DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

NATIONAL WATER SUPPLY AND DRAINAGE BOARD (NWSDB)

THE FOLLOW-UP COOPERATION STUDY

ON

THE PROJECT FOR REHABILITATION OF KILINOCHCHI WATER SUPPLY SCHEME

IN

DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

FOLLOW-UP SURVEY REPORT

MARCH 2020

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NJS CONSULTANTS CO., LTD.

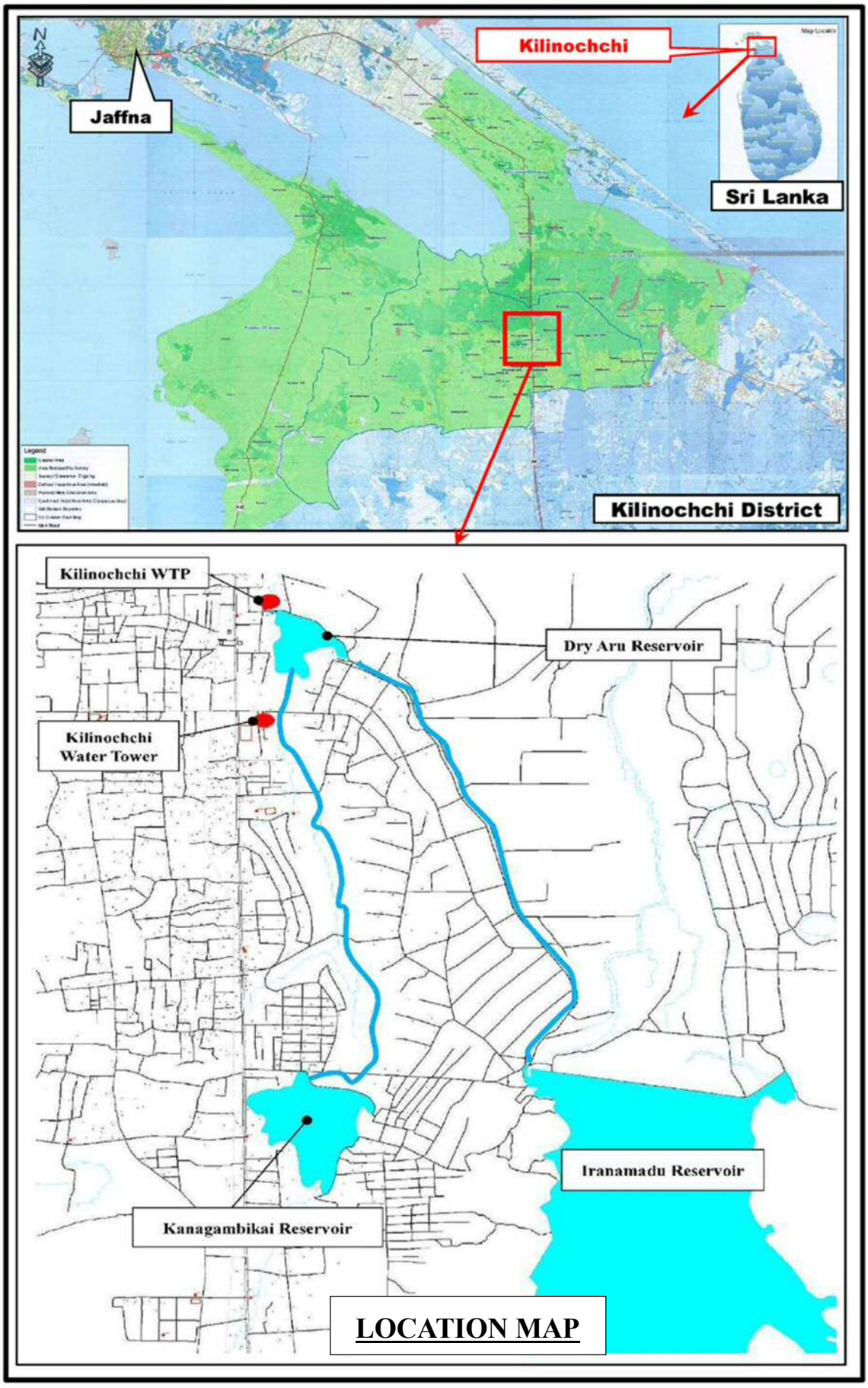
GL
JR
20-006

Table of Contents

List of Table and Figures

Table List

Figure List


Kilinochchi
Jaffna
Sri Lanka
Kilinochchi District
Kilinochchi WTP
Dry Aru Reservoir
Kilinochchi
Water Tower
Iranamadu Reservoir
Kanagambikai Reservoir
LOCATION MAP

