risk matrix on survey results, and formulate repair/replacement plan
		Corrective maintenance	・ Entirely outsourced to the private sector

Source: JET

Table S2. 6-2 shows the organizational structure for the phased introduction of preventive maintenance of sewer network facilities and the phased outsourcing of corrective maintenance to the private sector such as response to pipe clogging, which is shown in **Table S2. 6-1**.

Table S2. 6-2 Proposed Organization Structure for Maintenance of Sewer Network Facilities

Municipality	Position	Current number of staff	Stage 1	Stage 2	Stage 3
			Preparation	Stepwise introduction	Complete implementation*
Nadi	**Pipe fitter**	3	3	3	5
	Technical Assistant	3	3	3	5
	Other	2	2	2	3
Lautoka	**Pipe fitter**	2	3	3	5
	Technical Assistant	3	3	3	5
	Other	0	2	2	3

*Increase of service area
Source: Created by JET based on WAF data

(2) Sewerage Pump Stations

The WAF ME team will conduct preventive maintenance of pump stations (periodic inspection and equipment maintenance), as well as preventive maintenance of WWTP facilities. The ME team currently maintains not only the sewerage system but also the water supply system; since it is difficult to secure mechanical and electrical technicians in Fiji, this is considered to be an efficient O&M structure.

In order to implement preventive maintenance of various water supply/sewerage facilities in the Western Division, the Case-1 organization structure of Case-1 shown in **Table S2. 6-3** is required.

Table S2. 6-3 Proposed Organization Structure of ME Team

	Case-1			Case-2 (Outsourcing Periodical maintenance and major machine repairs to the private sector)		
	Inspection-1	Inspection-2	Repair	Inspection-1	Inspection-2	Repair
Supervisor (Mechanical)	1			1		
Mechanic	2	3	1	1	1	1
Electrician	1	1	1	1	1	1
Technical support	2	2	2	1	1	2

Source: JET based on the discussion with ME team
Inspection-1: In charge of Nadi, Sigatoka
Inspection-2: Lautoka, Ba, Tavua, Rakiraki

(3) WWTPs

The organizational structure for implementing O&M of WWTPs differs depending on the sewerage and sludge treatment process. **Table S2. 6-4** shows the treatment method and capacity, as well as the proposing O&M methods of the five WWTPs proposed in Nadi and Lautoka.

Table S2. 6-4 Treatment Process/Capacity and Proposed O&M Method for WWTPs

Municipality	WWTP	Sewerage Treatment		Sludge treatment	O&M method
		Process	Capacity (m^3/day)		
Nadi	Navakai	OD	29,800	Excess sludge: Thickening⇒Mechanical dewatering ⇒Sun drying	M-1
	Moala	TF	19,300	Primary sludge: Thickening⇒Transport to Natabua Excess sludge: Mechanical dewatering ⇒Sun drying	M-2
	Sabeto	TF	7,100	Primary sludge: Thickening⇒Transport to Natabua Excess sludge: Mechanical dewatering⇒Sun drying	M-3
Lautoka	Natabua	TF	44,400	Primary sludge: Thickening⇒Anaerobic digestion ⇒Mechanical dewatering ⇒Sun drying Excess sludge: Anaerobic digestion ⇒Mechanical dewatering⇒Sun drying Septage: Anaerobic digestion⇒Mechanical dewatering ⇒Sun drying * Accepting primary sludge from other WWTPs into digester *Accepting septage from 6-city/town into the digester	M-1
	Vitogo	TF	7,100	Primary sludge: Thickening⇒Transport to Natabua Excess sludge: Mechanical dewatering⇒Sun drying	M-3

Source: JET

Table S2. 6-5 shows specific O&M implementation methods for each of M-1 to M-3 shown in the O&M method of **Table S2. 6-6**.

Table S2. 6-5 O&M Implementation Method

M-1	Operation	Operation of sewerage/sludge treatment facilities in 3 shifts
	Maintenance	Patrol/inspection/maintenance works during daytime
	Water quality test	Simple test of pH, transparency, SV (in OD process), Dissolved Oxygen
M-2	Operation	Operation of sewerage/sludge treatment facilities in 2 shifts, Remote monitoring from the core WWTP at night
	Maintenance	Patrol/inspection/maintenance works during daytime
	Water quality test	Simple test of pH, transparency
M-3	Operation	Resident operation of sewerage/sludge treatment facilities during the daytime, Remote monitoring from the core WWTP at night
	Maintenance	Patrol/inspection/maintenance works during daytime
	Water quality test	Simple test of pH, transparency

Source: JET

Table S2. 6-6 Proposed Duties of Staff in Charge of WWTPs

Position		**Vitogo**	**Natabua**	**Sabeto**	**Navakai**	**Moala**
Chief of WWTP		1	1	1	1	1
Wastewater treatment	Deputy Chief (Wastewater)	-	1	-	1	-
	Operator (Wastewater)	2	2 x 3shifts	2	2 x 3shifts	2 x 3shifts
	Worker (Wastewater)	2	2	2	2	2
Sludge treatment	Deputy Chief (Sludge)	-	1	-	1	-
	Operator (Sludge)	2	3	2	3	2
	Worker (Sludge)	2	3	2	3	2
	Operator (Septage)	-	2	-	-	-
	Worker (Septage)	-	2	-	-	-
Laboratory Technician		-	1	-	1	-
Worker (Cleaning)		2	3	2	3	2
Total		11	25	11	21	15

Source: JET

7. COST ESTIMATIONS

(1) WWTP Construction Cost

Table S2. 7-1 shows the approximate construction costs have been estimated based on the approximate scale of civil works of the five WWTPs (land acquisition costs included).

Table S2. 7-1 WWTP Construction Costs

Municipality	WWTP	Treatment Process	Maximum Daily Flowrate (m^3/day)	Construction Cost (million FJD)
Lautoka	Vitogo	Trickling Filter	7,100	77
	Natabua	Trickling Filter	44,500	405
Nadi	Sabeto	Trickling Filter	7,100	78
	Navakai	Oxidation Ditch	29,800	312
	Moala	Trickling Filter	19,300	196

*1 FJD = 67.55 JPY (April 2024)
Source: JET

(2) WWTP O&M Cost Estimations

The O&M costs for WWTPs have been calculated using Japanese cost experience as shown in **Table S2. 7-2.**

Table S2. 7-2 WWTP O&M Costs

Municipality	WWTP	Treatment Process	O&M Cost (1000 FJD/yr)
Lautoka	Vitogo	Trickling Filter	1,350
	Natabua	Trickling Filter	3,866
Nadi	Sabeto	Trickling Filter	1,350
	Navakai	Oxidation Ditch	3,150
	Moala	Trickling Filter	2,433

*1 FJD = 67.55 JPY (April 2024)
Source: JET

(3) Sewer Network Construction/O&M Cost Estimations

The construction cost of the sewer network was estimated by taking the approximate quantity of pipeline length by section, and multiplying it by the unit price per meter of pipeline by section and depth set. **Table S2. 7-3** shows the construction and maintenance costs of sewer pipes.

Table S2. 7-3 Construction Cost and O&M Cost of Sewer Network

Service Area	Pipe Length (km)	Construction Cost (million FJD)	O&M Cost (1000 FJD/yr)
Vitogo	112	200	112
Natabua	207	301	207
Sabeto	126	325	126
Navakai	261	398	261
Moala	264	366	264

*1 FJD = 67.55 JPY (April 2024)
Source: JET

(4) Pump Station Construction/O&M Cost Estimations

Table S2. 7-4 shows the estimated construction/O&M costs of pumping stations.

Table S2. 7-4 Construction and O&M Costs for Pumping Stations

Service Area	Number of Pump Stations	Construction Cost (million FJD)	O&M Cost (1000 FJD/year)
Vitogo	21	17	1,285
Natabua	52	41	3,182
Sabeto	62	48	3,795
Navakai	67	52	4,100
Moala	102	76	6,242

*1 FJD = 67.55 JPY (April 2024)
Source: JET

8. ECONOMIC AND FINANCIAL ANALYSIS

The purpose of financial analysis is to evaluate the feasibility of implementing a project from the perspective of financial viability for the project proponent. On the other hand, the purpose of economic analysis is to verify the validity of project implementation from the viewpoint of national economy.

(1) Financial Analysis

The financial analysis based on the expenditure and income calculated under set assumptions resulted in the FIRR showing a negative return of -3.4%

The project implementing body needs not only capital investment costs but also a minimum amount of sewerage revenue equal to or greater than the operation and maintenance costs to continue the project. The sewerage usage fee required to finance the operation and maintenance costs is calculated to be at least 0.77 FJD/m^3.

(2) Economic Analysis

The economic analysis based on the same assumptions as the financial analysis resulted in the EIRR showing a positive return of 1.2%

The target EIRR for project implementation is 9%, or 6.0% for projects such as prevention of environmental pollution, poverty reduction in rural areas, and mitigation of natural disasters. The EIRR of Municipal Sewerage M/P is below both targets.

9. CONCLUSION AND RECOMMENDATIONS

(1) Conclusions

During the Municipal Sewerage M/P study, the 5-service area scenario was found to be most effective in reducing construction and O&M costs. Lautoka is divided into 2 service areas (Vitogo and Natabua), and Nadi is divided into 3 service areas (Sabeto, Navakai and Moala). Regarding the effluent standards to be applied to the proposed WWTPs, the option of discharging the effluent to accordance with the General standards at a point 1 km offshore has been approved through discussions with the DOE in order to reduce O&M costs. This option will apply to the Vitogo, Natabua, Sabeto and Moala WWTPs. Navakai WWTP in Nadi is located far from the sea and has no option but to discharge into the nearby Nadi River, and the SEZ standard will be applied.

As for sludge treatment, a centralized treatment of raw sludge at Natabua WWTP to generate electricity from digester gas in the future was formulated. To improve wastewater treatment services in areas where the sewerage system is not yet developed, the effectiveness of a septage collection and treatment system at the Natabua WWTP was confirmed. As for sludge disposal, since acceptance by landfill acceptance and effective use of sludge have not yet been realized, JET has proposed a sludge storage system at WWTPs.

As for sewer networks, an appropriate combination of gravity and pressurized flow is proposed, assuming a separate collection system. The outline of the five proposed service areas and their estimated construction costs are summarized below.

Table S2. 9-1 Outlines of Facilities and Construction Costs

Municipality	WWTP	Outlines of Facilities		Construction Costs (million FJD)
Lautoka	Vitogo	WWTP	Trickling Filter (Q=7,100m^3/day)	120
		Sewer (Trunk/Sub-trunk)	Dia.100-600mm L=41 km	75
		Pumping station (Trunk/Sub-trunk)	12 stations	10
	Natabua	WWTP	Trickling Filter (Q=44,500m^3/day)	500
		Septage treatment	Mechanical dewatering	11
		Sewer (Trunk/Sub-trunk)	Dia.100-750mm L=64 km	92
		Pumping station (Trunk/Sub-trunk)	30 stations	24
Nadi	Sabeto	WWTP	Trickling Filter (Q=7,100 m^3/day)	130
		Sewer (Trunk/Sub-trunk)	Dia.100-400mm L=49 km	120
		Pumping station (Trunk/Sub-trunk)	35 stations	27
	Navakai	WWTP	OD (Q=29,800 m^3/day)	312
		Sewer (Trunk/Sub-trunk)	Dia.100-900mm L=58 km	94
		Pumping station (Trunk/Sub-trunk)	37 stations	29
	Moala	WWTP	Trickling Filter(Q=19,300m^3/day)	271
		Sewer (Trunk/Sub-trunk)	Dia.100-900mm L=105 km	161
		Pumping station (Trunk/Sub-trunk)	54 stations	40

* 1 FJD = 67.55 JPY (April 2024 rate)
*Includes land acquisition costs for WWTPs
Source: JET

(2) Recommendation

i. Land for WWTPs

In formulating the Municipal Sewerage M/P, construction of two new WWTPs in Nadi/one new WWTP in Lautoka, as well as the expansion of the existing Natabua and Navakai WWTP was proposed. It should be noted that the selection of these WWTP candidate lands is based on on-map inspections of sites that were deemed to be possible for construction; in order to officially identify these locations as WWTP sites, evaluation of potential resettlement issues and investigation of land negotiation/acquisition processes for existing dwellings must be implemented, followed by sufficient consultation with the stakeholders.

ii. Environmental Impact Assessment of the Effluent Discharging Areas

Ocean outfall of the effluent is recommended for two new WWTPs in Nadi and one new WWTP in Lautoka. In addition, the replacement of existing ocean outfall pipe of Natabua WWTP is recommended in the Municipal Sewerage M/P. It is also necessary to conduct an Environmental Impact Assessment (hereinafter referred to as “EIA”) for the ocean outfall areas.

Regarding the basic data necessary for EIA, it is necessary to indicate the items to be investigated in the Pre-F/S implementation, referring to the survey results of the Kinoya WWTP in Suva, which is also planning to construct an ocean outfall pipe.

iii. Disposal and Effective Utilization of Sewerage Sludge

Currently, there is no disposal site for sewerage sludge in the Western Division, so the Municipal Sewerage M/P recommends the construction of a disposal site within the premises of Natabua WWTP. However, it requires a large footprint for disposing the sludge generated in 20 years, which will be a significant issue in increasing construction costs. Therefore, it is an urgent issue to consider disposal method and effective use of sewerage sludge.

As a disposal method, for example, acceptance to a domestic waste disposal site in Lautoka, and as an effective use, agricultural use will be worth considered. For the consideration, it is important to grasp the concentration of hazardous substances such as heavy metals in the sludge in the study. However in Fiji, there are only a limited number of laboratories that can implement the analysis, and sufficient analytical equipment has not been installed.

Since the concentration of hazardous substances in sludge will need to be analyzed long into the future, it is necessary to develop a system that allows analysis at the WAF water analysis laboratory.

iv. Information on Existing Pipelines and Exclusive Use of New Pipelines

Although information on existing sewer pipes is basically stored in GIS, there are many items of which numerical values are not entered in GIS information, making it difficult to evaluate the flow capacity, which is in a situation that is not easy to construct additional pipes. Therefore, an investigation of the facility

specifications (pipe material, cross section, pipe invert level) including the location of the existing sewer is necessary.

The route of the new pipelines proposed in this M/P must be adjusted in comparison with the location of existing households and their drainage pipes. In the case where pipelines must pass through privately owned land, a consultation process needs to be established with the Ministry of Land and iTaukei Land Trust Board (hereinafter referred to as "TLTB") regarding the acquisition of property easement.

v. Making Budget for Sewerage Works

In the Municipal Sewerage M/P, it was clarified that the sewerage service charges would need to be four times higher than the current charges in order to cover the O&M costs of the sewerage facilities. Therefore, it is necessary to consider measures taking into account of the increase in the burden on beneficiaries, such as gradual increases in tariffs.

On the other hand, public utility charges, including sewerage charges, have become an important policy issue for the government, making it difficult to revise charges easily. WAF is necessary to demand that the necessary maintenance costs be secured from the national budget.

vi. Organizational Structure on O&M

1) WWTPs

Navakai WWTP in Nadi, which is currently the only plant adopting a mechanical sewerage treatment process among the existing four WWTPs in the Western Division, is unable to comply with the effluent standards due to insufficient treatment capacity for inflow sewerage. In addition, due to the lack of budget and equipment for O&M, the facilities are severely deteriorated, making it difficult to carry out appropriate O&M. The Municipal Sewerage M/P proposed to introduce mechanical sewerage treatment (such as the OD and TF process) to all five WWTPs in Nadi and Lautoka, and it is essential to secure the budget and equipment for O&M.

In order to implement appropriate O&M at WWTPs to be constructed in the future, first of all it is necessary to secure O&M budget for the current Navakai WWTP, strengthen the capacity of WWTP staff, and implement appropriate O&M.

Such capacity building is difficult to implement by WAF alone, and it would be effective, for example, to strengthen capacity through JICA Technical Cooperation Project and to build an appropriate O&M system for the newly constructed WWTPs.

2) Water Analysis Lab

In Fiji, the wastewater discharge standards are set for hazardous substances such as heavy metals and cyanide as well as for general substances such as BOD and SS. However, due to the lack of analytical equipment, the water quality laboratory of WAF is not able to properly analyze all the substances, and the

heavy metals in the sludge cannot be analyzed at all. Therefore, it is essential to prepare analytical equipment for the laboratory and strengthen the capacity of the laboratory staff for the wastewater quality and sludge management, and regulation of liquid trade waste.

It will be effective to prepare the necessary equipment and materials through JICA Technical Cooperation Project and to strengthen the capacity of the staff.

3) Sewer Network

According to the National Development Plan that aims for 70% of the population to connect to centralized treatment systems by 2036, the increase of newly constructed sewer pipes by the expansion of service areas, as well as the deterioration of existing pipes, will progress year by year. The management of sewer network assets will be an extremely important issue.

Currently, sewer network (pipe) maintenance is basically carried out by WAF. But for the future WAF should set a policy that for example, WAF will mainly conduct inspections and surveys of pipes, and private sector will be entrusted to implement sewer pipe repairs such as removing clogging, and based on the policy WAF has to prepare the budget, human resources and equipment.

Since WAF has little experience in conducting pipeline inspections and surveys, it is effective to acquire the procedures and know-how through JICA Technical Cooperation Projects.

4) Mechanical and Electrical Equipment

Currently, the mechanical and electrical team is in charge of the maintenance of the mechanical and electrical equipment at all water supply and sewerage facilities in the Western Division.

WAF Western stated that this situation is caused by the lack of manpower and budget. According to the Mechanical Electrical Team, the number of working staff has gone down from 16 personnels to 9 personnel, making it impossible to conduct proper maintenance; this leads to the continuous failures of equipment, consuming much of the budget. Necessary materials and consumables cannot be prepared from the remaining budget, creating a vicious cycle.

In order to improve this situation, it is most important to first secure a budget for equipment maintenance.

In addition, so that maintenance can be carried out with a small number of staff, it is important to establish a system that the pipe maintenance team and the operation team in WWTPs carry out visual inspections of the equipment, and the mechanical and electrical team conducts daily and periodical inspections such as grease/oil and spare parts replacement.

Periodical maintenance by manufacturers is important to prevent equipment breakdowns and extend life of the equipment, so WAF has to secure the budget.

5) Liquid Trade Waste

In Fiji, there is a regulation and standard for discharging liquid trade waste into the sewerage system, but legal penalty clauses are still under consideration in the government, so compulsory regulation is not yet possible.

Section 3 PRE-F/S FOR PRIORITY PROJECT

1. PROJECT BACKGROUND

(1) Background

In the Western Division of Viti Levu, Fiji, four cities and towns have wastewater treatment plants, but due to overloading caused by increasing sewerage flows to the WWTPs, improper operation and maintenance, equipment failure, and aging facilities, wastewater is discharged without adequate treatment, posing concerns about water pollution. In response to these issues, the “Project for Formulation of Wastewater Treatment Master Plan in Western Division” was implemented from October 2021 to develop a Regional Wastewater Master Plan, including decentralized treatment systems in the Western Division, and to provide training to improve the maintenance and management capacity of sewerage facilities.

In the first year's Output 1, "Regional Wastewater Master Plan", the service areas for the achievement of the National Development Plan of "70% access to centralized treatment systems" were identified for six cities and towns in the Western Division (Lautoka, Nadi, Ba, Tavua, Rakiraki, and Sigatoka).

In the second year's Output 2 "Municipal Sewerage Master Plan", a municipal sewerage master plan was formulated for the target cities, Lautoka City and Nadi Town. Based on WAF's request to divide the service areas into multiple service areas, Lautoka City was divided into Vitogo and Natabua service areas and Nadi Town was divided into Sabeto, Navakai and Moala service areas. Based on discussions with the DOE, it was decided that Navakai WWTP would adopt the Oxidation Ditch process, which meets the SEZ discharge standards, and the other four WWTPs would use the Trickling Filter process, which meets the general discharge standards with ocean outfall pipes. As the priority of development is considered high for the already developed Natabua and Navakai service areas, priority projects will be selected, and Pre-F/S will be carried out.

(2) Purpose of the Project and Outputs

In the third year of the Project, a Pre-F/S for the priority projects will be formulated on the basis of Outputs 1 and 2. The achievement of these outputs will facilitate the implementation of the capacity improvement and expansion project for sewerage facilities in the Western Division and contribute to the improvement of the urban, public health and water environment in the Western Division. This Pre-F/S study will investigate and organize the project objectives/contents/cost estimations, project implementation structure, O&M organization structure, and environmental and social considerations.

(3) Current Challenges

Both Navakai and Natabua WWTPs have been in operation for 40 to 50 years, and although the Navakai WWTP has been upgraded to the IDEA process, the current inflow is considered to exceed treatment capacities. In addition, due to factors such as lack of maintenance and long-term failures of mechanical equipment, including aerators, the effluent has not been adequately treated and effluent standards have not been met. Since WAF's effluent quality does not meet effluent standards, it cannot actively increase the number of new connections; thus the main challenge is to increase the capacity of the WWTPs to comply

with effluent standards.

In addition, there are several problems such as the lack of proper treatment and final disposal of sludge. **Table S3. 1-1** shows the general problems of the two WWTPs.

Table S3. 1-1 Current Challenges of Natabua, Navakai WWTP

Category	Natabua WWTP	Navakai WWTP
Wastewater Treatment	▪ Treated water does not satisfy effluent standards ▪ Lack of treatment capacity ▪ Decreased effective pond volume (in other words, the treatment capacity) due to lack of sludge dredging	▪ Treated water does not satisfy effluent standards ▪ Lack of treatment capacity ▪ Lack of aerators (planned: 8 units, currently working: 4 units) ▪ Unhealthy condition of IDEA pond activated sludge (over aging due to lack of excess sludge withdrawal)
Sludge Treatment	▪ Lack of sludge dredging (Only implemented once since operation commencement 40 years ago) ▪ Lack of proper final disposal site (dumped at open lot in vicinity of WWTP) →sludge and leachate flowing out to nearby water bodies through rain/wind	▪ Lack of excess sludge withdrawal ▪ Broken aerobic digestion pond aerator (planned: 2 units, currently working: 1 unit) ▪ Broken sludge dewaterer ▪ Lack of proper final disposal site (dumped onsite) →sludge and leachate flowing out to nearby water bodies through rain/wind
Other	▪ Lack of proper Operation and Maintenance (O&M) ▪ Septage dumped to unlined pit → no proper treatment, flows out to nearby water bodies	▪ Lack of proper O&M

Source: JET

The following tables shows the effluent quality of the Natabua WWTP and Navakai WWTP. The treated effluent quality from both WWTPs often does not meet Fiji's discharge standards, with the BOD compliance rate (number of effluent samples that meet the standard / total number of effluent samples) being approximately 50% for Natabua and 60% for Navakai.

Table S3. 1-3 Natabua WWTP Water Analysis Results

Year	Influent							Effluent						
	T-SS	BOD	COD	T-N	T-P	FOG	Faecal Coliforms	T-SS	BOD	COD	T-N	T-P	FOG	Faecal Coliforms
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Col./100ml	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Col./100ml
Gen Std.								60	40	—	25	5	5	400
2014	530	320	590	8.4	4.6	240	—	82	**64**	170	4.4	3.4	38	—
2015	480	300	580	11	3.7	150	—	44	**65**	130	4.9	2.2	33	—
2016	440	390	830	—	0.6	22	—	52	**44**	120	—	0.8	4.2	—
2017	850	330	600	51	3.6	24	54,000,000	110	**69**	190	26	2.3	7.3	1,169,600
2018	300	210	520	41	2.3	71	260,000,000	55	**51**	140	22	1.2	32	22,012
2019	370	220	410	28	5.8	86	300,000,000	53	39	110	20	4.0	15	208,491
2020	870	220	530	20	8.1	170	96,000,000	58	36	120	15	5.7	40	98,200
2021	430	170	480	22	7.0	130	360,000,000	57	**83**	210	1.9	3.9	49	772,720
2022	260	220	390	18	11.0	120	420,000,000	78	**84**	170	18	7.0	51	46,078
2023	480	260	370	23	15.0	87	9,400,000	27	35	90	14	7.0	23	10,171
Avg.	520	310	620	28	3.0	100	210,000,000	69	**59**	150	14	2.0	23	332,467

Source: Created by JET based off WAF data

Table S3. 1-2 Navakai WWTP Water Analysis Results

Year	Influent							Effluent						
	T-SS	BOD	COD	T-N	T-P	FOG	Faecal Coliforms	T-SS	BOD	COD	T-N	T-P	FOG	Faecal Coliforms
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Col./100ml	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Col./100ml
Gen. Std.								60	40	—	25	5	5	400
2014	970	500	930	9.2	3.5	260	—	80	**55**	140	5.4	2.8	52	—
2015	930	360	880	9.2	2.8	190	—	44	**41**	91	5.6	2.3	55	—
2016	590	450	1300	13.0	2.3	24	—	54	**49**	120	11	1.6	11	—
2017	510	320	650	58.0	3.3	17	370,000,000	160	**85**	230	32	1.5	10	7,724,182
2018	450	240	590	47.0	3.2	57	300,000,000	120	**68**	180	29	2.4	23	8,893,200
2019	250	190	440	33.0	6.5	140	330,000,000	43	29	77	27	5.9	60	562,350
2020	200	140	430	20.0	7.6	130	98,000,000	24	20	100	15	2.8	36	3,154,333
2021	200	130	290	21.0	9.0	150	170,000,000	29	31	54	20	4.3	54	1,936,067
2022	260	220	390	18.0	11.0	120	160,000,000	78	**83**	190	17	8.0	55	6,419,720
2023	400	210	330	25.0	13.0	150	9,500,000	60	**45**	77	21	10.0	43	9,029
Avg.	690	370	870	27.0	3.0	110	210,000,000	91	**60**	150	17	2.1	30	4,099,840

Source: Created by JET based off WAF data

2. PLANNING BASIS AND DESIGN CONDITIONS

(1) Priority Projects for the Pre-F/S

Table S3. 2-1 shows the comparative assessment of candidate cases. Upon determining the Pre-F/S priority projects, WAF placed importance in the compliance of legal effluent standards by existing WWTPs. For this reason, the upgrade of Natabua and Navakai WWTP, which have large treatment capacities, were selected.

Table S3. 2-1 Candidate Case Comparison of Priority Projects

Item	Case 1: Nadi sewer & WWTP	Case 2: Lautoka sewer & WWTP	Case 3: Nadi & Lautoka & WWTP
Persons connected to sewerage system	Lautoka: 29,000 Nadi: 21,100	Lautoka: 40,500 Nadi: 15,800	Lautoka: 29,000 Nadi: 15,800
Effluent BOD (mg/L)	Natabua: 56 Navakai: 20	Natabua: 40 Navakai: 47	Natabua: 40 Navakai: 20
Effluent BOD load (BOD-t/yr)	304	331	237
Removed BOD load (BOD-t/yr)	94	67	161
Construction cost (mil. FJD)	413	356	399
Cost/ Removed BOD load (mil. FJD/t/yr)	4.4	5.3	2.5

Source: JET

(2) Necessity of the Project

This project aims to contribute to the protection/improvement of water environment and public health in the Natabua (Lautoka City) and Navakai (Nadi Town) area by expanding sewerage and sludge treatment facilities of the area. Since the contents of the project matches with the target areas' needs as well as Fiji's national development policies, the project's validity and necessity to support its implementation is high. Specific points are as follows:

1. Natabua (Lautoka City) and Navakai (Nadi Town) are areas with highest population growth in the Western Division of Viti Levu, and are expected to continue its growth in the future. The service population of the two areas are expected to increase to about 1.3 times that of 2023 by year 2043.

2. Although there are currently no immediate plans to expand the water supply facilities in the target area, measures are being taken to reduce non-revenue water ratio to 20% in the long term as part of a Japanese technical cooperation project ("The Project for Capacity Development of Non-Revenue Water Reduction in Nadi and Lautoka Area"). Increase in domestic, commercial and tourist water consumption is expected.

3. In result of the above, the amount of generated sewerage in Natabua (Lautoka City) and Navakai (Nadi Town) is expected to steadily increase through 2043.

4. Tourism revenue accounts for approximately 25% of Fiji's gross domestic product (hereinafter referred to as “GDP”), and approximately 40% of tourists to Fiji stay in Lautoka/Nadi, and 10% stay on the islands around Nadi. Since marine and coastal resources form the backbone of resorts, there is a high need to conserve public waters as a tourism resource.

5. However, the compliance rate of effluent quality from both Natabua/Navakai WWTP as of 2023 is only about 60%, suggesting the discharge of insufficiently treated sewerage. The effluent, including untreated sewerage/wastewater, is causing deterioration of the water quality of public waters.

6. This project will upgrade the sewerage/sludge treatment facilities of Natabua and Navakai WWTP to achieve the proper treatment of inflowing sewerage. By treating sewerage up to levels meeting effluent standards, the assurance of legal compliance, as well as the improvement of downstream water quality are expected, further leading to the preservation of marine environment (tourism resources). Therefore, the implementation of this project is highly significant.

7. The National Development Plan 2036 (hereinafter referred to as “NDP 2036”) states that "the development/expansion of sewerage systems will be promoted in all urban areas, to achieve 70% population access to central sewerage systems by 2036." In addition, the Water Sector Strategy 2050 (published by MPW[3] and WAF in April 2024) lists the expansion plans for Natabua and Navakai WWTP as projects to be achieved by 2040, based on the Municipal Sewerage M/P. This project is consistent with these policies, and the validity of its implementation is high. In parallel, it is also important to implement restoration projects of existing facilities, as well as improvements in intangible initiatives of facility maintenance/management.

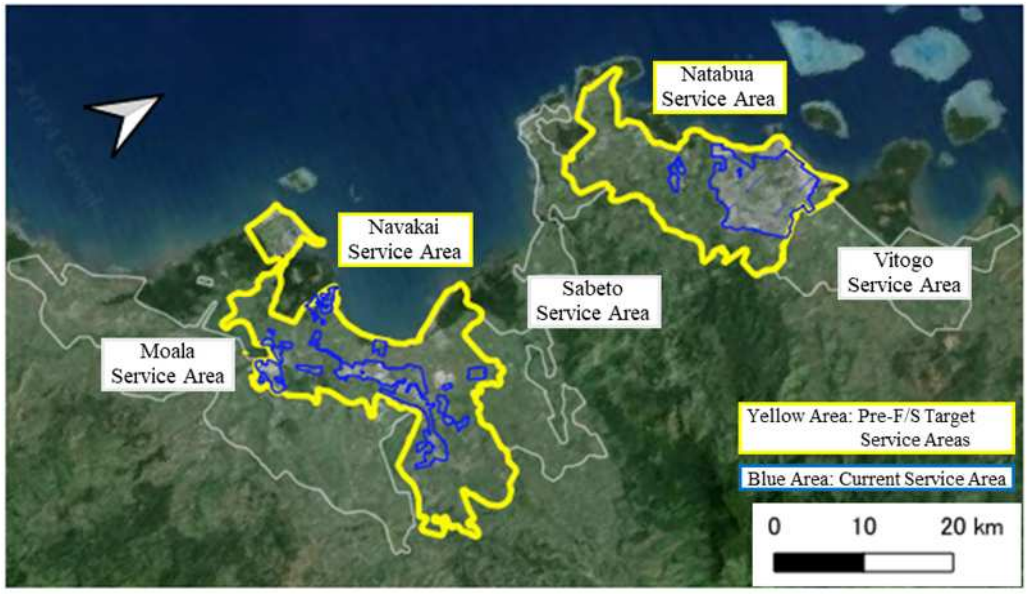
(3) Target Year

The target year is set at 2043, in accordance with the Municipal Sewerage M/P.

(4) Service Area

The proposed service area is the same as that of the Municipal Sewerage M/P, shown in Figure S3. 2-1. There is no change to the sewerage planning area because the area is set to achieve the National Development Plan’s goal of "making 70% of the population accessible to centralized sewerage services."

[3] MPW: Ministry of Public Works, Meteorological Services and Transport (after organizational restructuring: former MIMS)



Source: JET

Figure S3. 2-1　Service Area (Natabua/Navakai Service Areas)

(5) Planned Wastewater Flow

Fundamental planning frames such as the planned service population, unit wastewater volume etc. are set in accordance with the Municipal Sewerage M/P (**Table S3. 2-2**).

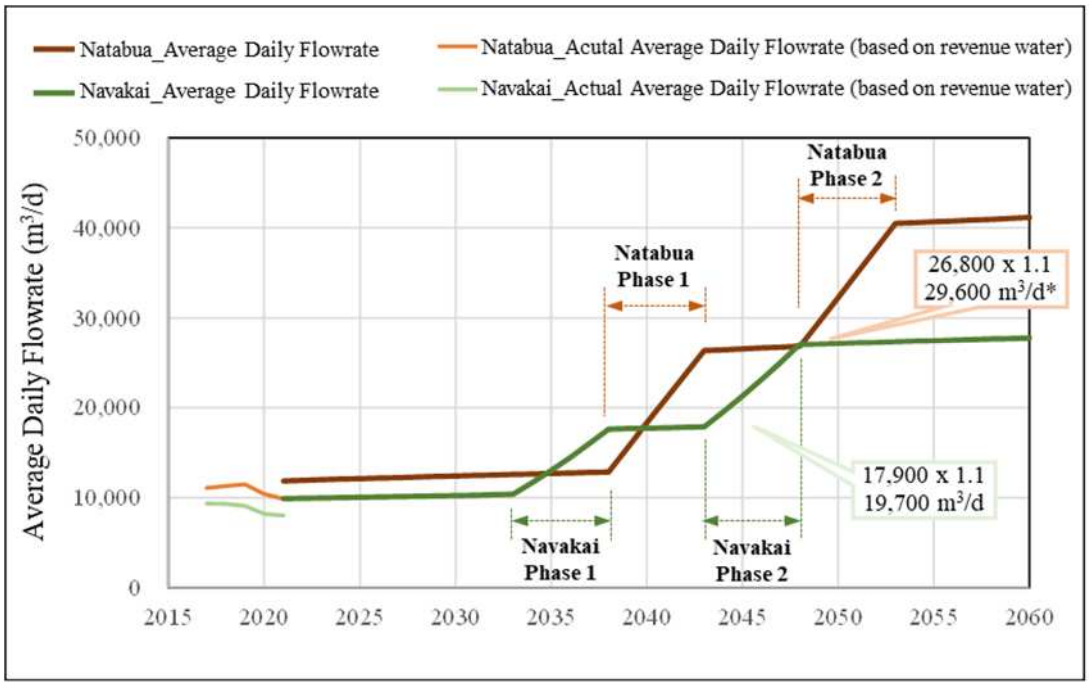
Table S3. 2-2　Wastewater Flow of Each Service Area in 2043

No.	Parameter	Units	Lautoka		Nadi			Total
			Vitogo	Natabua	Sabeto	Navakai	Moala	
1	Population	capita	15,130	105,590	13,510	52,740	35,420	222,390
2	Water Consumption	m^3/capita/day	0.220	0.220	0.220	0.220	0.220	
3	Return Ratio	%	90	90	90	90	90	
4	Unit wastewater Flow	m^3/capita/day	0.200	0.200	0.200	0.200	0.200	
5	Domestic Flow	m^3/day	3,026	21,118	2,702	10,548	7,084	44,478
6	Non-Domestic Flow	m^3/day	2,760	15,640	3,110	14,000	8,810	44,320
7	Generated Wastewater	m^3/day	5,786	36,758	5,812	24,548	15,894	88,798
8	Infiltration ratio	%	10	10	10	10	10	
9	Infiltration water	m^3/day	579	3,676	581	2,455	1,589	8,880
10	Total Inflow ADWF	m^3/day	6,365	40,434	6,393	27,003	17,483	97,678
11	Total Inflow PDWF	m^3/day	7,001	44,477	7,033	29,703	19,232	107,446

Source: JET

(6) Target Treatment Flow of the Pre-F/S

Taking into consideration the current influent flowrate, planned wastewater flow, and development steps of both WWTPs, the Pre-F/S's target treatment flow of Natabua WWTP was set at 29,600 m^3/day (maximum daily flow), and for Navakai WWTP was set at 19,700 m^3/day (maximum daily flow) as shown in **Figure S3. 2-2.**



*Raw sewerage from sewer network. Does not include other wastewaters accepted at Natabua WWTP
Source: JET

Figure S3. 2-2 Estimation of Natabua/Navakai WWTP Inflow

(7) Planned Influent Quality

This project will set WWTP-specific influent wastewater qualities based on recorded raw data.

i. Natabua WWTP

Natabua WWTP's influent quality was set as shown in **Table S3. 2-3**. Its wastewater treatment system's treatment target will include "raw sewerage (influent from sewer network)," "dewatered septage leachate," and "pre-treated distillery wastewater." Raw sewerage water quality was determined based on Natabua WWTP's raw influent data from 2014-2019 and 2023, which excludes periods effected by the COVID-19 pandemic.

Table S3. 2-3 Natabua WWTP Influent Wastewater Quality

BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)	Water Temperature (℃)
398	500	45	11	20

*Mixture of raw sewerage, dewatered septage leachate, and pre-treated distillery wastewater
Source: JET

ii. Navakai WWTP

Navakai's treatment target will be solely "raw sewerage," with water qualities shown as **Table S3. 2-4**. Similar to Natabua WWTP, raw sewerage water quality was determined based on Natabua WWTP's raw influent data from 2014-2019 and 2023, which excludes periods effected by the COVID-19 pandemic.

Table S3. 2-4 Navakai WWTP Influent Water Quality

BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)	Water Temperature (℃)
367	544	37	6	20

Source: JET

(8) Effluent Quality

As stated earlier, this Pre-F/S study will set the target effluent standards for Natabua WWTP and Navakai WWTP as General standards (+ ocean outfall pipe) and SEZ standards, respectively.

As a sidenote, DOE commented that when adopting "General standards + ocean outfall pipe", it is necessary to submit an Environmental Impact Assessment to the DOE and hold discussions at the F/S stage.

- Effluent volume and water quality to be discharged from WWTPs
- Degree of effluent dilution and environmental carrying capacity of the planned discharging area
- Environmental/biological assessment of planned discharging areas, etc.