1. Background

In response to a request from the Government of Democratic Socialist Republic of Sri Lanka (hereinafter referred to as "Sri Lanka"), the Government of Japan launched grant aid for "The Project for Rehabilitation of Kilinochchi Water Supply Scheme" in 2011, aiming at improving the supply of safe water and sanitation, and promoting the repatriation of internally displaced persons through the civil war. This project was completed in September 2016, with the rehabilitation and improvement of the Kilinochchi Water Treatment Plant (hereinafter referred to as "KWTP") and Water Transmission and Distribution Pipe Facilities that were damaged by the civil war lasted over 20 years. In addition to the rehabilitation and construction of the facilities, the Consultant has also prepared subsequently the facility operation manual in 2018 as a part of the software component, and the practical training was also provided in 2018.

The rehabilitation and construction work of KWTP was completed and commissioned in 2016. KWTP received the supply of raw water from the Iranamadu reservoir through the Dry Aru reservoir. However, as the improvement work had been carried out for the Iranamadu reservoir which is upstream of the Dry Aru reservoir since March 2015, KWTP was operated using the stored rain water in the Dry Aru for first few months only. Moreover, KWTP could hardly be operated since completion due to the record-breaking drought that occurred in 2016. It became in operational in March 2018.

Table 1-1 Major Incidents related to the Operation of KWTP

Years	Content
September 2016	Completion of the project and commencement of operation of KWTP
August-December 2016	Drought due to record-breaking little rainfall[1]
November 2016	Operations resumed with a temporary rise of the water level of the Dry Aru reservoir due to rainfall. However, increased turbid substances were deposited in the slow sand filtration media due to inflow from roughing filtration treated water with high turbidity (44-114 NTUs).
June 2017	✓ Stopped operation of KWTP due to high turbidity of raw water ✓ Stopped in January & restarted in March 2017
July-October 2017	✓ Stopped operation of KWTP due to low water level of Dry Aru ✓ From August to October, the chromaticity of the raw water increased with the growth of algae.
November-December 2017	Stopped operation of KWTP due to high turbidity of raw water
March 2018	✓ Completion of improvement works of the Iranamadu reservoir ✓ Normal operation of the slow sand filter (SSF) No.3 from 3rd March, start of water supply to 276 house consumers
May 2018	Preparation of O&M Manual (First Edition) given by the NJS
August-October 2018	Stopped operation of KWTP due to odour and chromaticity were detected in the treated water because of growing of algae in the raw water after 26th August.
November 2018	SSF No. 2 from 31st October due to high turbidity of raw water, and restarted SSF No. 3 from 29th November
December 2018	From 22nd December, SSF No.2 stopped due to heavy rain and high turbidity, and from 1st January, SSF No.3 was in operation

[1]Source: Sri Lanka Initial Rapid Assessment on Drought 2016/17, 15 January 2017, Ministry of Disaster Management and World Food Programme

Years	Content
January-September 2019	From 1st January, slow filtration No.3 was in operation Odour and chromaticity were confirmed in the treated water as algae grew in the raw water after 12th August, then the operation was stopped.
March 2019	Revised of O&M Manual (Second Edition) given by the NJS

After the completion of the improvement of the Iranamadu reservoir in November 2017, the supply of water to the Dry Aru reservoir was resumed. However, the supply of water to KWTP was temporarily shut down, due to unacceptable odour and colour in the treated water caused by high turbidity during the rainy season and generation of algae in the dry season

In April 2019, JICA conducted an ex-post survey. As per the survey, the following confirmations and conclusions were drawn:

- The raw water quality may be changed from that of the preparatory survey and water quality shall be confirmed through a further study.
- There are no established methods for the operation and maintenance (O&M) of KWTP in the event of critical water quality issues of raw water quality such as large generation of algae in dry season and high turbidity in rainy season.
- Operation & Maintenance of KWTP have been done according to the O&M Manual given by the NJS. However, in the event of critical water quality issues of raw water quality such as large generation of algae in dry season and high turbidity in rainy season. KWTP is unable to produce drinking water which complies with SLS 614: 2013.

Discussions between NWSDB and JICA based on the above concerns were carried out. It was confirmed to implement the "the Follow-Up Cooperation Study on the Project for Rehabilitation of Kilinochchi Water Supply Scheme" (hereinafter referred to as “the FU Study") in order to consider the countermeasures for these issues.

2. Survey Objective

The main objective of the Study is to review the current situation of KWTP including present O&M procedures and to investigate the present condition of the water quality of water sources. In addition, identification of necessary changes / improvement/enhancement in facilities (Unit treatment process) will be proposed. Based on the study results, the Study Team will propose necessary modifications for treatment process against problems caused by adverse water quality conditions such as algae outbreaks in dry season and high turbidity in rainy season of raw water of KWTP.

3. Survey Result (Dry Season: First Field Survey)

3-1 Current Status of Dry Aru and Iranamadu Reservoir

3-1-1 Iranamadu Reservoir

The Iranamadu reservoir is lower in water level, and the water level of the discharge channel has dropped more than 5m from the reservoir bottom on the right bank of the channel. Due to the lower water level, about 400m from the forest edge of the shore is exposed to the reservoir bottom with sand. It is believed that this can be affected by the cattle which are set for grass-grazing here, and its excreta is one of the root causes of

the eutrophication of the Iranamadu reservoir and the Dry Aru reservoir.

As for irrigation channels from Iranamadu reservoirs to Dry Aru reservoirs, the Department of Irrigation will basically open the runoff gates at the outlets of Iranamadu reservoirs for the period from April to August every year to flow the required water volume based on the requests from farmers. Therefore, during this period, water flows from Iranamadu reservoir into the Dry Aru reservoir. The below photos provide an overview of the Iranamadu Reservoir during the dry season period.

Left Bank side gate, Spillway is back side

Cows are grazing grasses

Dark Green at the Water Edge

Collection of Samples: Central area

Photo 3-1 Status of Iranamadu Reservoir (Dry Season)

3-1-2 Dry Aru Reservoir

Even at the end of the dry season in the first half of September, the water was almost full although no spillage occurred. The shore (dam body) was filled with water, and the cattle were not eating grass at the bottom of the pond, but a herd of cattle was walking on the dam body. The appearance of water is slightly better than that of the Iranamadu reservoir. The below photos depict the status of Dry Aru Reservoir under dry period.

Weir North End, Discharge Gate, and Intake Facility

Water Border at the center of the Dam

Collection of Samples: Central Pond

Collection of Samples: Intake Point

Photo 3-2 Status of Dry Aru Reservoir (Dry Season)

3-1-3 Result of Water Quality Analysis in the Reservoirs

During the first field survey, water quality analyses was conducted at an interval of five times (once a week, and is still ongoing) in the Iranamadu reservoir, the Kanagambikai reservoir, and the Dry Aru reservoir. Detailed sampling locations are shown in **Figure 3-1** and its results are shown in **Appendix 1**.

Comparing the Iranamadu and Dry Aru reservoir, the Iranamadu reservoir showed higher values for turbidity, BOD, COD, T-N, T-P and chlorophyll a. Japanese environmental standards for lakes and marshes stipulate that T-N is less than 0.2mg/L and T-P is less than 0.01mg/L for the purpose of water supply (type II, grade 1-3 water supply), and also COD is less than 3mg/L for the purpose of water supply (type A, grade 2-3 water supply). Comparing all the results from August 30 to September 19 with this standard, both the Iranamadu and Dry Aru reservoirs were higher than these standards.