3. NATABUA WWTP

(1) Natabua WWTP

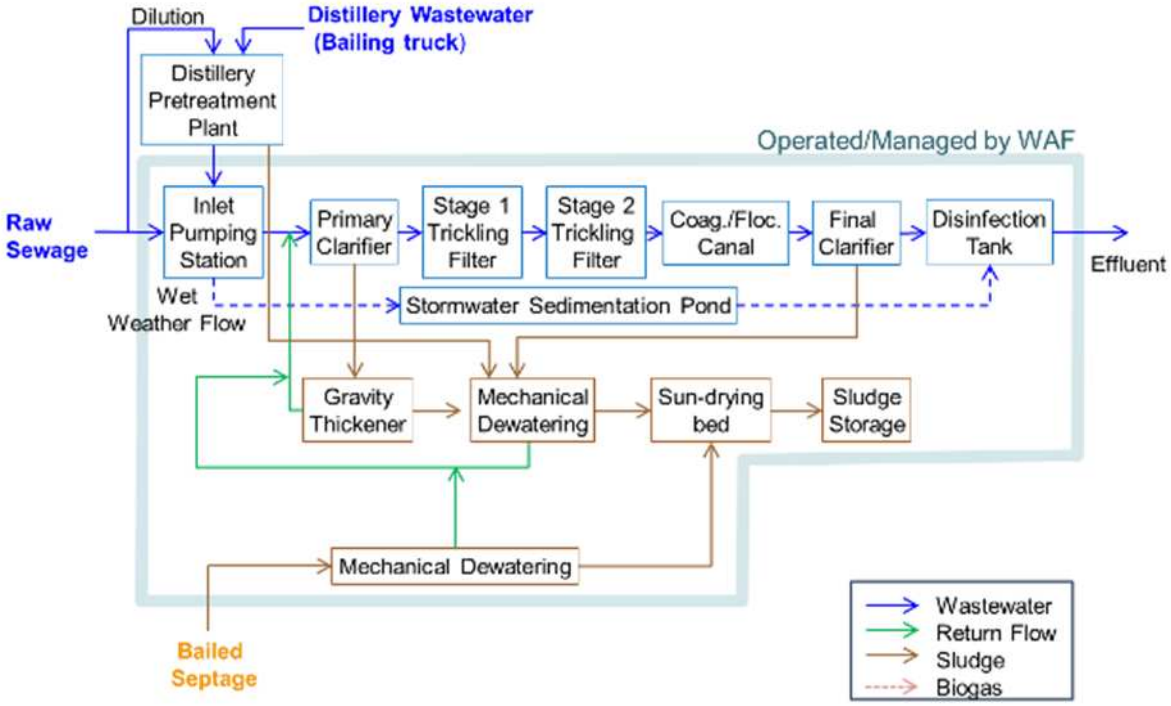
Natabua WWTP will switch its treatment method from the current "stabilization pond" to the "two-stage trickling filter + post-coagulation," process increasing its capacity to a daily maximum of 29,800 m^3/day in Phase 1, then up to a daily maximum of 44,800 m^3/day in Phase 2. Natabua WWTP will also accept septage/sewerage sludge from other WWTPs to its treatment system; facilities having co-relation with Natabua WWTP are listed in **Table S3. 3-1**.

Table S3. 3-1 Facilities Co-related with Natabua WWTP

Facility	Description	Co-relation with Natabua WWTP	Planned Time of Construction	Pre-F/S Target
Septage Treatment Facilities	Treats septage bailed in by bailing trucks	・Septage dewatering → Drying → storage within Natabua WWTP boundary ・Dewatered leachate treated by Natabua wastewater treatment system	Phase 1 or before	Included
Distillery Pretreatment Plant	Pretreats distillery wastewater bailed in from South Pacific Distillery Inc.	・Dilute distillery wastewater using part of raw sewerage flowing into Natabua ・Pretreated wastewater treated by Natabua wastewater treatment system ・UASB unit sludge co-treated with Natabua WWTP sewerage sludge in Sludge Digestion Facility	Phase 1	Not Included
Outer Sludge Receival Tank	Received thickened raw sludge bailed from planned future WWTPs (Vitogo, Sabeto, Moala)	・Received sludge co-treated with Natabua WWTP sewerage sludge in Sludge Digestion Facility	Phase 2	Included
Sludge Digestion Facility	Anaerobically digests Natabua, Vitogo, Sabeto, Moala WWTP sewerage sludge and Distillery Pretreatment Plant UASB sludge. Produced biogas is collected and senet to Biogas Power Generation Plant	・Anaerobic digestion of Natabua sludge and sludge bailed from other WWTPs ・Digested sludge is dewatered → Drying → storage within Natabua WWTP boundary ・Dewatered leachate treated by Natabua wastewater treatment system	Phase 2 or after	Included
Biogas Power Generation Plant	Refines biogas methane gas, which is utilized for power generation	・Received biogas produced from Sludge Digestion Facility	Phase 2 or after	Not Included

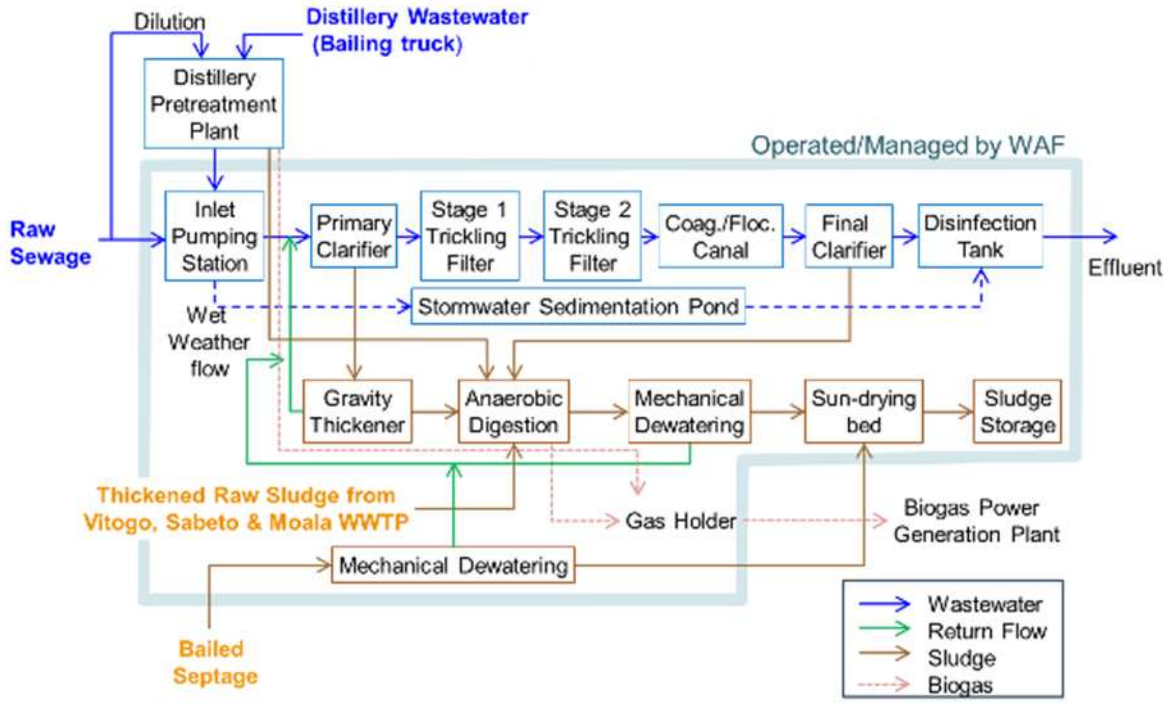
Source: JET

The treatment flow of Phase 1 and Phase 2 are shown in **Figure S3. 3-1**, **Figure S3. 3-2** respectively.



Source: JET

Figure S3. 3-1 Natabua WWTP Treatment Flow Diagram (Phase 1)



Source: JET

Figure S3. 3-2 Natabua WWTP Treatment Flow Diagram (Phase 2)

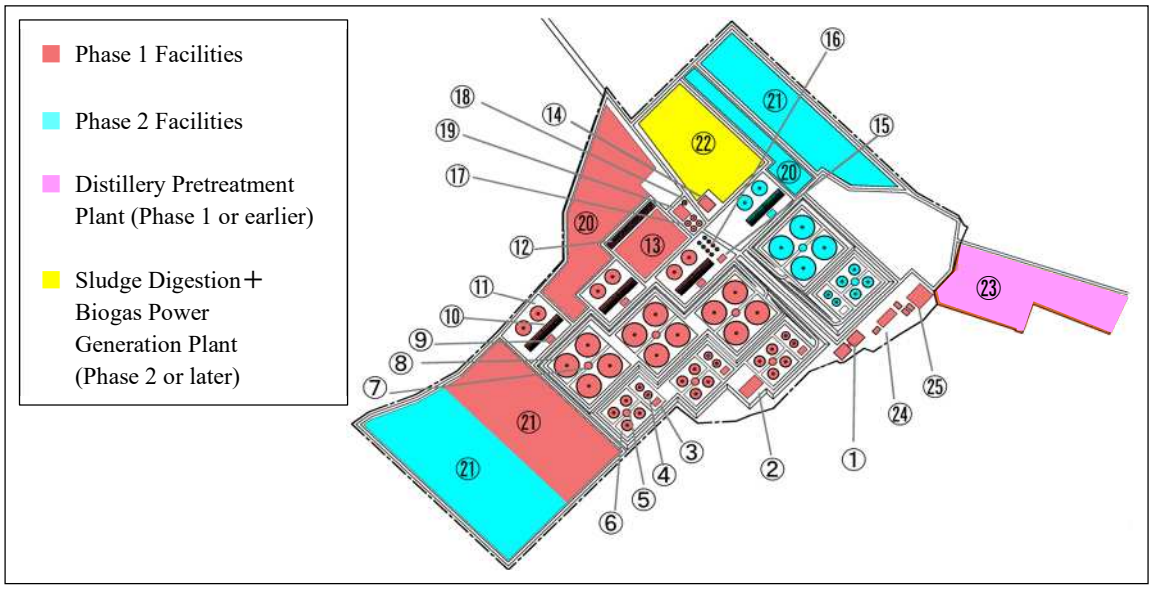
Table S3. 3-2 Natabua WWTP Facility Overview

Parameters		Phase 1	Phase 1 +Phase 2
Treatment Target		【Wastewater】 ・Raw Sewerage ・Pretreated distillery wastewater 【Sludge】 ・Septic Sludge ・Pretreatment Plant Sludge	【Wastewater】 ・Raw Sewerage ・Pretreated distillery wastewater 【Sludge】 ・Septic Sludge ・Pretreatment Plant Sludge ・Other WWTP thickened raw sludge
Treatment Method		Two-stage Trickling Filter with post-coagulation	
	Composition of one treatment line	1 Primary clarifier 2 Stage one trickling filter 2 Stage two Trickling Filter 1 Coagulation/Flocculation Canal 1 Final Clarifier	
Max Daily Flowrate		29,800m^3/ day	44,800 m^3/ day
Number of Treatment Lines		6 lines	8 lines total
Intended Treatment Capacity per line		5,600 m^3/day (6,100 m^3/day per line including all return flows)	
Max Treatable Capacity per line*1		6,600 m^3/day per line (including all return flows)	
Footprint	**Total**	24.51 ha*2*3	46.5 ha*2*3
	Sewerage Treatment Facilities	16.36 ha	24.51 ha
	Sludge Drying Bed*4	3.68 ha	4.93 ha
	Sludge Storage Space*4	4.48 ha	13.99 ha
	Anaerobic Digestion + Biogas Power Plant	0.00 ha	3.05 ha

*1 Max. capacity is based off minimum HRT requirements and maximum loads of basins. To ensure treated water quality, capacity margins must be included in the design
*2 Does not include Distillery Pretreatment Plant (Assumed footprint: 2.88 ha)
*3 Includes parts of current Natabua WWTP boundaries
*4 Including roads, buffer zones, etc. on premises
Source: JET

Since the current treatment system must continue its operation during the Phase 1 construction period, Phase 1 facilities (colored red in the Figure) are located outside the current WWTP, or placed in areas not interfering with current operating facilities.

The Distillery Pretreatment Plant is not included in this Pre-F/S's project scope, but will be planned to be constructed at the same time as Natabua WWTP Phase 1 facilities, under WAF requests. The Sludge Digestion Facility and Biogas Power Generation Plant are planned for construction in Phase 2 or after. It should also be noted that the site area for sludge drying beds and sludge storage can be reduced or removed in case sludge utilization schemes or sludge final disposal sites are found/formulated offsite.



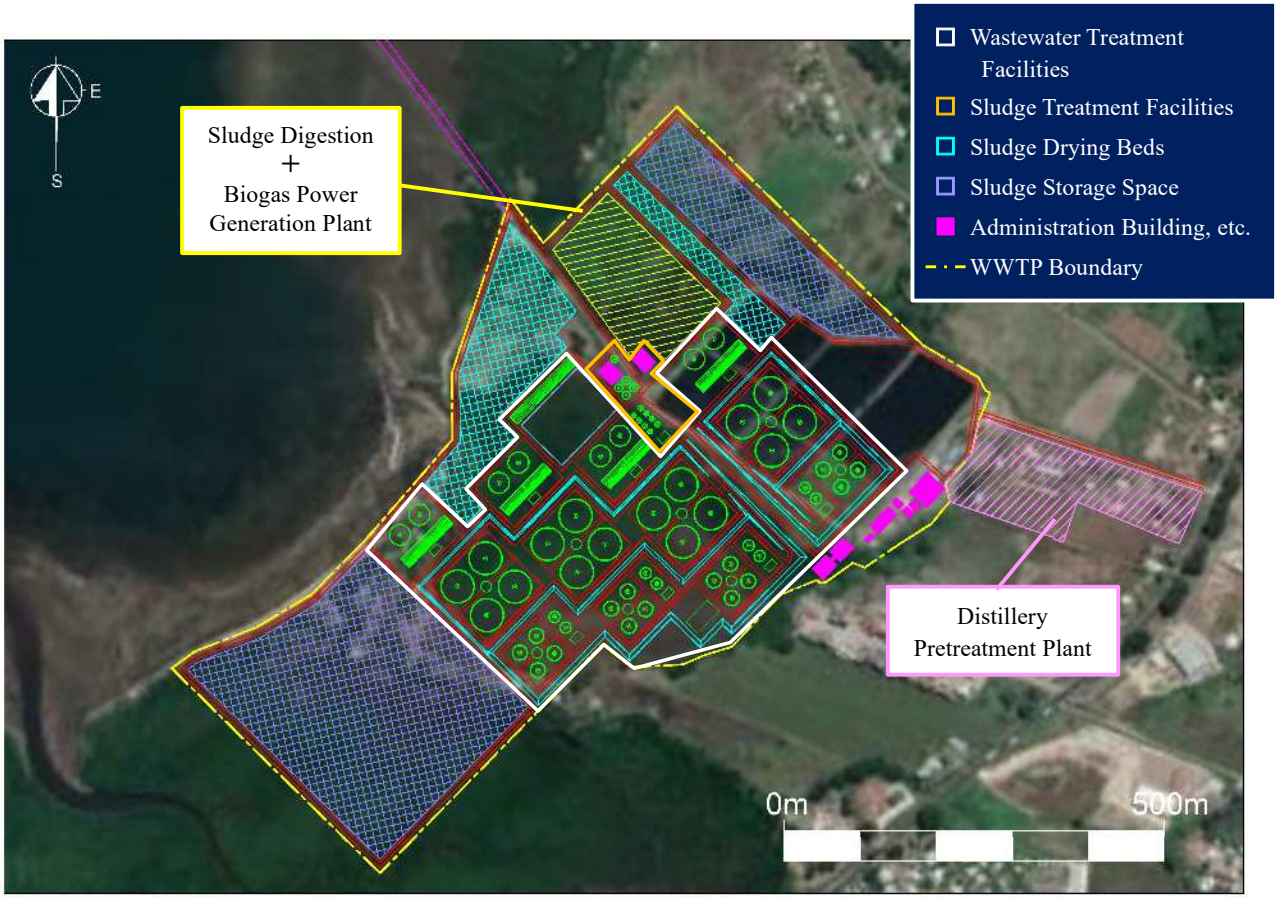
Source: JET

Figure S3. 3-3　Natabua WWTP Facilities

Table S3. 3-3　Natabua WWTP Facilities

Ref. No.	Facility	Remarks
1	Inlet Pump Station	Includes Sewerage and Stormwater pumps
2	Distribution Chamber①	Influent from: Inlet Pump Station, Distribution to: Distribution Chambers②, Stormwater Sedimentation Pond
3	Distribution Chamber②	Influent from: Distribution Chamber①, Distribution to: Primary Clarifiers
4	Primary Clarifiers	8 basins, Diameter: 14m
5	Distribution Chamber③	Influent from: Primary Clarifiers, Distribution to: Stage 1 TF
6	Stage 1 Trickling Filters	16 towers, Diameter: 19m (BOD removal)
7	Distribution Chamber④	Influent from: Stage 1 TFs, Distribution to: Stage 2 TFs
8	Stage 2 Trickling Filters	16 towers, Diameter: 43m (BOD + N removal)
9	Distribution Chamber⑤	Influent from: Stage 2 TFs, Distribution to: Coag./Floc. Canals
10	Coagulation/Flocculation Canals	8 canals (P removal)
11	Final Clarifiers	8 basins, Diameter: 27m
12	Disinfection Tank	Minimum contact time: 15 min
13	Stormwater Sedimentation Pond	
14	Effluent Pump Station	Pump to ocean outfall
15	Sludge Distribution Chamber	
16	Gravitational Sludge Thickeners	8 tanks, Diameter: 6 m
17	Sludge Receival Tank	Phase 1: Thickened raw sludge + excess sludge Phase 2: Thickened raw sludge from other WWTPs 4 tanks, Diameter: 10 m
18	Septage Receival Tank	Diameter: 6 m, Included in project scope
19	Sludge Dewatering Building	Includes dewatering machine for septage treatment
20	Sludge Drying Beds	3.76 ha (Includes space for septage)
21	Sludge Storage Space	11.48 ha (Includes space for septage)
22	Sludge Digestion + Biogas Power Generation Plant	Biogas Power Generation Plant not included in project scope
23	Distillery Pretreatment Plant	Not included in project scope
24	Administration Building	Includes emergency power generator
25	M/E Team Workshop	Currently stationed at Natabua WWTP

Source：JET

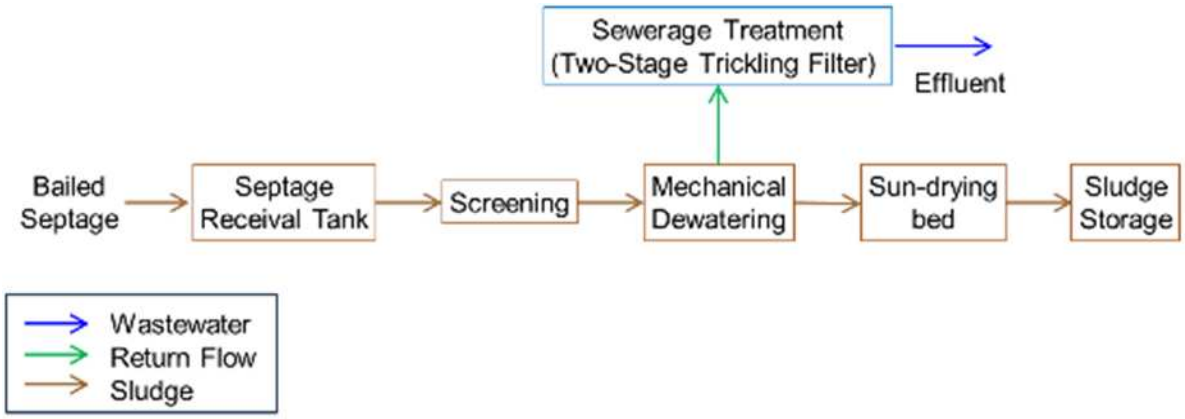


出典：JET

Figure S3. 3-4　Natabua WWTP Facility Layout

(2)　Septage Treatment Facility

The treatment flow of the septage treatment facility is shown in Figure S3. 3-5. The septage produced by household and commercial facilities of Ba and Ra provinces is periodically collected by private sector bailing companies and bailed to Natabua WWTP. The maximum daily average of collected septage in the future (2017-2036) was forecasted to be 65 m^3/day. As household connections to the WAF sewerage system increases, this value is expected to decrease. The construction period of the septage treatment plant will be set as Natabua Phase 1 construction or earlier.