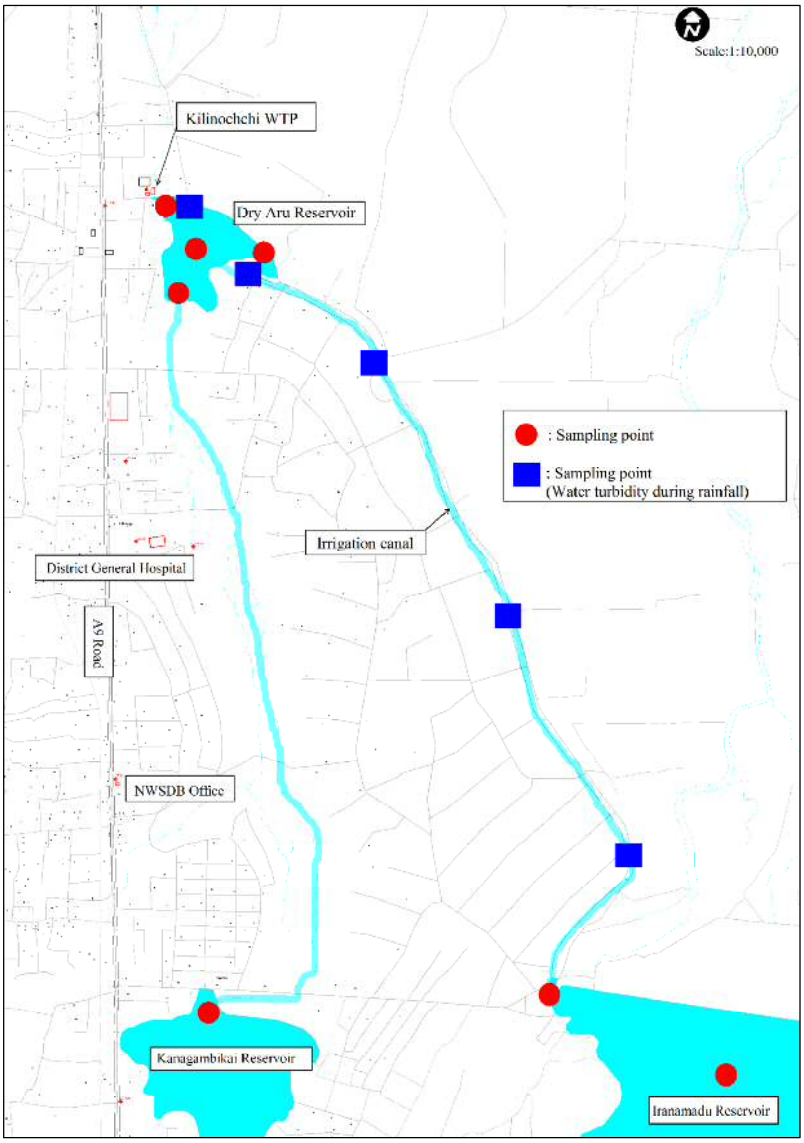


Figure 3-1 Adopted Point for Water Quality Analysis

The following are some remarkable points concerning the results of algae identification analysis carried out once a month.

① *Cylindrospermopsis* sp. which produces cylindrospermopsin, a toxic substance, was found in the surface and middle layers of the Iranamadu reservoirs, the Kanagambikai reservoirs, and Dry Aru reservoirs.

② *Microcystis*, a blue algae that grows large in eutrophicated lakes and reservoirs to form water flakes and causes blue grass odour, was found in Iranamadu and Dry Aru reservoirs.

Note) Microcystis has been reported to produce microcystine, a toxic substance.

③ In addition, the following algae causing odour, cohesion failure, filtration blockage, leakage from the filter basin, etc. were found in Iranamadu reservoirs and Dry Aru reservoirs.

- ✓ *Cyclotella (diatoms): When floating, large multiplication causes coagulation failure and leakage from filters.*
- ✓ *Nitzschia (diatoms): When floating, it grows large, causing filtering blockages and leaks from filters.*

- ✓ *Synedra (diatoms): When floating objects grow large, they produce odours (earth odours), causing coagulation sedimentation failure and filtration blockage.*
- ✓ *Ankistrodesmus (green algae): When grown large, it causes leakage from the filter basin.*
- ✓ *Scenedesmus (green algae): Large multiplication causes blue grass odour and colouring trouble.*
- ✓ *Staurastrum (green algae): When grown large, it forms a bloom of green water and emits a blue grass odour. Filtration blockage may also occur.*

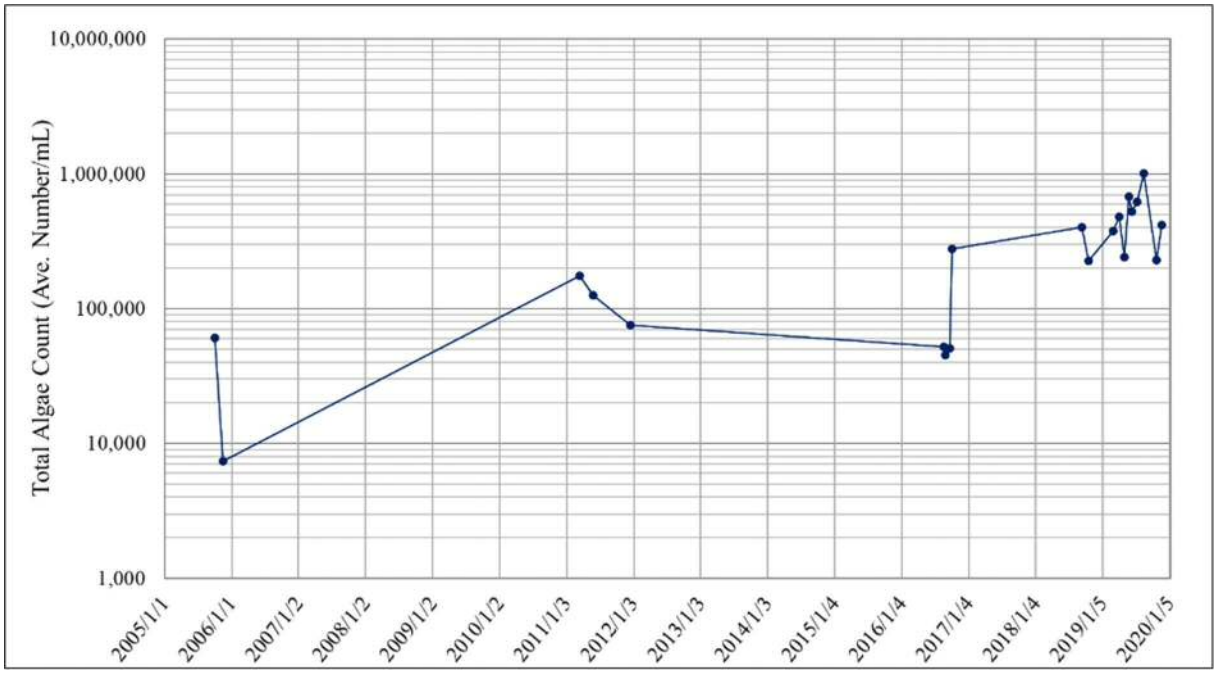
④ The algal populations were more in Iranamadu reservoir than in Dry Aru reservoir, particularly in the central surface layer.

Note) Algae identification analyses and water sampling conducted in this FU Study were in accordance with Standard Methods for the Examination of Water and Wastewater (newest edition), and plankton nets (nominal opening: 55 µm) were used for water sampling. Therefore, minute algae have not been captured or identified. On the other hand, NWSDB is sampling water without using plankton nets, and the number of algae is increasing. However, when the identified algae are compared, there are many common belongings, and the analytical results of this FU Study are considered to be reasonable.

The results of the algae identification analyses of Dry Aru reservoirs from 2005 to 2019, which were obtained from NWSDB, revealed the following points.

① Algal populations in Dry Aru reservoirs are on the rise (see **Figure 3-2**).

② Based on 2019 data, the dominant species of algae found in Dry Aru reservoirs is Anacystis species of blue-green algae.