Source: JET

Figure S3. 3-5 Septage Treatment Facility Treatment Flow Diagram

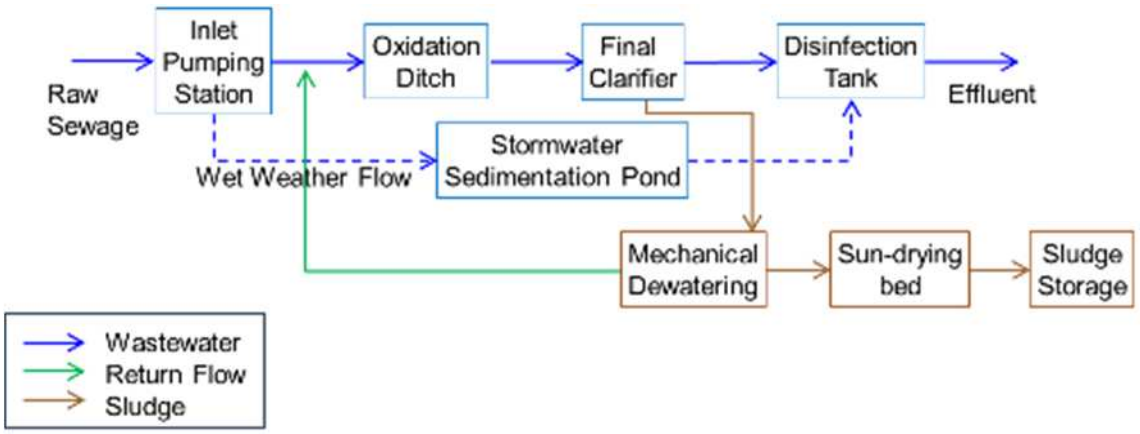
Table S3. 3-4 Equipment and Specifications of the Septage Treatment Facility

Equipment	Specifications	
Septage Receival Tank	**Tank Diameter (m)**	6
	Tank Capacity	113m^3 x 1tank
Screen Equipment	**Type**	Drum screen (equipped with washing unit and control panel)
	Treatment Capacity	32 m^3/hr x 0.2kW1 unit
	Screen Opening Width (mm)	1.0
Septage Dewatering Equipment	**Sludge Solids Content (t/day)**	1.56
	Input Sludge (m^3/day)	65
	Input Sludge (kg/day)	173.3
	Dewatering Method	Multi-plate screw press dewaterer
	Dewatering Capacity	400 kg-DS/h x 8.3kW x 5 units
	Operation (hr/day)	7 days a week, 9-hour operation per day
	Dewatered Sludge (m^3/day)	6

Source: JET

4. NAVAKAI WWTP

Navakai WWTP will switch its treatment method from the current "IDEA process" to the "OD process," increasing its capacity to a daily maximum of 19,700 m^3/day in Phase 1, then up to a daily maximum of 29,900 m^3/day in Phase 2. Navakai WWTP's treatment flow and facility overview is shown in Figure S3. 4-1 and **Table S3. 4-1**, respectively.



Source: JET

Figure S3. 4-1 Treatment Process Flow of Navakai WWTP

Table S3. 4-1 Natabua WWTP Facility Overview

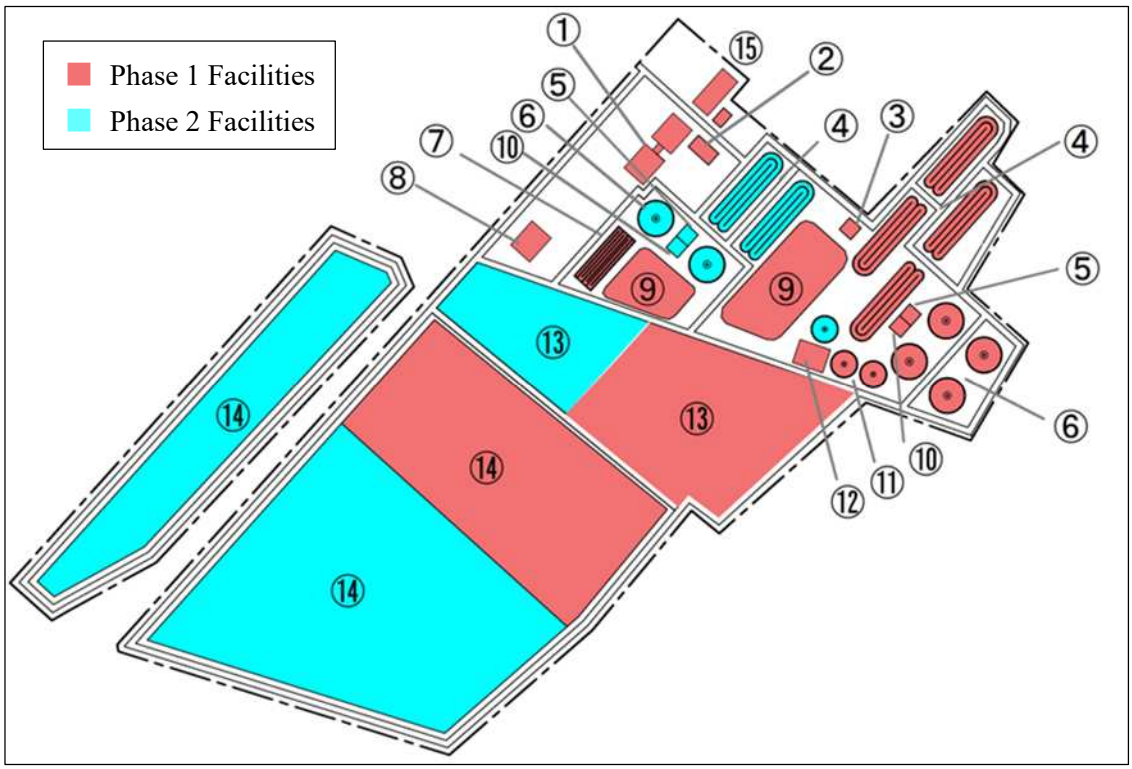
Parameters		Phase 1	Phase1 +Phase 2
Treatment Target		Raw Sewerage	
Treatment Method		Oxidation Ditch Method	
Max Daily Flowrate		19,700 m^3/day	29,900 m^3/day
Number of Treatment Lines		4 lines	6 lines (total)
Intended Treatment Capacity per line		4,900 m^3/day per line	4,900 m^3/day per line
Max Treatable Capacity per line*1		6,800 m^3/day per line	6,800 m^3/day per line
Footprint	**Total**	12.16 ha	20.86 ha
	Sewerage Treatment*2	7.08 ha	7.08 ha
	Sludge Drying Bed	1.99 ha	3.02 ha
	Sludge Storage Space	3.10 ha	10.77 ha

*1 Max. capacity is based off minimum HRT requirements and maximum loads of basins. To ensure treated water quality, capacity margins must be included in the design
*2 Including current Navakai WWTP boundary
Source: JET

Since the current IDEA treatment system must continue its operation during the Phase 1 construction period, Phase 1 facilities (colored red in the Figure) are located outside the current WWTP, or placed in areas not interfering with current operating facilities. When Phase 1 facilities are completed and the current system ends its operation, construction of Phase 2 facilities (colored blue in the Figure) will commence within the current site, utilizing the existing IDEA Pond and Maturation Pond (⑨ in the Figure) as Stormwater Sedimentation Ponds.

It should also be noted that the site area for sludge drying beds and sludge storage can be reduced or

removed in case sludge utilization schemes or sludge final disposal sites are found/formulated outside the WWTP.



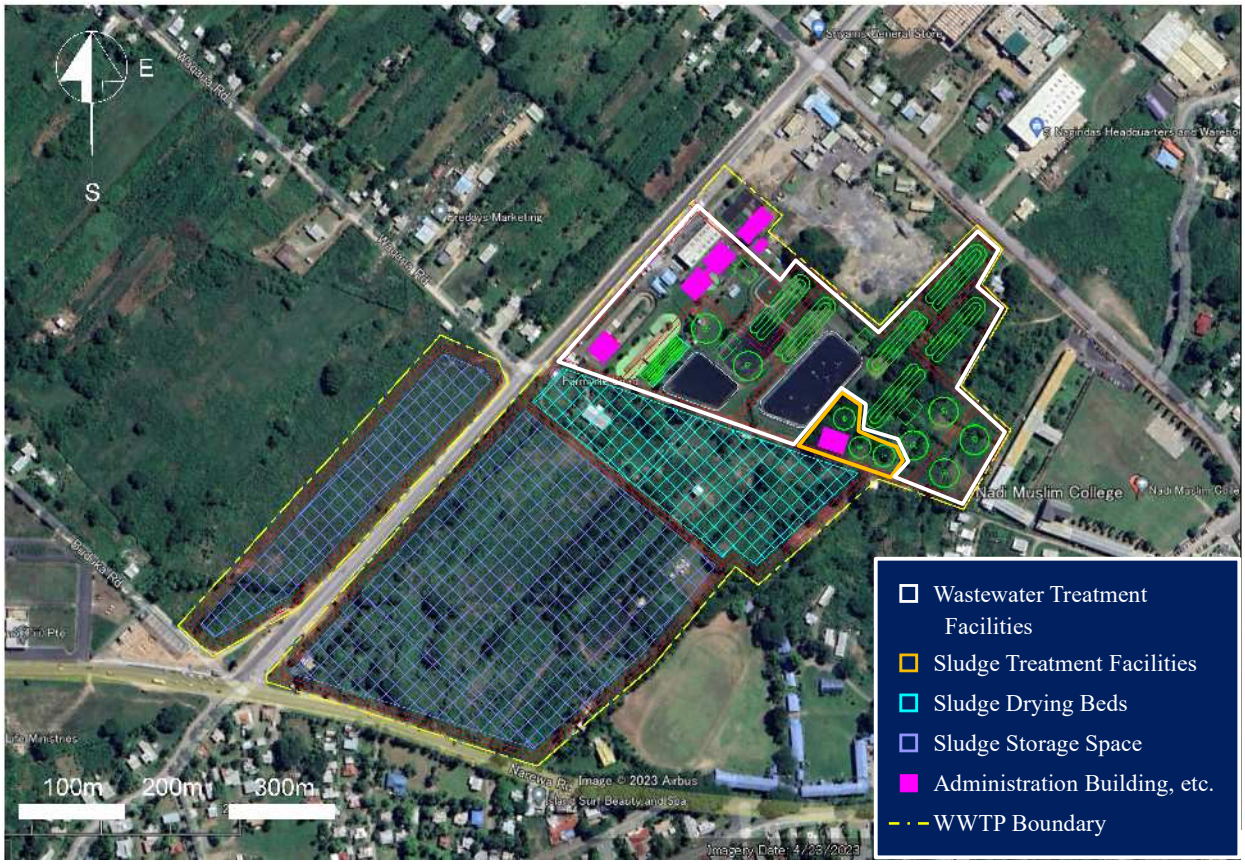
Source: JET

Figure S3. 4-2　Navakai WWTP Layout Plan

Table S3. 4-2　Navakai WWTP Facilities

Ref. No.	Facility	Remarks
1	Inlet Pump Station	Includes Sewerage and Stormwater pumps
2	Distribution Chamber①	Influent from: Inlet Pump Station Distribution to: Distribution Chamber②, Phase 2 OD tanks, Stormwater Sedimentation Ponds
3	Distribution Chamber②	Influent from: Distribution Chamber① Distribution to Phase 1 OD tanks
4	Oxidation Ditch Tanks	HRT: 21.4 hr
5	Distribution Chamber③	Influent from: OD tanks Distribution to: Final Clarifiers
6	Final Clarifiers	Diameter: 27 m
7	Disinfection Tank	Minimum contact time: 15 min.
8	Effluent Pump Station	Pump to Nadi River
9	Stormwater Sedimentation Pond	Utilize existing IDEA pond
10	Return Sludge Pump Station	
11	Sludge Receiving Tank	Diameter: 20 m
12	Sludge Dewatering Building	
13	Sludge Drying Beds	3.02 ha
14	Sludge Storage Space	10.77 ha
15	Administration Building	Includes emergency power generator and electricity room

Source: JET



Source: JET

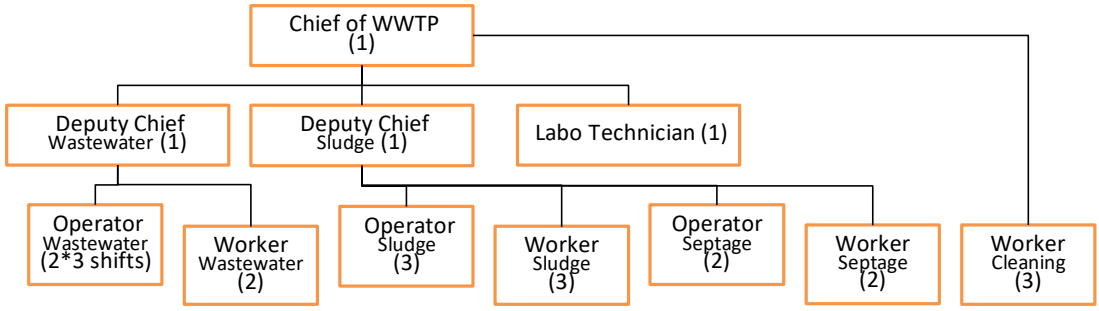
Figure S3. 4-3　Navakai WWTP Facility Layout

5. OPERATION AND MAINTENANCE (O&M)

(1) Natabua WWTP

For Natabua WWTP in Lautoka the TF process is proposed for wastewater treatment, and thickening/anaerobic digestion/mechanical dewatering/sun drying process is for sludge treatment. The WWTP plans to receive thickened sludge from three other WWTPs (excluding Navakai WWTP), as well as septage from Ba and Ra provinces to the anaerobic digesters. Since the operation of the biogas utilization facility to be constructed at the WWTP will be outsourced to the private sector, O&M of the digesters and biogas utilization facility will not be included in the proposed organization.

The proposed organization structure of the WWTP is shown in **Figure S3. 5-1**, and the proposing duties of each staff in charge in the figure are shown in **Table S3. 5-1**.



Source: JET

Figure S3. 5-1 Proposed Organization Structure of Natabua WWTP

Table S3. 5-1 Proposed Duties of Staff in charge of Natabua WWTP

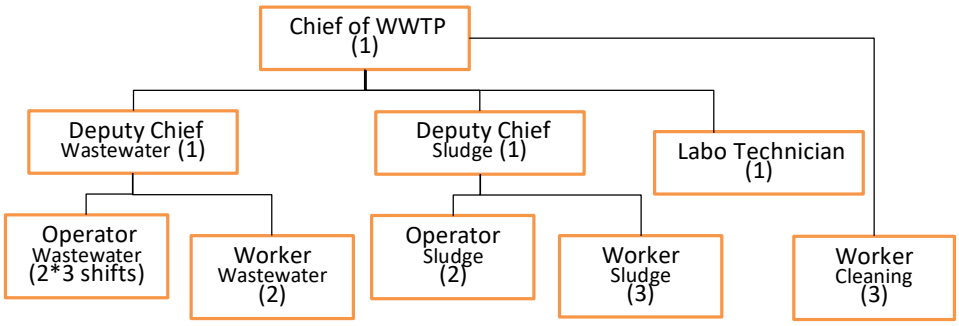
Position		Main duties
Chief of WWTP		・ Management of WWTP
Wastewater treatment	Deputy Chief (Wastewater)	・ Operation management of sewerage treatment facilities ・ Management of daily/monthly reports
	Operator (Wastewater)	・ 3 shifts ・ Operation of sewerage treatment facilities ・ Visual inspection of treatment status ・ Checking the operation status of mechanical/electrical equipment ・ Preparation of daily reports
	Worker (Wastewater)	・ Support for visual inspection and inspection of operation status ・ Screenings/scum removal works
Sludge treatment	Deputy Chief (Sludge)	・ Operation management of sludge treatment facilities ・ Operation management of septage acceptance/ treatment facilities ・ Management of daily/monthly reports
	Operator (Sludge)	・ Operation of sludge treatment facilities ・ Preparation of coagulant liquid ・ Measurement of sludge moisture contents ・ Preparation of daily reports
	Worker (Sludge)	・ Support for preparation of coagulant liquid ・ Cleaning of sludge treatment facilities
Septage treatment	Operator (Septage)	・ Septage accepting works ・ Operation of septage treatment facilities ・ Preparation of septage acceptance and treatment reports
	Worker (Septage)	・ Support for septage acceptance ・ Support for operation of septage treatment facilities ・ Cleaning of septage acceptance and treatment facilities
Laboratory Technician		・ Implementation of simple water quality test ・ Preparation of daily water quality report ・ Management of water quality data of other WWTPs
Worker (Cleaning)		・ Housekeeping, cleaning of WWTP ・ Routine tasks

Source: JET

(2) Navakai WWTP

The OD process for sewerage treatment, and thickening/mechanical dewatering/sun drying in sludge treatment is proposed in Navakai WWTP in Nadi. Since the treatment capacity is large and the effluent must comply with the SEZ, it is necessary to pay attention to operation compared to other WWTPs.

The proposed organization is shown in Figure S3. **5-2** and the proposed duties of each staff in charge in the figure are shown in **Table S3. 5-2**.



Source: JET

Figure S3. 5-2 **Proposed Organization Structure of Navakai WWTP**

Table S3. 5-2 Proposed Duties of Staff in Charge of Navakai WWTP

Position		Main duties
Chief of WWTP		Management of WWTP
Wastewater treatment	Deputy Chief (Wastewater)	Operation management of sewerage treatment facilities Management of daily/monthly reports
	Operator (Wastewater)	3 shifts Operation of sewerage treatment facilities Visual inspection of treatment status Checking the operation status of mechanical/electrical equipment Preparation of daily reports
	Worker (Wastewater)	Support for visual inspection and inspection of operation status Screenings/scum removal works
Sludge treatment	Deputy Chief (Sludge)	Operation management of sludge treatment facilities Management of daily/monthly reports
	Operator (Sludge)	Operation of sludge treatment facilities Preparation of coagulant liquid Measurement of sludge moisture contents Preparation of daily reports
	Worker (Sludge)	Support for preparation of coagulant liquid Cleaning of sludge treatment facilities
Laboratory Technician		Implementation of simple water quality test Preparation of daily water quality reports Management of water quality data of other WWTPs
Worker (Cleaning)		Housekeeping, cleaning of WWTP Routine tasks

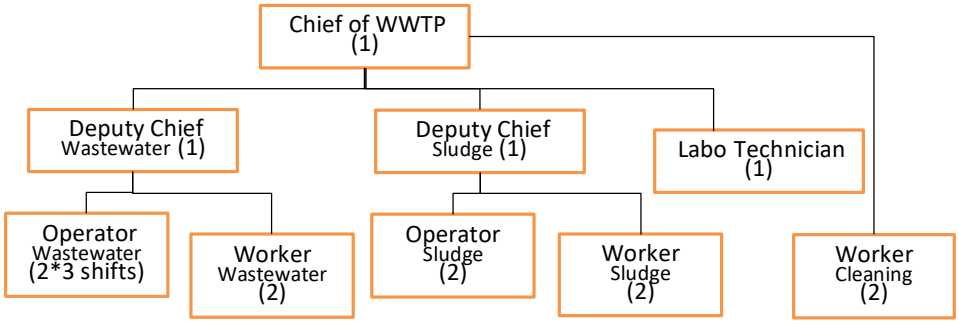
Source: JET

In Phase 1, Natabua WWTP is planned to construct a 30,000 m^3/day-capacity TF treatment system (3/4 of its overall capacity), and Navakai WWTP is planned to construct a 20,000 m^3/day-capacity OD treatment system (2/3 of its overall capacity).

For Navakai WWTP, 3 sludge workers/2 cleaning workers were proposed as shown in **Figure S3.5-3**. For Phase 1 facilities with 2/3 of the total capacity, the number of necessary workers will be calculated as follows:

Sludge workers: 3 staff×2/3＝2 ⇒ 2 staff
Cleaning workers: 2 staff×2/3＝1.3 ⇒ 2 staff

As a result, one less sludge worker staff is needs, so Phase 1 Navakai WWTP's O&M organization structure will be as shown in **Figure S3. 5-3**.



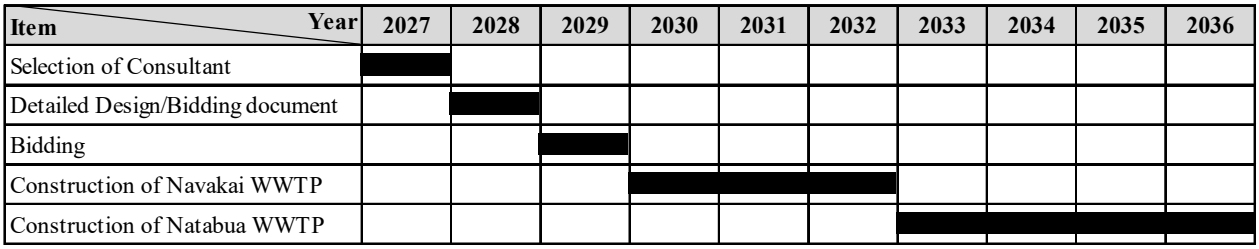
Source: JET

Figure S3. 5-3 Proposed O&M Organization Structure of Navakai WWTP (Phase 1)

6. IMPLEMENTATION SCHEDULE AND PROJECT COSTS

(1) Implementation Schedule of the Prioritized Projects

The implementation schedule for the prioritized projects follows the development schedule for the Natabua and Navakai WWTP considered in this Pre-F/S, and is shown in **Figure S3. 6-1**. Given WAF's opinion that there is an opportunity to advance the development of the two WWTPs, the Water Sector Strategy 2050 schedule will not be applied. Construction of the facilities is expected to be completed around 2036 for the Natabua WWTP and around 2032 for the Navakai WWTP.



Source: JET

Figure S3. 6-1 Assumed Implementation Schedule (Phase 1)

The implementation schedule is estimated based on the required period shown in **Table S3. 6-1**.

Table S3. 6-1 Required Period of Each Phase

Phase	Duration (years)
F/S study	1 year
Consultant Selection	1 year
Detailed Design	1 year
Bidding procedure for the contractor	1 year
Construction of Natabua WWTP	4 years
Construction of Navakai WWTP	3 years

Source: JET

(2) WWTP Construction Costs

The approximate quantities of civil works were estimated based on the outline design of the facilities, and mechanical and electrical costs were also estimated based on the quotation in Fiji. The construction costs for both WWTPs in Phase 1 are presented in **Table S3. 6-2**. Land acquisition costs are not included in the construction costs, but are included in the project costs. The upgrade costs for Phase 1 are expected to be approximately 217 million FJD for the Natabua WWTP and 130 million FJD for the Navakai WWTP.

Table S3. 6-2 Summary of Construction Costs for WWTPs

WWTP	Treatment Process	Construction Costs (million FJD)				Equivalent JPY (million JP)
		Civil/Arc.	Mechanical	Electrical	Total	
Natabua	TF	128	44	29	201	13,578
Navakai	OD	71	43	19	133	8,984

*1 FJD ＝ 67.55 JPY (April 2024)
Source: JET

(3) WWTP O&M Costs

The WWTPs' O&M costs was calculated as the sum of electricity, maintenance, and labor costs as shown in **Table S3. 6-3**.

Table S3. 6-3 O&M Costs for WWTPs

WWTP	Treatment Process	O&M Cost (1000 FJD/ year)				Equivalent JPY (million JP/year)
		Electricity	(million JP)	Labor	Total	
Natabua	TF	1,554	1,791	355	3,700	250
Navakai	OD	2,028	1,184	266	3,478	235

*1 FJD ＝ 67.55 JPY (April 2024)
Source: JET

(4) Project Costs

i. Condition of Cost Estimations

The conditions for the project cost estimation are shown in **Table S3. 6-4**. Although the project cost scale for the upgrade of WWTPs is the scale of a loan project, the donor has not been decided, so the conditions are only for reference.

Table S3. 6-4 Conditions for the Project Cost Estimation

No.	Item	Value	Remarks/Sources
1	Exchange Rate	1 USD = 151.37 JPY 1 USD = 2.2409 FJD 1 FJD = 67.5498 JPY	JICA Rate April 2024
2	Price Escalation Rate (Foreign Currency)	2.70 %/year	Japan Ministry of Internal Affairs and Communications Year 2020-standard Consumer Price Index (as of April 2024)
	Price Escalation Rate (Local Currency)	3.60 %/year	Consumer Price Index by Fiji Bureau of Statistics (as of April 2024)
3	Physical Contingency Rate	5 %	JICA Cost Estimation Manual
4	Value Added Tax (VAT)	15 %	From Fiji Government website
5	Import Tax	15 %	From Fiji Government website
6	Administration Cost	5 %	JICA Cost Estimation Manual
7	Interest rate (Construction)	2.00 %	Terms and Conditions of Japanese ODA Loan
	Interest rate (Consulting Service)	0.20 %	Terms and Conditions of Japanese ODA Loan
8	Front End Fee	0.2 %	JICA Cost Estimation Manual

Source: JET

ii. Consulting Service Fee

Consulting services will be allocated as 10% of the construction cost (excluding price escalation and physical contingency).

iii. Land Acquisition Costs

The land acquisition costs are calculated to approximately 37 million FJD. This includes the sludge storage site footprint, so upon determination of a sludge utilization scheme, may be reduced.

iv. Project Costs

The Phase 1 project cost was calculated as shown in **Table S3. 6-5**. The total project cost was 816 million FJD, and the loan amount was 547 million FJD. Fiji's share of the cost（including land acquisition costs, VAT, administrative costs and import taxes) will be approximately 269 million FJD.

Table S3. 6-5 Phase 1 Project Costs and Loan amount (Draft)

Component	Foreign Currency (million JPY)	Local Currency (million FJD)	Total (million FJD)
A. FOREIGN PORTION	**29,128**	**116**	**547**
I) Procurement / Construction	26,668	106	501
ICB1:WWTP1_Const	7,202	27	133
ICB2:WWTP2_Const	12,633	46	233
Base cost	19,835	73	367
Price escalation	5,564	28	111
Physical contingency	1,270	5	24
II) Consulting services	2,460	9	46
Base cost	1,983	7	37
Price escalation	253	1	5
Physical contingency	224	1	4
B. BORROWER PORTION	**-**	**229**	**229**
I) Procurement / Construction	-	-	-
a. Land Acquisition	-	46	46
b. Administration cost	-	30	30
c. VAT	-	89	89
d. Import Tax	-	65	65
TOTAL (A+B)	**29,128**	**345**	**776**
C. Interest during Construction	2,626	-	**39**
For Construction	2,573	-	38
For Consultant	53	-	1
D. Front End Fee	**79**	**-**	**1**
GRAND TOTAL (A+B+C+D)	**31,834**	**345**	**816**

Source: JET

7. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

Environmental and Social Considerations were implemented in the Pre-F/S study to achieve the below goals:

- Examine scoping for the selected priority projects to extract important environmental/social consideration factors
- As support for preparing Environmental Impact Assessment (hereinafter referred to as "EIA") reports in accordance with the Fijian laws to obtain the environmental clearance, confirm ambient water quality and land use status of the target areas at Initial Environmental Examination (hereinafter referred to as "IEE") levels.
- Prepare and support consultations/meetings between the involved authorities and stakeholders needed for the implementation of the Priority Projects.

The findings from the Pre-F/S stage environmental and social considerations study are summarized as below:

- Water quality analysis at the planned effluent discharge destinations showed results close to that of past WAF analyses. Other than high fecal coliform count values, results did not show signs of water pollution. Results of water quality and ecological monitoring conducted by South Pacific Distilleries Ltd. (hereinafter referred as "SPD") also conclude that the environmental impact by discharged effluent is small.
- Implementation of the priority projects will likely result in the resettlement of 7 households for Navakai WWTP, and 18 households for Natabua WWTP. The resettling households for Natabua WWTP are informal settlements, so in the formulation of future resettlement plans, it its extremely important to take into consideration the impact on low-income family livelihood, cooperating/coordinating with involved organizations.
- To share information on the priority projects' environmental impacts, land acquisition, household resettlement, and land development plans, individual consultations were conducted with key stakeholders in the scoping stage, as well as a workshop inviting all involved stakeholders/donor parties. Information on future necessary procedures was also shared.
- Studies and activities to be implemented for the EIA formulation on the F/S stage was proposed based on the social and environmental characteristics found in this Pre-F/S study

8. PROJECT EFFCT

(1) Quantitative Effect

In this project, the sewerage population coverage rate is used as the effect indicator. The operational indicator will be set as the WWTP's treated water flowrate and treated population.

Table S3. 8-1 Operation and Effect Indicator Target Values

WWTP	Indicator	Current (2024)	Target Value
Natabua	Effluent quality (mg/L)	BOD_5：35、TSS：27	BOD_5≦40、TSS≦60
	Effluent standard compliance rate (%)	BOD_5：62.5%、TSS：87.5%	BOD_5：100%、TSS：100%
	Daily average flowrate (m^3/day)	10,800 (Estimated value from revenue water)	26,800
	Treated Population	54,000	134,000
Navakai	Effluent quality (mg/L)	BOD_5：60、TSS：91	BOD_5≦20、TSS≦30
	Effluent standard compliance rate (%)	BOD_5：40%、TSS：62.5%	BOD_5：100%、TSS：100%
	Daily average flowrate (m^3/day)	8,800 (Estimated value from revenue water)	17,800
	Treated Population	44,000	89,000

Source: JET

(2) Financial Analysis

The financial analysis was conducted to measure the financial profitability of the project for the implementing agency. The resulting FIRR value was -2.8%.

To generate revenues that can at least cover O&M costs, a tariff increase of at least 0.72 FJD/m^3 is required.

(3) Economic Analysis

The EIRR from the implementation of this project is plus 9.0%. The implementation standard for projects such as preventing environmental pollution, reducing poverty in rural areas, and combating natural damage is set at 6.0%. The EIRR from the implementation of this project exceeds this standard.

The sensitivity analysis of benefits relative to changes in costs showed that even if benefits are held constant and costs rise by 20% from the base scenario, the EIRR will be over 7%, exceeding the implementation target.

Table S3. 8-2 EIRR Sensitivity Analysis for Cost Changes

Cost	Down 20%	Down 10%	Unchanged	Up 10%	Up 20%
EIRR	11.5%	10.1%	9.0%	8.1%	7.2%

Source: JET

(4) Qualitative Effects

In previous sections, the quantitative effects of the project were explained; this section will summarize the major quantitative effects that are expected by the implementation of this project, as follows:

- Reduction of absenteeism from workplaces due to sickness
- Increase in agricultural/fishery productivity
- Increase in land value

9. CONCLUSION AND RECCOMENDATIONS

9.1 Conclusion

The Lautoka/Nadi region will account for approximately 40% of the population of the Western Viti Levu region as of 2023, and is one of Fiji's leading tourist destinations. However, inadequately treated sewerage that does not meet Fiji's effluent standards is discharged into coastal areas of Viti Levu. This project will properly treat this untreated wastewater, improving the water quality of the coastal waters and allowing for the continued development of tourism in Fiji, which has abundant tourism resources.

This project is considered to contribute to the sustainable economic development of Lautoka/Nadi by reducing water pollution in public waters and improving public health. This project is also in line with Fiji's National Development Plan and the Japanese government's aid policy for Fiji.

9.2 Sustainability

Project impacts will be sustainable through (i) the use of innovative technologies appropriate to the conditions in the Nadi-Lautoka region, (ii) efforts to build O&M capacity, (iii) an appropriate wastewater tariff structure, and (iv) the development and implementation of an appropriate sludge reuse and disposal plan.

(1) Sustainability of the Project

The proposed Natabua and Navakai WWTPs will be directly managed by WAF in the initial phase of operation. Since WAF already operates and maintains the existing WWTPs, there should be no technical problems if the number of maintenance personnel for the WWTP is increased, and they are properly trained. In addition, while outsourcing maintenance to the private sector is an option, financial decisions (including possible considerations to increase tariffs) are required as the maintenance costs will be higher than if the plant is managed directly by WAF.

Natabua and Navakai WWTP proposed in this Pre-FS to also include sludge storage spaces within the WWTP’s boundary. This will ensure that there will be no problems with the disposal of sludge from the WWTP for the time being, but this sludge storage space approach is only a physical response. For fundamental improvement, it is necessary to formulate and implement a plan for the effective use and disposal of sludge.

(2) Financial Sustainability

With public financial support, such as debt repayments from the Ministry of Finance, WAF has operated a number of projects related to the construction of water supply and sanitation facilities in Fiji with little disruption. However, WAF has posted deficits in its financial management in the last three years. Consequently, payments for these losses are covered as borrowings by the Ministry of Finance. Therefore, it could be vulnerable for WAF to ensure funds, especially liquidity at hand.

Taking this into consideration, it is desirable for the federal government to take the following actions to strengthen WAF's financial basis：

- Improve the flow of funds
- Revise sewerage tariffs
- Expand the annual government subsidy system

9.3 Recommendations

The recommendations for the implementation of the priority projects identified in this Pre-F/S are as follows.

(1) Consultation on the WWTP site

WAF needs to conduct awareness-raising activities on the importance of the WWTP, deepen understanding of the project objectives, and expedite the land acquisition process. In order to identify the site for the Natabua WWTP and Navakai WWTP, it is necessary to conduct sufficient consultations with relevant parties after evaluating potential relocation issues and studying the negotiation/acquisition process for the land of existing residential areas.

(2) Formulation of the Effective Sludge Utilization and Disposal Plan

WWTP planned in the Pre-F/S have a sludge storage space within its own WWTP site. Obviously, a large area is required for a sludge storage area, which is also a factor that increases the construction cost of WWTP. Ideally, it would be desirable to find an effective way to utilize the dried sludge or to dispose of the sludge in an off-site landfill. To achieve this, it is necessary to formulate an effective utilization and disposal plan. A realistic approach would be to formulate a plan for the effective use and disposal of sludge through programs such as Japan's technical cooperation projects.

In addition, this sludge was collected from Natabua and Navakai WWTPs to analyze its components. The results of the analysis were compared with the standards for sludge disposal/effective use set by WHO, US EPA, Australian Water Association (hereinafter referred to as “AWA”), EU, Japan Sewerage Works Association, etc. The following points were found as a reference of reuse methods on the sludge generated at Natabua and Navakai WWTPs when each standard value was used as a reference.

- Although there are restrictions on long-term use, it can be used as a fertilizer or conditioner for green fields
- Although there are some restrictions, it can be utilized/recycled without negative impacts on agricultural/natural environments and human health
- It can be disposed of in landfills without liner sheets or leachate collection and treatment systems.

The relatively high concentrations of copper and zinc may be the result of higher concentrations in the natural soil of Fiji, a volcanic island, which may have been introduced with leachate. For this reason, it is

recommended that the composition of surrounding soil samples be analyzed along with the sludge and that the results be considered in setting future sludge disposal or effective utilization standards in Fiji.

(3) Consideration of the Water Quality Impacts on the Discharge Ocean Area in the Feasibility Study

Regarding the basic data required for the environmental impact assessment, it is necessary to organize the items to be studied in the implementation of the F/S with reference to the Kinoya WWTP, which has already been studied. In order to study the effects of discharging treated water through the ocean outfall pipe to the destination waters, actual data such as water quality surveys of the inflowing rivers and the destination sea area and current tidal surveys will be required. In addition, it will be necessary to formulate a simulation model of the sea area that can describe the water quality obtained from these data.

After formulating the simulation model, it will be necessary to quantitatively estimate the extent to which the volume and quality of water discharged from the WWTP will affect the water quality of the surrounding sea areas.

(4) Additional Soil Surveys During the Full Feasibility Study

In the outline design of the Pre-F/S, two soil boring surveys were conducted at each WWTP. Although surveys were conducted within the existing site boundary in Natabua WWTP, most of the facilities in the Phase 1 will be constructed outside the existing WWTP site. During the design of the full feasibility study, borehole survey will need to be conducted at the expanded south of existing site. The same applies for Navakai WWTP, where additional borehole surveys will be required in the expanded area east of the existing site.

(5) Septage Treatment

There are many residents in the surrounding target area who will not receive sewerage services. WAF will provide the benefits of sewerage services to the target service area through this project and will also need to accept sludge from outside the service area and treat it at the Natabua WWTP.

(6) Secure the O&M Budget

In the Municipal Sewerage M/P and Pre-F/S, it became clear that in order to cover the O&M costs of the sewerage facilities with sewerage tariffs, the current tariffs would have to be four times higher. Increasing sewerage tariff is difficult as a national policy, but if it is to be implemented, the burden on beneficiaries must be taken into account, such as a step-wised increase. WAF and MOF need to hold thorough discussions to ensure that necessary O&M costs are secured from the national budget. One proposal is to collect a kind of environmental tax from tourists, in addition to the revenue from sewerage tariff, to cover the O&M costs of the sewerage system.

(7) Organizational Structure on O&M

i. WWTPs

Navakai WWTP in Nadi, which is currently the only one among the existing four WWTPs in the Western Division that uses a mechanical sewerage treatment process, is unable to comply with the effluent standards due to insufficient treatment capacity for inflow sewerage. In addition, due to the lack of budget and equipment for O&M, the facilities are severely deteriorated, making it difficult to carry out appropriate O&M.

In the future, the introduction of mechanical sewerage treatment such as OD process and TF process into all five WWTPs in Nadi and Lautoka is proposed in the Municipal Sewerage M/P, and it is essential to secure the budget and equipment for O&M.

In order to implement appropriate O&M at WWTPs to be constructed in the future, first of all it is necessary to secure O&M budget for the current Navakai WWTP, to strengthen the capacity of staff in WWTPs, and to implement appropriate O&M. Such capacity building is difficult to implement at WAF, and it would be effective, for example, to strengthen capacity through JICA Technical Cooperation Project and to build an appropriate O&M system for the newly constructed WWTPs.

ii. Water Analysis Lab

In Fiji, the wastewater discharge standards (effluent standards) is set for hazardous substances such as heavy metals and cyanide as well as for general substances such as BOD and SS. However, due to the lack of analytical equipment, the water quality laboratory of WAF is not able to properly analyze all the substances, and the heavy metals in the sludge cannot be analyzed at all. Therefore, it is essential to prepare analytical equipment for the laboratory and strengthen the capacity of the laboratory staff for the wastewater quality and sludge management, and regulation of liquid trade waste. It will be effective to prepare the necessary equipment and materials through JICA Technical Cooperation Project and to strengthen the capacity of the staff.

iii. Mechanical and Electrical Equipment

Currently, the mechanical and electrical team is in charge of the maintenance of the mechanical and electrical equipment at all water supply and sewerage facilities in the Western Division.

However, the team has implemented only visual inspection of pumps and repair of some equipment, leading to the rapid aging/deterioration of equipment.

The reasons are as follows:

- It is difficult to secure the necessary number of personnel for maintenance due to the outflow of appropriate personnel overseas.
- Ample budgets, as well as materials and consumables necessary to implement preventive/predictive

maintenance of equipment is not prepared.

- Periodical maintenance of equipment by manufacturers has not been implemented due to budget shortages.

To improve this situation, first of all, what is the most important is to secure a budget for equipment maintenance.

In addition, so that maintenance can be carried out with a small number of staff, it is important to establish a system that the pipe maintenance team and the operation team in WWTPs carry out visual inspections of the equipment, and the mechanical and electrical team conducts daily and periodical inspections such as grease/oil and spare parts replacement.

To maintain stable wastewater treatment, periodic maintenance by manufacturers is important, preventing equipment breakdowns and extending equipment lifespan; prompt emergency repairs in the event of breakdowns are also essential. It is common to outsource maintenance and repair of complex equipment to manufacturers/maintenance companies, since they often cannot be directly handled by WAF M/E staff. In addition to budget-securing, WAF must implement measures to smoothly and promptly conclude contracts with such companies.

Section 4 CAPACITY DEVELOPMENT OF WAF AND RELEVANT AGENCIES

1. CAPACITY STRENGTHENING

Output 4 of the Project is “The project implementation system of the Water Authority of Fiji (WAF) and related organizations will be strengthened.” To this end, the strengthening of the organizational structure of WAF and the capacity of the sewerage works management including O&M will be implemented in the Project. Because the organizational structure depends on the scale of WWTP and the sewerage/sludge treatment process etc., it will be considered in the formulation of the Municipal Sewerage M/P.

According to JICA, “by defining capacity as the developing country's own problem-solving capacity, capacity cannot be transferred from the outside, but is endogenous, which is continuously increased by the efforts of developing countries themselves.” “In order to strengthen the ability to deal with issues, instead of ‘closing the gap’ by relocating the systems of developed countries, there is a need for assistance methods that support the intrinsic efforts of developing countries themselves as ‘catalysts,’ such as sharing knowledge and ideas that help developing countries make decisions and take actions.”

Therefore, the Japanese side did not unilaterally give lectures and guidance, but strengthened capacity through exchange of opinions, collaboration, and co-creation with the Fijian side.

(1) Strengthening Methods

Output 4 of the project is “The project implementation system of the Water Authority of Fiji (WAF) and related organizations will be strengthened.” After determining the target capacity level based on the current level, the activities of capacity development during the three years of the project were decided by the process shown in **Figure S4. 1-1**.

1. Capacity Assessment	Implement in collaboration with JET and C/Ps
2. Setting Goal	Setting the goal capacity based on the result of the capacity assessment
3. Request Survey	Investigate the request of C/Ps in trainings
4. Formulation of Training Plan	Formulate training plan to achieve the goal through collaboration between JET and C/Ps
5. Establishment of Implementation System	Establishing the training implementation system through discussion between JET and Fukuoka City
6. Preparation of Training Materials	Prepare suitable training materials to achieve the goal
7. Implementation of Training	Implement interactive trainings between JET and C/Ps
8. Consideration for Improvement	Check the result of the training and consider for improvement

Source: JET

Figure S4. 1-1 Process of Capacity Development

As shown in the figure,

(1) JET and C/Ps collaborate to assess the current capacity,

(2) Set the target capacity at the end of the project based on the result of the assessment,

(3) Conduct a request survey for WAF and DWS,

(4) JET and C/Ps collaborate to formulate training plan to achieve the goal,

(5) Establish a training implementation system to promote training effectively and efficiently through discussion between JET and Fukuoka City,

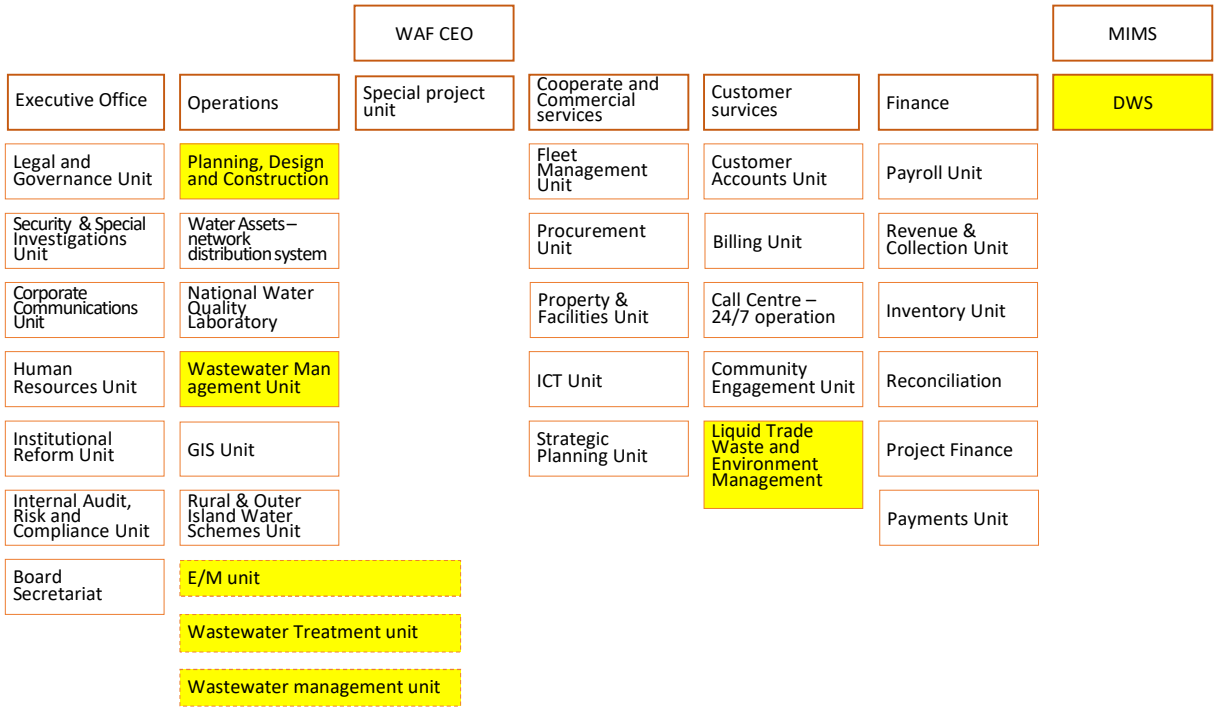
(6) Prepare appropriate training materials to achieve the goals,

(7) Conduct training using the training materials prepared.

(8) After the training is completed, the results of the training will be evaluated and considered for improvement, which will be used as a reference when the sewerage sector of Fiji continuously conducts training to relevant staff.

(2) Capacity Assessment

Figure S4. 1-2 is the organization chart of MIMS and WAF. The organizational units shown in yellow are related to the sewerage works and capacity assessment was implemented in those units.



*MIMS: before organizational restructuring; current MPW
Source: JET

Figure S4. 1-2 Organizational Units Implemented Capacity Assessment

Table S4. 1-1 shows the main tasks of these units.

Table S4. 1-1 Main Tasks of Organization Units Implemented the Capacity Assessment

Organi-zation		Unit			Main tasks
1	MIMS*	DWS			Promotion of water supply and sanitation projects in rural areas. Technical evaluation of de-centralized wastewater treatment facilities.
2	WAF	Operation Department	Planning/Design/Construction		Planning/design of water and sewerage project, Supervision of WAF's own budget projects.
3			WAF Western	Sewerage Treatment	O&M of sewer networks and WWTPs.
4				Mechanical/Electrical	Maintenance of M/E equipment in water and sewerage facilities.
5		Customer Service Department	Liquid Trade Waste Management		Monitoring and guidance of liquid trade waste.

*MIMS: before organizational restructuring; current MPW
Source: JET

(3) Setting Goals

Based on the results of the capacity assessment, discussions were held with the C/Ps, and the target capacities for each sewerage works field at the end of this project were set as shown in **Table S4. 1-2**.

Table S4. 1-2 Target Capacities at the End of the Project

Field		Target capacity
1	Sewerage works management	✧ Management level of WAF and DWS understands the management policies and processes of sewerage works of Japan through discussions with the Japanese municipality.
2	Planning/ Design	✧ Staff in planning/design of WAF understand the formulation procedure of sewerage M/P through collaborative works with JET and start to formulate the M/P.
3	Project management	✧ Staff of the special project WAF share information with JET and learn the issues in implementing sewerage projects in foreign countries and use this knowledge as a reference for implementing their own projects.
4	O&M of sewerage facilities	
1)	Maintenance of sewer systems	✧ Sewer system maintenance staff understand the procedures of inspection, cleaning, and repair of the sewer system, and understand how to formulate SOPs for them. ✧ Sewer system maintenance staff recognize the danger of sewer system maintenance work and implement the work safely.
2)	O&M of WWTPs	✧ Operation staff understand the basics of sewerage and sludge treatment technology. ✧ Operation staff understand how to formulate O&M manuals, SOPs and checklists for treatment facilities and start to formulate them. ✧ Operation staff recognize the danger of operation work and implement the work safely.
3)	Maintenance of M/E equipment	✧ Maintenance staff of M/E equipment understand the meaning of preventive maintenance of equipment and how to formulate maintenance plans of equipment. ✧ Maintenance staff of M/E equipment recognize the danger of M/E works and implement the work safely.
5	Liquid trade waste (LTW)	✧ Staff of liquid trade waste unit understand the laws, regulations, and standards of LTW in Japan. ✧ Staff of liquid trade waste unit understand how LTW is regulated in Japan.
6	On-site sanitation	✧ Staff of DWS and planning/design unit of WAF understand the laws, regulations, and standards of on-site sanitation in Japan. ✧ Staff of DWS and planning/design unit of WAF understands the functions and efficiency of on-site sanitation processes.

Source: JET

(4) Implementation of Training

i. Training Implementation System

For the capacity development (hereinafter referred as "CD") of sewerage works management and O&M of sewerage facilities, it is effective to ask for the cooperation of a Japanese municipality that is actually implementing sewerage works in Japan.

In Fiji, Fukuoka City carried out the "Project to Support Reducing Unaccounted for Water Control on NADI/LAUTOKA Regional Water Supply in Fiji" from 2013 to 2016 as a JICA Partnership Program, and the "Project to Support Strengthening Water Supply Service on NADI/LAUTOKA Region" from 2018 to 2022. There is a strong connection between WAF and Fukuoka City. In addition, the Road and Sewerage Bureau of Fukuoka City was a member of the survey team in the "Fiji Western Region Sewerage Master Plan Formulation Project Detailed Plan Formulation Survey" conducted in 2020, and has sufficient knowledge and information about the sewerage works in Fiji. **Table S4. 1-3** shows the role-sharing between JET and Fukuoka City in the implementation of the training programs.

Table S4. 1-3 Role-sharing between JET and Fukuoka City in the Implementation of Training

	JET	Fukuoka City
Expert Subject	Planning/design of sewerage project. Project management.	Management of sewerage works. O&M of sewerage facilities.
Roles	Implementation of training of expert subjects. OJT in Fiji.	Implementation of on-line training of expert subjects. Acceptance of training in Japan.

Source: JET

ii. Training Program

Based on the capacity assessment and the request survey, JET repeated discussions with DWS and WAF and prepared the training program (draft) in **Table S4. 1-4**.

Table S4. 1-4 Training Program (draft)

Training Category		Program		Training Method	Target
1	Sewerage Works Management	Management of Sewerage Works		L&D	Management level of DWS and WAF
2	Planning/ Design	Planning		L&D OJT	Planning and design staff of WAF (and DWS)
		Sewer Networks Design			
		WWTP Design			
3	Project Management	Budget Management		L&D	Staff of WAF relating to water and sewerage project
		Schedule Management			
		Stakeholder Management			
4	O&M of sewerage facilities	Sewerage and Sludge Treatment Technology	Sewerage treatment	L&D	Staff of WAF Western relating to O&M of sewerage works
			Sludge treatment		
			Effluent quality management		
		Maintenance of M/E Equipment	Maintenance plan and procedures	L&D	
			Instruction of plan and Procedures	OJT	
		Maintenance of Sewer Network (PIpeline)	Maintenance plan and procedures	L&D	
			Instruction of plan and Procedures	OJT	
		O&M of WWTP	O&M plan of WWTP	L&D	
			Daily inspection of WWTP	L&D, OJT	
			Water quality analysis	L&D, OJT	
		Health and Safety	Health and safety plan	L&D, OJT	
			Risk management	L&D, OJT	
			Emergency response	L&D, OJT	
5	Liquid Trade Waste	Laws, Regulations		L&D	Staff of Customer Service Department
		Regulation procedures		L&D	
6	On-site sanitation	On-site sanitation system (Johkasou)	Laws, Regulation and Standards	L&D	Management level of DWS (and WAF)
			O&M	L&D	
		Farm village drainage works in Japan	Planning and design	L&D	
			O&M	L&D	

Source: JET

iii. Implementation Methods of Trainings

Trainings of each training category were conducted with attention to the items shown in **Table S4. 1-5**.

Table S4. 1-5 Items to Pay Attention in the Training

Category	Items to pay attention to
1	Sewerage works management training is targeted towards management level of DWS and WAF with reporting on the current state of sewerage works in Japan, transition to corporate accounting, asset management, etc. After that, Japanese and Fijian side will exchange opinions and share information.
2	Planning and design of sewerage works training is mainly targeted towards WAF staff in charge of planning and design. However, DWS staff are also in charge of decentralized wastewater treatment projects, so they will be added as necessary. Fukuoka City will provide information on sewerage planning, sewer pipe design, and WWTP design in Japan, and then exchange opinions with the Fiji side to share the information. In M/P formulation and Pre-F/S implementation, JET will collaborate while providing information through OJT to improve capacity.
3	Project management training will be carried out by JET who have experience in project management overseas.
4	O&M of sewerage facilities training is mainly targeted towards WAF staff in charge of O&M of sewerage facilities. Technical knowledge of each program is provided by Fukuoka City and shared by exchanging opinions. JET will support the creation of O&M manuals, SOPs etc. by OJT. Regarding health and safety, JET will give advice on risk management, etc. while conducting on-site safety patrols, and improve the capacity of WAF staff through open discussion and exchange.
5	Regulations for LTW training is mainly targeted towards the staff of the Customer Service Department of WAF and staff of WWTP that receive LTW effluent. Fukuoka City will provide information on laws and regulations related to LTW in Japan, actual regulations and guidance methods, and share knowledge by exchanging opinions.
6	De-centralized wastewater works training is mainly targeted towards staff in DWS that are responsible over the works, but since there is a possibility that WAF will formulate small-scale sewerage projects in the future, staff of WAF in charge of planning and design will also be added. Fukuoka City will provide information on the planning and O&M of the Johkasou projects and the rural agricultural community drainage projects in Japan and will share knowledge by exchanging opinions.

Source: JET

Lectures and exchange of opinions generally were conducted online. The implementation method is shown in **Table S4. 1-6**.

Table S4. 1-6 Implementation Method of Online Training

	Implementation items	Person in charge
1	Preparation of lecture materials (Japanese)	Fukuoka City
2	Translation of materials into English	JET
3	Preparation of Fiji side materials (English) (if necessary)	WAF
4	Translation of Fiji side materials into Japanese	JET
5	Lecture (by using English materials)	Fukuoka City, JET
6	Exchange of opinions (by using Japanese interpreter)	Fukuoka City, JET, WAF

Source: JET

Training on the “On-site sanitation” shown as item 6 of **Table S4. 1-5**, was conducted not on-line but in the Japan Visit Program.

iv. Training in Japan

A training session in Japan wase held as a part of the CD program, hosted by Fukuoka City. The training schedule is as shown in **Table S4.1-7**. The program included an introduction to sewerage works of Fukuoka City and discussion sessions with staff during visits to various facilities. The schedule also included the introduction of Japanese technologies that can be introduced in Fiji through knowledge acquisition of Japanese Johkasou and a factory tour of a sludge dewatering factory. Originally the training was scheduled to be held in 2022 but was postponed due to COVID-19 and was carried out in December 2023.

Table S4. 1-7 Schedule of Training in Japan

Date		Schedule
12/11	**Mon**	JICA Briefing, Program orientation and Japanese class at JICA Kyushu
12/12	**Tues**	Introduction of sewerage works in Fukuoka City Introduction of sewerage works in Fiji Courtesy Visit to Director of Road and Sewerage Bureau of Fukuoka
12/13	**Wed**	Visit Chubu WWTP
12/14	**Thur**	Visit sewer pipe construction and sewer pipe cleaning sites
12/15	**Fri**	Visit Wajiro and Tsuyazaki WWTP (OD process)
12/16	**Sat**	Holiday
12/17	**Sun**	Holiday
12/18	**Mon**	Visit Yasu and Noichi WWTP in Kochi prefecture (advanced OD process)
12/19	**Tues**	Introduction of Member Companies of International Business Platform Fukuoka Visit Fukuoka Sewerage Museum
12/20	**Wed**	Wrap-up meeting at Fukuoka City
12/21	**Thur**	Visit Tokyo Rainbow Sewerage Museum Lecture on Septic Tank Situation Overseas and Introduction of Johkaso for Improvement
12/22	**Fri**	Courtesy Visit to Director-General of Sewerage and Wastewater Management Department Factory tour in sludge dewatering machine factory

Note: the schedule above not include travelling days
Source: JET

v. JICA knowledge co-creation program

Furthermore, the JICA Knowledge Co-Creation Program (hereinafter referred to as “KCCP”) is effective due to its intensive nature, and trainees are able to gain perspectives of a wide range of issues and solutions from countries other than Japan and Fiji, which is important for the discovery and learning processes and is expected to be an effective training method. For this reason, participation to the Program from Fiji was in discussion with JICA and C/P organizations but no one was selected from Fiji during the project period.

2. IMPLEMENTATION STATUS OF TRAINING

(1) Online Training Program

In accordance with the training program shown in **Table S4. 1-4,** the first training on 20, April 2022 to the 8th training on 23 May 2024, 8 on-line trainings were implemented. The outlines of each training results are shown below.

1) The First training "Sewerage Works Management"

The training on the sewerage works management was held on 20, April 2022 for the management level staff of DWS and WAF. The outline of the training is as shown in **Table S4. 2-1**.

Table S4. 2-1 Outline of the Training on Sewerage Works Management

Subject	The 1st On-line Training "Sewerage Works Management"
Date	20, April 2022 10:00-12:00 (JST) 13:00-15:00 (FJT)
Venue	WAF Central, WAF West, WAF North, DWS, Fukuoka City, JICA Global Environment Department
Participants	DWS 2, WAF 25, JICA Global Environment Department 2, JICA Fiji Office 2, JET 3
Agenda	1.Opening remarks (JICA Global Environment Department, WAF, Road and Sewerage Department of Fukuoka City) 2. Explanation of training implementation method Source: JET 3. Sewerage works management in Japan (Fukuoka City) 4. Sewerage works management in Fiji (WAF) 5. Discussion 6. Closing remarks (WAF)
Outline	This training program was conducted in collaboration with WAF and the Road and Sewerage Department of Fukuoka City. The topic of the first training was "Sewerage works management." 1. Sewerage works management in Japan (Fukuoka City) *Introduction of the history and relevant laws of sewerage works in Japan *Introduction of the effective methods for reduction of expenditure and increase of revenue to solve the issues of sewerage works 2. Sewerage works management in Fiji (WAF) *Introduction of the history of WAF, and the outline of sewerage facilities and sewer network managed by WAF *Introduction of the current situation/issues and the measures planned by WAF
Discussion	1. Infiltration/inflow *WAF is implementing a 5-year project for mitigation of infiltration/inflow from June 2021. Through the training, Fukuoka City will share with WAF their knowledge regarding infiltration/inflow in rainy weather. 2. Training for health/safety and emergency response *Fukuoka City will provide training on health/safety and emergency response regarding the aged pipe collapse that occur frequently in Fiji for targeting staff of WAF and general public. 3. Initiatives for Climate Resilience *Climate change resilience has begun to be considered in the design of sewerage facilities, etc. throughout Fiji, including WAF. *In Japan, the urban inundation measure plan by sewerage has been revised to a plan that takes into account the effects of climate change, and the national guidelines have been revised to promote planned advance disaster prevention. 4. Sludge treatment plan *In Fiji, there is no standard for final disposal and utilization of sludge. Some examples of utilization of sewerage sludge in Fukuoka City were introduced.

Source: JET

2) The second training “Sewerage Planning and design”, “Sewerage Treatment Plant Design”

On 19, July 2022, the training on "Sewerage Planning" and "Sewer Pipe Design" was held, but due to an occurrence of a collapsed sewer pipe, staff in charge attended to deal with the trouble, and participants of the training were small, so the training was held again on July 27.

And on 28, July, training on "Sewerage Treatment Plant Design (Mechanical), (Electrical), (Civil)" was held. The outline is shown in **Table S4. 2-2** and **Table S4. 2-3**.

Table S4. 2-2 Outline of the Training on Sewerage Planning and Sewer Pipe Design

Subject	The second on-line training “Sewerage planning and sewer pipe design
Date	19, July 2022 10:00-12:30（JST）、13:00-15:30 (FJT) 27, July 2022 14:00-16:45（FJT）Retraining (due to small number of participants on 19th caused by attending to sewer pipe trouble）
Venue	WAF Central, WAF West, Fukuoka City, (retraining wad by JET)
Participants	WAF staff in charge of planning/design
Agenda	1. Sewerage Planning (Fukuoka City) 2. Sewer Pipe Design (Fukuoka City) 3. WAF Wastewater Project Updates (WAF)
Contents	1. Sewerage planning *Introduction to basic knowledge about sewerage in Japan *Outline of sewerage planning *Formulation of master plan 2. Sewer pipe design *Setting conditions for sewer pipe design *Things to consider in design *Manholes *Selecting construction methods 3. WAF Wastewater Project Updates (WAF) *Current status of WAF sewerage projects *Introduction to various rules and standards in WAF *Introduction to flagship projects (capital investment) *Capital investment track record *Implementation of planning and design *Planning and design/on-site issues
Q&A	Main questions from WAF 1. Sewerage planning *How to calculate the planned sewerage volume *How to measure the actual inflow sewerage volume *How to calculate the tourism wastewater volume *Funding sources for storm water management in Japan 2. Sewerage pipeline design *Current status of pressure pipe usage in Japan *Infiltration condition of storm water in Japan 3. Main questions from Fukuoka City *Current status of training in Fiji *Position of the M/P to be formulated in this project *Securing a budget to realize the M/P

Source: JET

Table S4. 2-3 Outline of the Training on Sewerage Treatment Plant Design (Mechanical), (Electrical), (Civil)

Subject	The second on-line training “Sewerage Treatment Plant Design (Mechanical), (Electrical), (Civil)”
Date	28, July 2022 10:00-13:00（JST）、 13:00-16:00 (FJT)
Venue	WAF Central, WAF West, Fukuoka City
participants	WAF staff in charge of planning and design
Agenda	1. Sewerage design and supervision/mechanical (Fukuoka City) 2. Sewerage design and supervision/electrical (Fukuoka City) 3. Sewerage design and supervision/civil works (Fukuoka City)
Contents	1. Sewerage design and supervision/mechanical *Sewerage treatment process *Machinery and equipment for each facility in a WWTP 2. Sewerage design and supervision/electrical *Configuration and overview of electrical equipment *Electrical equipment for each facility in a WWTP *Introduction to FORViS (remote monitoring system) in Fukuoka City 3. Sewerage design and supervision/civil works *Role and structure of sewerage system *Setting planned sewerage volume *Configuration of pumping station *WWTP
Q&A	Main questions from Fiji regarding the lecture 1. Mechanical *Treatment methods of collected sludge in Japan *Use of pretreatment in the disinfection process of treated wastewater *Types of sludge dewatering machines in Japan *Odor control measures at WWTPs *Sludge incineration temperature *Using digestion gas for incineration *Removal of harmful components from digestion gas 2. Electrical *Contents of the FORViS system *Receiving voltage at WWTPs in Japan *Capacity of emergency power generation equipment 3. Civil engineering *Consideration of infiltration water in pump station design *Methods for improving the sedimentation efficiency of the primary sedimentation tank *How to set the sodium hypochlorite dosage

Source: JET

3) The third training "Construction Supervision of Sewerage project"

The training on "Construction Supervision of Sewerage project" was conducted online on 16, September 2022 for construction supervision staff from the WAF Central and West. The outline is shown in **Table S4. 2-4**.

Table S4. 2-4 Outline of the Training on Construction Supervision of Sewerage Project

Subject	The third on-line training "Construction Supervision of Sewerage Project"
Date	16, September 2022 10:00-13:00（JST）、 13:00-16:00 (FJT)
Venue	WAF Central, WAF West, Fukuoka City
Participants	WAF Central and West staff in charge of construction supervision
Agenda	1. SOP of Sewer Rising main maintenance works (WAF) 2. Construction Supervision of Sewerage Projects (Fukuoka City) 3. Discussion
Contents	1. SOP of Sewer Rising main maintenance works (WAF) *Introduction of SOP for WAF pressure pipe repair work 2. Construction Supervision of Sewerage Projects (Fukuoka City) *Supervisory roles and construction management *On-site safety measures *Emergency response in the event of an accident
Q&A	1. Q&A on the introduction of pressure pipe repair work (WAF) *Implementation status of preventive maintenance of pipe facilities *GPS data management of pipe facilities *Implementation method of repair work (direct management or outsourced) *Frequency of repair work *Implementation status of pipe rehabilitation of aging pipes *Time required to complete work 2. Q&A on sewerage supervision work (Fukuoka City) *Inspection method of delivered equipment *The meaning of photo recording in progress management *Rescue plan for on-site safety management *How to use information sharing via LINE app *SOP for health and safety in WAF (Australian standards is used) and that in Japan

Source: JET

4) The fourth training "Sewerage and Sludge Treatment Technology"

The training on the sewerage and sludge treatment technology was conducted on-line on 24, November 2022 for staff in charge of operation and maintenance of WWTPs of WAF West. The outline of the training is shown in **Table S4. 2-5**.

Table S4. 2-5 Outline of the training on Sewerage and Sludge Treatment Technology

Subject	The fourth on-line training "Sewerage and sludge treatment technology"
Date	24 , November 2022 12:00-15:40（JST）、 15:00-18:45 (FJT)
Venue	WAF Central, WAF West, Fukuoka City
Participants	WAF West staff in charge of O&M of WWTP
Agenda	1. Basics of sewerage treatment technology (Fukuoka City) 2. Basics of sludge treatment technology (Fukuoka City) 3. Effluent quality control (Fukuoka City) 4. Discussion
Contents	1. Basics of sewerage treatment technology *Introduction video of the Seibu sewerage treatment plant *Basics of sewerage treatment technology 2. Basics of sludge treatment technology *The necessity and purpose of sludge treatment *Types of generated sludge *Sludge thickening *Anaerobic digestion *Sludge dewatering *Sludge incineration and utilization 3. Effluent quality control *Basic flow of sewerage treatment *Daily water quality test *Periodic effluent water quality test *Introduction to the water quality laboratory *Transparency test *Introduction to advanced treatment processes in Fukuoka City *Inspection of the sludge treatment process *Impact of sludge return flow water *Odor control
Q&A	1. Q&A on the basics of sewerage/sludge treatment technology (Fukuoka City) *Limits on sludge treatment technology available in Fiji (WAF comments) *Future necessity for effective use of sewerage sludge (WAF comments) *Odor control measures available in WWTPs in Fiji *Inspection and maintenance methods for sludge dewatering machines 2. Questions and answers on water quality management (Fukuoka City) *How to use water quality data for O&M of WWTPs *How to introduce simple water quality test methods such as transparency 3. Questions and answers on other matters *Request for implementing OJT on O&M of WWTPs *Request for training on sludge withdrawal methods from the IDEA reaction tank

Source: JET

5) The fifth training "Maintenance Management of Sewer Pipes"

The training on the maintenance management of sewer pipes was held on April 24, 2023, for staff in charge of the maintenance of sewer pipe facilities in the WAF West. The outline of the training is shown in **Table S4. 2-6**.

Table S4. 2-6 Outline of the Training on "Maintenance Management of Sewer Pipes"

Subject	The fifth on-line training "Maintenance Management of Sewer Pipes"
Date	24, April 2023 11:00-12:40（JST）、 14:00-15:30 (FJT)
Venue	Meeting room Navakai WWTP, Fukuoka City
Participants	WAF West staff in charge of sewer pipe maintenance
Agenda	1. Maintenance management of sewer pipes in Fukuoka City 2. Discussion
Contents	1. Maintenance management of sewer pipes in Fukuoka City 1.1 Current status of Fukuoka City 1.2 Current state of sewer pipes 1.3 Asset management initiatives: maintenance of sewerage system, asset management overview *Pipe maintenance *Pipe cleaning, inspection and investigation *Pipe cleaning *Patrol and inspection *Pipe investigation by TV camera *Repairs *Cleaning and inspection of storm water culverts and screens *Pressure pipe *Disposal of sludge in pipes 1.4 Stock management initiatives: Stock management plan *Pipe inspection frequency *Pipe investigation and inspection frequency *Outline of stock management plan *Screening survey 1.5 Asset management initiatives: Sewerage ledger system *Purpose of sewerage ledger *Creation of sewerage ledger *Use of sewerage ledger
Q&A	1. Q&A on the maintenance of sewer pipes (Fukuoka City) *Existence of sewer pipes with a diameter of 800 mm or more that people can enter in Japan (Fiji does not have them) *Existence of CCTV cameras for pipe inspection (Fiji does not have, Fukuoka City outsources to the private sector) *Existence of high-pressure cleaning vehicles for pipe cleaning (WAF does not have and outsources to the private sector, Fukuoka City does the same) *Implementation method of regular inspection and cleaning of sewer pipes for the purpose of preventive maintenance that WAF is currently unable to implement *Status of combined sewer systems in Fukuoka City 2. Questions from Fukuoka City regarding the maintenance of sewer pipes in Fiji *Treatment and disposal process of sludge generated during pipe cleaning (WAF: dumped in WWTP) *Effective use of sewerage sludge in Fiji (WAF: does not implement it, but is interested) *Existence of sewer pipe ledger in Fiji (WAF: there is, but inaccurate due to old)

Source: JET

6) The sixth training "Maintenance of Mechanical and Electrical Equipment"

The training on the maintenance of mechanical and electrical equipment was conducted on-line on 25, April 2023 for staff in charge of maintenance of mechanical and electrical equipment in WAF West. The outline of the training is shown in **Table S4. 2-7**.

Table S4. 2-7 Outline of the Training "Maintenance of Mechanical and Electrical Equipment"

Subject	The sixth on-line training "Maintenance of Mechanical and Electrical Equipment"
Date	24, April 2023 11:00-12:40（JST）、 14:00-15:30 (FJT)
Venue	Meeting room Navakai WWTP, Fukuoka City
Participants	WAF West staff in charge of maintenance of mechanical and electrical equipment
Agenda	1. Maintenance of Mechanical and Electrical Equipment～Establishing Stock Management for Sewerage Facilities 2. Discussion
Contents	1. Maintenance of mechanical and electrical equipment in Fukuoka City 1.1 Definition and purpose of stock management *Definition of stock management *Purpose of stock management *Introduction flow of stock management 1.2 Sewerage ledger system *Role of ledger system *Establishing flow of ledger system 1.3 Method of stock management *Preventive maintenance *Corrective maintenance 1.4 Setting priorities for replacement *Setting target service life *Risk assessment 1.5 Maintenance of facilities and equipment *Using LCC comparison to choose between replacement and life extension *Example of life extension works
Q&A	1. Q&A on the maintenance of mechanical and electrical equipment in Fukuoka City *How to create mechanical and electrical equipment ledger that WAF does not currently have (Fukuoka City: The first step in creating an equipment ledger is to grasp the current state of the equipment) *Consideration of making it mandatory for manufacturers and contractors to create equipment and construction information as a method of developing an equipment ledger (WAF's comment) *The need for lectures on stock management, ledger management, etc. in the training in Japan (WAF's comment)

Source: JET

7) The seventh training “Liquid trade Waste Management”

The training on the liquid trade waste management was conducted on-line on 25, July 2023 for WAF staff in charge of liquid trade waste. The outline of the training is shown in **Table S4. 2-8**.

Table S4. 2-8 Outline of the Training “Liquid Trade Waste Management”

Subject	The seventh on-line training “Liquid Trade Waste Management”
Date	26, July 2023 10:00-12:00（JST）、 13:00-15:00 (FJT)
Venue	WAF Central, WAF West, WAF North, Fukuoka City
Participants	WAF staff in charge of liquid trade waste management
Agenda	1. Characteristics of sewerage and environmental laws / regulations 2. Purpose of water quality regulation in sewerage system 3. Water quality regulation mechanism under the Sewerage Act 4. Response in the event of a water quality accident 5. Discussion
Contents	1. Characteristics of sewerage and environmental laws/regulations *Environmental conservation of public waters *Improvement of water quality in closed water areas *Basic Law for the Environment *Coordination with water quality standards in the Sewerage Act 2. Purpose of water quality regulations in sewerage system *Water quality standards set for wastewater discharged into sewerage *Impacts of discharge of bad quality wastewater *Examples of bad quality wastewater *Examples of discharge of bad quality 3. Water quality regulations under the Sewerage Act *Notification system for specific facilities *Monitoring and on-site inspections *Measures to be taken when water quality standards are violated 4. Responses in the event of water quality accidents *Obligations of business operators in the event of an accident such as the leakage of harmful substances *Measures to be taken when harmful substances flow into WWTP
Q&A	1. Questions and answers regarding Fukuoka City's business wastewater regulations *Identification process of the businesses that illegally dumped sludge into the sewer system *Penalties for violations such as illegal dumping of sludge *Disposal methods of sludge generated at factories in accordance with the law *Water quality laboratories that monitoring of Liquid trade waste *Measures to be taken when high BOD load wastewater flows into WWTP *How to deal with businesses that repeatedly violate regulations *Connection status of specific facilities to the sewer system *Wide-area monitoring method for water quality *Obligation to install grease traps, measures against waste oil spills from ordinary households *Notification of business connection to the sewer system *Wastewater quality monitoring by businesses *Number of notifications for business connection to the sewer system 2. Current situation and system of liquid trade waste regulations in Fiji (WAF's presentation) *Current situation of the legal system for liquid trade waste in Fiji *Activities of the WAF's liquid trade waste unit *Inspection method for liquid trade waste *Permission system for business connection to the sewer system

Source: JET

8) The eighth training "Project Management"

The training on the project management was held on-line on 23, May 2024, for WAF staff in charge of project management and planning/design with instructors from Nihon Suido Consultants Co. Ltd. The outline of the training is shown in **Table S4. 2-9**.

Table S4. 2-9 Outline of the Training "Project Management"

Subject	The eighth on-line training "Project Management"
Date	23, May 2024 11:00-12:30（JST）、 14:00-15:30 (FJT)
Venue	WAF Central, WAF West, Nihon Suido Consultants Co., Ltd.
Participants	WAF staff in charge of project management, planning/design
Agenda	1. Project management 2. Discussion
Contents	1. Introduction of project management What is ODA? Types of work Project flow and types 2. Examples of problems Design stage Bidding stage Construction stage
Q&A	1. Q&A to a lecture on project management *How to carry out a macro check of rebar quantities *Required rebar to concrete ratio *Standards to use when local design standards are not available for pipeline design *Measures to prevent damage to existing underground structures during pipe jacking work *How to respond when design defects become apparent during the construction phase

Source: JET

(2) Japan Visit Program

The Japan Visit Program was originally planned to be implemented in Phase 1of the project to efficiently achieve Outpu-4, allowing the participants to learn about the current state of sewerage works in Japan at an early stage. The visit program was actually implemented in December 2023 to avoid the COVID-19 pandemic.

1) Purpose of the program

- Learn through lectures and visits about the implementation status of sewerage works in advanced sewerage cities in Japan, and develop awareness when considering implementation methods for sewerage works suitable for Fiji.
- Learn through lectures and visits about Japanese sewerage and wastewater treatment technologies that can be used stably and sustainably, and develop awareness when considering technologies suitable for Fiji.
- Visit properly operated and maintained sewerage facilities to develop awareness when considering operation and maintenance methods suitable for Fiji.

2) Participants

In order to achieve the above-mentioned objectives, the program was attended by officials from the following organizations involved in the implementation of sewerage projects in Fiji: the Ministry of Public Works, Meteorological Services and Transport, which is responsible for sewerage works; the Ministry of Economy, which is responsible for all project budgets including sewerage works; the Department of Environment (directly under the Prime Minister's Office), which has jurisdiction over the environmental impact of sewerage projects and the discharge standards of WWTPs; the Ministry of Local Governments, which has jurisdiction over local governments implementing sewerage projects; and WAF, which actually implements the sewerage works. The list of participants is shown in **Table S4. 2-10**.

Table S4. 2-10 Participants of Japan Visit Program

Name	Gender	Institution	Department/Division	Position
Jeet Vishwa	Male	Ministry of Public Works and Meteorological Services & Transport	Water & Sewerage	Senior Technical Officer
Tuima Makereta Baleimusuka	Female	Ministry of Finance, Strategic Planning, National Development & Statistics	Strategic Planning	Senior Project Monitoring and Evaluation Officer
Raj Kritika	Female	Department of Environment-Office of Prime Minister	Environment	Senior Environment Officer
Raratabu Aisake Sokovagone	Male	Ministry of Local Government	Town and Country Planning	Principal Town Planner
Nambiar Edwin Yogesh	Male	Water Authority of Fiji	Wastewater Management Western	Project Leader
Radio Sikeli	Male	Water Authority of Fiji	Wastewater Management - Central	Supervisor Wastewater Transportation Central
Jale Viliame Colati	Male	Water Authority of Fiji	Wastewater Management - Northen	Technical Officer
Moceisui Iliesa Nadau	Male	Water Authority of Fiji	Wastewater Management - Western	Technical Officer
Matai Tevita Tamanikalougata	Male	Water Authority of Fiji	Wastewater Management - Central	Technician Wailada WWTP
Prakash Roneel	Male	Water Authority of Fiji	Wastewater Management - Western	Technician Natabua WWTP

Source: JET

3) Implementation and cooperation organizations

The implementation and cooperation organizations for the program were as follows.

Implementation organization: Fukuoka City Road and Sewerage Bureau

Cooperating organizations: Fukutsu City Urban Development Department Sewerage Division (Fukuoka Prefecture)
Konan City Water Supply and Sewerage Division (Kochi Prefecture),
Tokyo Sewerage Museum “Rainbow” Tokyo Metropolitan,
Japan Education Center of Environmental Sanitation

4) Implementation method

Fijian C/Ps have obtained a wide range of information on sewerage planning, project implementation, O&M, etc. during the three-year JICA project. However, in order to transfer the experience of Japan in the development of sewerage works to the C/Ps, it is most effective for them visit Japan and learn about the implementation status and future plans of the works of the local government that is implementing the sewerage works.

In the Japan Visit Program, the participants visited the Fukuoka City Road Sewerage Bureau, the implementation agency, to learn about the implementation status of sewerage projects, sewer network (pipe) maintenance, O&M of WWTP facilities, sludge treatment and effective utilization, as well as the implementation status of daily water quality tests that are recommended to be conducted at WWTPs in Fiji in this project, in the water quality laboratory, thereby gaining an "awareness" of sewerage planning and O&M works in Fiji.

Furthermore, the program will introduce Japanese technologies that are recommended to introduce in Fiji, including the Dual DO Control OD Process that automatically controls the appropriate airflow volume, Johkasou that is an individual wastewater treatment technology, and dehydrators that have excellent performance for dewatering sludge in small-scale WWTPs, and will raise the opportunity for their introduction.

5) Schedule

The schedule is as shown in **Table S4. 2-11**.

Table S4. 2-11 Schedule of Japan Visit Program

Date	Contents	Style	Purpose	Venue
8 (F)	Travel (Fiji→Narita)			
9 (S)	Travel (Narita→JICA Kyushu)			
10 (S)	Holiday			
11 (M)	Briefing Program orientation Japanese class	Lecture Lecture Lecture	Overview of the program, Simple training of Japanese	Kitakyushu City (JICA Kyushu)
12 (T)	Travel (Kitakyushu City →Fukuoka City) Overview of sewerage works of Fukuoka City Overview of sewerage works in Fiji Director of the Road and Sewerage Bureau	 Lecture Present. Courtesy visit	 Introduction to sewerage works of Fukuoka City Introduction to sewerage works in Fiji	 Fukuoka City Director's room
13 (W)	Chubu WWTP	Lecture Site visit	AO sewerage treatment facilities, reclamation treatment facilities, sludge utilization facilities, and water quality laboratory	Fukuoka City
14 (T)	Sewer pipe construction site Sewer pipe cleaning and investigation sites	Site visit Site visit	Observation of sewer pipe rehabilitation work, Observation of sewer pipe cleaning, investigation by TV camera	Fukuoka City
15 (F)	Wajiro WWTP Tsuyazaki WWTP	Lecture Site visit Lecture Site visit	AO process treatment facility, Phosphorus recovery facility OD process treatment facility	Fukuoka City Fukutsu City
16 (S)	Holiday			Fukuoka City
17 (S)	Holiday			Fukuoka City
18 (M)	Travel (Fukuoka→Kochi) Yasu-cho WWTP Noichi WWT	 Site visit Site visit	 Dual DO Control OD process facility (introduction of technology from member companies of International Business Platform Fukuoka)	Konan City
19(T)	Travel (Kochi→Fukuoka) Introduction to Japanese sewerage technology Sewerage Museum	 Lecture Site visit	 Introduction of technologies from member companies of International Business Platform Fukuoka Introduction of public awareness activities	 Fukuoka City Fukuoka City
20 (W)	Wrap-up meeting Travel (Fukuoka→Tokyo)	Present.	Participant's presentations on their training results	Fukuoka City
21 (T)	Tokyo Rainbow Sewerage Museum Japan Education Center of Environmental Sanitation	Site visit Lecture	Introduction of public awareness activities of Tokyo Metropolitan Introduction of Johkasou technology and overseas expansion	Tokyo Metropolitan
22 (F)	Director-General of Sewerage and Wastewater Management Department, MLIT AMCON Co., LTD. Moving (Narita→Fiji)	Courtesy visit Factory visit	 Introduction of small sludge dewatering machine technology and overseas expansion	DG room Yokohama City

Source: JET

3. IMPLEMENTATION OF OJT

In addition to online training from Japan by Fukuoka City and Nihon Suido Consultants Co., Ltd., OJT was conducted on-site in Fiji. The implementation status is as follows.

(1) Simple water quality measurement at WWTP

The online training on "Sewerage/Sludge Treatment Technology" held in November 2022 introduced that effluent quality can be estimated in real time by measuring the transparency (hereinafter referred to as “Tr”). The staff in the WWTPs of WAF West who participated in the training had many questions about the measurement method and equipment used, and WAF also recognized the need for it. However, WAF was unable to measure because there is no equipment necessary for measurement.

In addition, one of the reasons why Navakai WWTP is not able to comply with the discharge standards is due to the lack of activated sludge control in the IDEA tank, and in order to improve, it is necessary to measure the activated sludge concentration. Because WAF does not have equipment to measure sludge concentration, JET has recommended to measure the Sludge Volume (hereinafter referred to as “SV”) using a graduated cylinder as a way to estimate the concentration. However, WAF was unable to measure it because there is no appropriate graduated cylinder.

Under these conditions, after discussions with Fukuoka City, it was determined that the best way would be that Fukuoka City directly instruct WAF staff on how to measure transparency and SV through OJT when JICA Headquarters and Fukuoka City visited Fiji in November 2023. JET procured a transparency meter and a graduated cylinder, and Fukuoka City conducted the OJT. The implementation method of OJT is as shown in **Table S4. 3-1**.

Table S4. 3-1 Implementation Method of OJT on Measurement of Transparency and SV

Date	9, November 2023 11:30~14:30	
Venue	Meeting room of Navakai WWTP, Effluent gate (for Transparency), IDEA reaction tank (for SV)	
Participants	WAF West staff in charge of O&M of WWTP	
Instructor	Staff in Chubu WWTP, Sewerage Facility Division, Road/Sewerage Bureau Fukuoka City	
Method	Overview (meeting room)	Explanation of the significance of measuring transparency and SV, How to use measuring equipment, Overview of the measurement method
	Transparency (Effluent gate)	Effluent from the effluent gate is sampled, and transparency measurement method was instructed by Fukuoka City and then measured by WAF staff.
	SV (Outlet of IDEA tank)	Activated sludge was collected at the outlet of the IDEA tank, and SV measurement was instructed by Fukuoka City and measured by WAF staff.
	Discussion (meeting room)	Participants deepened their understanding through discussions on sampling and measurement methods, and analysis of measurement results.

Source: JET

(2) Creation of SOPs

In order to make it easier for WAF staff to continue measuring transparency and SV, of which measurement method were instructed in the OJT in November 2023, it was concluded through discussion with the technical officer of Navakai WWTP that it is necessary to create SOPs for the measurement method. Since WAF has no experience in creating SOPs, JET proposed that JET create a sample and WAF modifies it so that it can be easily used at the WWTP site. **Figure S4. 3-1** shows a part of the SOPs related to SV proposed to WAF. It is expected that WWTP staff will use this sample to develop SOPs for other operations.

SOP Sewerage Works		Name	Title	Date
	Prepared			
	Reviewed			
	Approved			

1	Name of Procedure	Measurement of Sludge Volume （SV）
2	Scope	Collect a specified amount of activated sludge into a cylinder, and measure the sludge interface height after settling for 30 minutes. This allows the activated sludge concentration to be estimated.
3	Equipment/Consumables	2L mess-cylinder Sludge sampling apparatus Timer
4	Prior Confirmation	Measurement should be carried out at the same time every day. The walls of the mess-cylinder used must be clean. The mess-cylinder used must be placed on a stable and level surface when taking measurements. In preparation for rain weather, a simple roof above the cylinder will be desirable, if possible.
5	Potential Hazards	Risk of touching contaminated activated sludge Risk of falling into the IDEA tank
6	PPE	Protection gloves Work clothes, Work shoes
7	Emergency Dial	

8	Procedure	
	Work Contents	Notes
8-1	Preparation	
i	Put a 2L mess-cylinder on a stable and level surface.	Sampling point is desirable near the outlet point of effluent.
ii	Place a sludge sampling apparatus.	
iii	Prepare a timer for measuring 30min.	
iv	Prepare a recording sheet to record the result.	
8-2	Work procedure	
i	Take sludge by the apparatus and pour gently into the mess-cylinder until it reaches to 2L mark.	
ii	Start the timer and wait 30 minutes.	
iii	In 30 minute, read the height of the sludge interface.	
iv	Write the measured height into the recording sheet.	
8-3	Cleaning-up	
i	Discharge the sludge in the cylinder in the IDEA tank.	The sludge contains hazardous bacteria! You must not discharge it in grassy area etc.
ii	Wash the cylinder and the collecting	Without washing cylinder and apparatus,

Source: JET

Figure S4. 3-1 SOP for Measurement of SV (part)

(3) Measurement of dissolved oxygen and activated sludge concentration in the IDEA tank

The effluent quality from Navakai WWTP generally does not comply with Fiji's discharge standards. It has been said that the reason for the poor quality is a short of facility capacity due to the inflow of high-load sewerage. In the SV measurement of activated sludge conducted in November 2023 described in **(1)**, it became clear that the sludge consists of rapidly settling sludge and highly turbid treated water on top of it, as shown in **Figure S4. 3-2**.

Source: JET

Figure S4. 3-2　SV Measurement at Navakai WWTP

The causes of such activated sludge are supposed to be: (1) The dissolved oxygen (hereinafter referred to as “DO”) concentration is low and normal aerobic activated sludge flocs cannot be formed; (2) The sludge becomes old due to insufficient withdrawal of excess sludge, and the sludge concentration becomes too high. However, the cause could not be identified and unable to propose appropriate countermeasures.

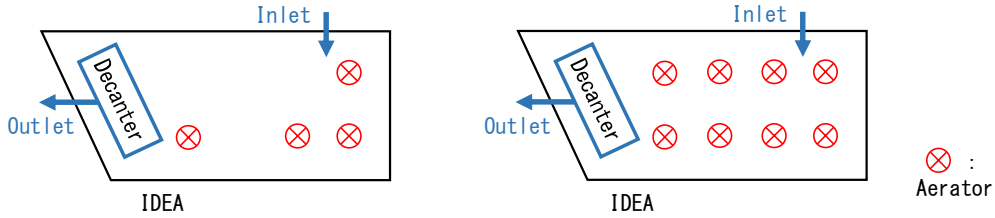
Therefore, JET brought a sludge concentration meter (MLSS meter) and a dissolved oxygen meter (DO meter) from Japan, in collaboration with the staff of WAF West, carried out the measurement of MLSS and DO at the IDEA tank of the Navakai WWTP on Tuesday, May 14, 2024. The measurement method is as shown in **Table S4. 3-2**.

Table S4. 3-2　Measurement Method of DO and MLSS at IDEA Tank

Date	14th May 2024　9:50～11:15
Site	IDEA-1 tank Navakai WWTP
Equipment	DO：HACH MLSS: HACH
Method	Measured at the set measuring points while moving on a boat over the tank Continued aeration until just before the measurement, after the aeration stops moved to the measurement point immediately and measured.

Source: JET

Figure S4. 3-3 shows the number of aerators under operation and their positions at the IDEA-1 tank.



Source: JET

Figure S4. 3-3　Positions of Aerators on IDEA-1 Tank (Left: Actual, Right: Original Design)

In the original design of the IDEA tank, eight aerators were planned to be installed as shown in the reference, but on the day of measurement, four aerators were in operation. The measurements were taken at 9 points in the tank, 3 at different depths, for a total of 27 points. The result of the measurement is as shown in **Table S4. 3-3**.

Table S4. 3-3　Result of DO and MLSS measurement

DO	The DO concentration at 27 points in the tank was in the range of 0.05 to 0.2 mg/L, which is extremely low compared to the 1 mg/L required for a typical activated sludge process reaction tank. There is a shortage of dissolved oxygen. Particularly near the tank outlet, where there are fewer aerators, there is a tendency that the DO concentration comes to be lower on the depth. There is insufficient mixing.
MLSS	Near the inlet part of the tank, 0.3 to 0.9 m of sludge has accumulated. Near the inlet part, many aerators are installed, as shown in Figure S4. 3 3, so there is not much difference in sludge concentration between the upper and lower layers. In the middle of the tank and near the outlet, there are fewer aerators, so mixing is insufficient, and the sludge concentration becomes higher on the depth. In addition, about 0.2 m of sludge has accumulated at the bottom. Even in the upper layer, the sludge concentration is high at around 4,000 mg/L.

Source: JET

Based on the results of the measurements, JET summarized the current situation of the Navakai WWTP and proposed to WAF West the improvement procedure of the situation. The proposal consisted of additional installation of aerators, removal and reproduction of sludge in the IDEA tank, and proper sludge treatment and disposal. The outline of the proposal is shown in **Table S4. 3-4**.

Table S4. 3-4 Improvement Procedure of Navakai WWTP

Additional installation of aerator	*For the currently operating IDEA-1 tank, mixing within the tank is able to be sufficient by increasing the number of aerators up to the original design of eight. *The results of the DO concentration show that the currently used IDEA-1 tank alone is insufficient, and it is necessary to operate the IDEA-2 (currently suspended and number of aerators: 0). *The new number of aerators required is: 4 to IDEA-1 tanks (in addition to the existing four), 4 to IDEA-2 tanks, 2 to aerobic digester tanks, for a total of 10 aerators. *When installing aerators, it is essential to have a system in place to reliably carry out daily and periodic inspections, and emergency response measures, as well as the necessary equipment / materials, and consumables such as grease.
Removal and reproduction of sludge	Sludge removal *Currently, the IDEA tank contains old, heavy, and almost inactive sludge at a high concentration of 4,000 to 5,000 mg/L. In addition, 0.3 to 0.9 m of sludge has accumulated near the inlet of the tank. Even if the required number of aerators is installed, treatment performance cannot be expected to improve, and sludge removal is necessary first. *The accumulated sludge volume is estimated to be 240 m^3, and the suspended sludge is estimated to be 1,540 m^3 at the time of settling. It is necessary to remove it and dump it at a disposal site. Sludge reproduction *It is efficient to grow new activated sludge using the IDEA-2 tank, which is currently out of operation. *When the activated sludge grows, it is necessary to remove the excess sludge every day to keep the sludge concentration constant.
Proper treatment and disposal of sludge	Excess sludge *Excess sludge (estimated at 600m^3/day) needs to be removed every day. Aerobic digestion tank *Properly managed excess sludge is already stabilized, and odor problems are almost negligible, so aerobic digestion tanks can be operated continuously. Sludge drying bed *The sludge drying bed needs to accept the amount of aerobically digested sludge generated every day. If the capacity is insufficient, other methods of drying the sludge need to be considered. Sludge disposal *Properly managed excess sludge is sufficiently stabilized, so it is thought that it can be dumped into the septic tank sludge dumping area of the Natabua WWTP. *Without proper sludge treatment and disposal, treatment condition of the WWTP will soon return to the current situation.

Source: JET

(4) Equipment ledger for mechanical and electrical equipment

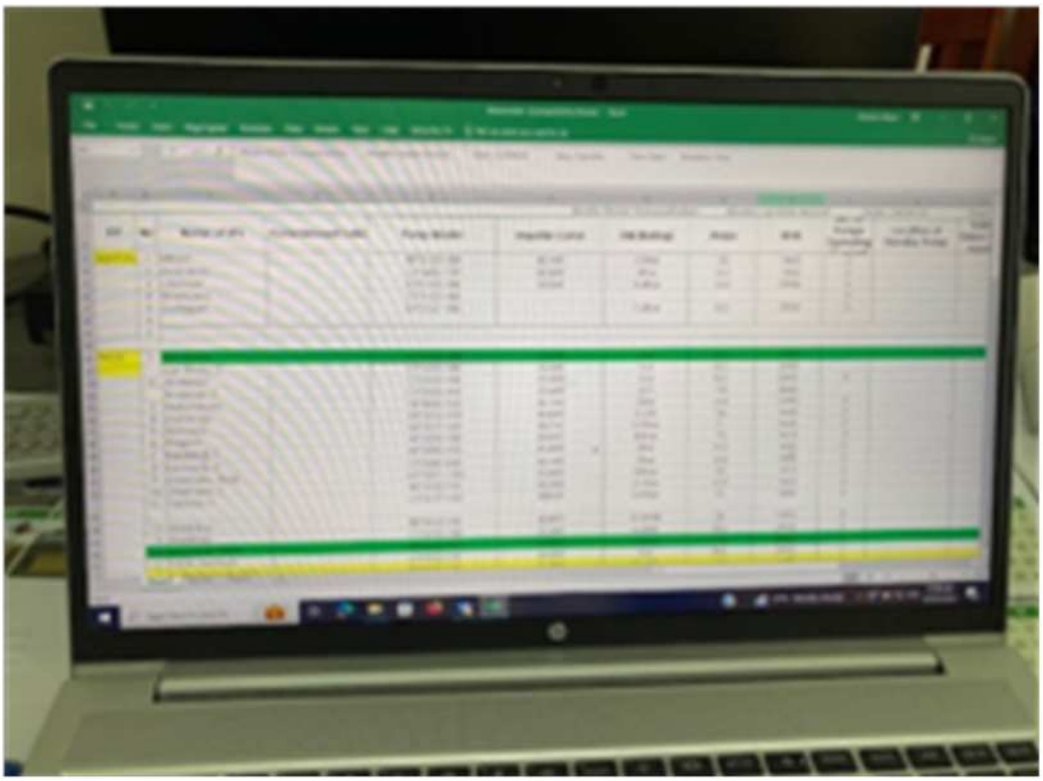
In the online training "Mechanical and Electrical Equipment Maintenance" held on April 25, 2023, the mechanical and electrical equipment maintenance team of WAF West asked a question about how to create an equipment ledger, and the training instructor (Fukuoka City) responded that it is important to first prepare the format of the ledger and start filling out what are known.

In response to this, the JET suggested to the chief of the team to prepare a format in Excel based on the entry items of the ledger system shown in the training materials, and the chief created the format and started entering data.

When JET checked the progress of the ledger development during in January 2024 and found that all the water and sewerage equipment in the Western Division was registered in an Excel-format ledger, but much

of the data such as model, capacity, and installation location had not been entered.

According to the chief, they will enter data to the extent possible and to link it to maintenance and repair records in the future. **Figure S4. 3-4** shows a part of the equipment ledger under preparation.



Source: JET

Figure S4. 3-4　Equipment Ledger Under Preparation

4. STATUS OF ACHIEVEMENT OF THE GOALS AT THE END OF THE PROJECT

The status of achievement of the set goals at the end of the project is shown in **Table S4. 4-1**.

Table S4. 4-1 Status of Achievement of the Goals at the End of the Project

Work		Goal	Status of achievement
1	Sewerage works management	・Management level of WAF and DWS understands the management policy and processes of the sewerage works of Japan through discussion with the municipality.	・Through the online training on "Sewerage Business Management" and the discussions with Fukuoka City during the training in Japan, the management level of DWS and WAF gained knowledge and information on management policies and sewerage works processes in Japan.
2	Planning/Design	・Staffs in planning/design of WAF understand the formulation procedure of sewerage M/P through collaborative works with JET and start to formulate the M/P.	・WAF staff in charge of planning and design got knowledge of planning and design methods while working with JET to formulate the M/P and implement Pre-F/S during the project. ・Through online training on "Sewerage Planning and Sewer Pipe Design," WAF staff in charge of planning and design obtained knowledge and information about planning and design methods in Japan.
3	Project management	・Staffs of the special project WAF share the information with JET and know the issues in implementing sewerage projects in foreign countries and use them as a reference for implementing their own projects.	・Through the online training on "Project Management." WAF staff in charge of project management and planning / design gained knowledge and information about overseas project management methods and examples of problems that actually occurred.
4	O&M of sewerage facilities		
1)	Maintenance of sewer system	・Sewer system maintenance staffs understand the procedures of inspection, cleaning and repair of the sewer system and understand how to formulate SOPs for them. ・Sewer system maintenance staffs recognize the danger of sewer system maintenance work and implement the work safely.	・Through the online training on "sewer pipe maintenance," WAF West staff in charge of sewer pipe maintenance gained knowledge and information about maintenance precautions and asset management, etc. ・WAF does not have the necessary equipment and is therefore unable to carry out any pipe inspections or investigations, and so there is no need to create SOPs. ・Pipe cleaning is carried out based on SOPs created by WAF central, and there is currently no need to review it. ・WAF has been conducting annual training for staff on confined space working etc. and staff understand the risks.

Work		Goal	Status of achievement
2)	O&M of WWTPs	・Operation staffs understand the basic knowledge in sewerage and sludge treatment technology. ・Operation staffs understand how to formulate O&M manual, SOPs and checklist for the treatment facilities and start to formulate them. ・Operation staffs recognize the danger of operation work and implement the work safely.	・Through the online training on "Sewerage/Sludge Treatment Technology", the OJT on Transparency /SV by Fukuoka City and the visit of WWTP during the training in Japan, WAF staff in charge of O&M of WWTP gained knowledge and information related to sewerage/sludge treatment. In the OJT, JET presented sample SOPs for transparency and SV measurement, which allowed WAF West staff in charge of O&M of WWTP to gain knowledge about creating SOPs. ・WAF has been conducting annual training for staff on confined space working, etc. and staff now understand the risks.
3)	Maintenance of M/E equipment	・Maintenance staffs of M/E equipment understand meaning of preventive maintenance of equipment and how to formulate maintenance plans of equipment. ・Maintenance staffs of M/E equipment recognize the danger of M/E works and implement the work safely.	・In the online training on "Maintenance of Mechanical and Electrical Equipment," WAF West staff in charge of the maintenance of mechanical and electrical equipment gained knowledge and information on equipment ledger systems, risk assessments, and extending the service life of equipment. ・Based on the above training, the mechanical and electrical equipment maintenance team of WAF West has started creating an equipment ledger. ・WAF has conducted annual staff training on working in confined spaces etc. and staff now understand the risks.
5	Liquid trade waste (LTW)	・Staffs of liquid trade waste unit understand the law, regulation and standards of LTW in Japan.	・In the online training on "Liquid Trade Waste Management," WAF staff in charge of the liquid trade waste gained knowledge and information about relevant laws and regulations in Japan, examples of hazardous wastewater, and wastewater regulation systems.
6	On-site sanitation	・Staffs of DWS and planning/design unit of WAF understand the laws, regulation and standards of on-site sanitation in Japan. ・Staffs of DWS and planning/design unit of WAF understand the function and efficiency of on-site sanitation processes.	・In the Japan Visit Program, the participants, including staff of DWS which is in charge of decentralized wastewater treatment in Fiji, visited the Japan Education Center of Environmental sanitation, which spreads and raises awareness of Japanese Johkasou technology, and obtained knowledge and information about Johkasou technology and overseas expansion.

Source: JET