Note) Data are available from NWSDB.

Figure 3-2 Changes in the Number of Algae in Dry Aru Reservoir (2005-2010)

From the above, it is inferred that eutrophication and accompanying algae multiplication are progressing in Iranamadu reservoirs, affecting the water quality of Dry Aru reservoirs during the dry season. Furthermore, since algae population in Dry Aru have been increasing and algae which adversely affect the water treatment have been detected, the water quality of Dry Aru reservoir in the dry season is considered as deteriorated.

3-2 Operation Status of KWTP

3-2-1 Operation Status of Water Treatment Plants in Dry Season (before continuous operation)

The following **Table 3-1** shows the operation status of roughing filter (hereinafter "RF") and slow sand filter (hereinafter "SSF") in KWTP survey from September 7 to 12 before the start of the continuous trial operation. The operation schedule of intake pump has not changed since the survey in February 2019, and intermittent operation in which 1 to 2 hours of operation per day and 4 to 5 hours of stoppage are repeated every 6 hours (see the **Figure 3-3** below).

SSF treated water is discharged without sending to the clear water reservoir, since colour and odour exceed the Sri Lanka Standard 614. For this very reason, SSF treated water from packaging plant in KWTP (treated water volume: 500m^3/day), tube well water in KWTP and near the intake facilities are supplied in line with water demand.

Table 3-1 Operation Status of KWTP in August 30 to September 12

Item	Operation status	Remarks
Capacity (RF+SSF)	161 to 1,110m^3/day, Mean: 701m^3/day	Refer to the figure below for the operation status of the water intake pump.
Amount of Water Withdrawal (Package Plant)	Unknown	
Water Supply	185 to 474m^3/day, Average: 370m^3/day	SSF treated water is discharged due to deterioration of treated water quality, and package plant treated water and well water in the plant are sent.
RF Operating Conditions	Two-pond operation	Filtration rate: 1.4 to 10, Average: 6.3m/day (Design value: 36 m/day)
SSF Operation Status	Three-pond operation	Filtration rate: 0.2-1.0, Average: 0.7m/day (Designed values: 2.4 to 4.8m/day)
Raw Water Quality	Turbidity: 28 to 53 NTU, Average: 45 NTU	
Treated Water Quality	Turbidity: 1.0 to 12 NTU, Average: 3. 7 NTU	Sri Lanka Water Quality Standard 614: 2 NTU
	Colour: 20 to 92 unit, Average: 43 unit	Sri Lanka National Water Quality Standard 614: 15 unit
	Odour: Plant odour (Algae-Odour, Vegetable-Odour)	Sri Lanka Water Quality Standard 614: Unobjectionable

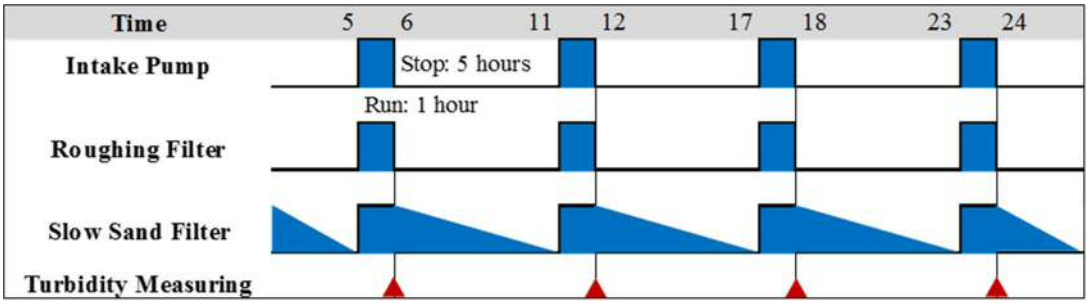


Figure 3-3 Operation Schedule of Each Facility and Equipment

On September 11, total manganese and total iron were measured in the treated water of No.2 and No.3 SSF using a simple water quality analysis kit, and total iron of 2.0mg/L or more was detected in both SSFs (see

Photo 3-3). From this, it is possible that the filter layer of SSF was anaerobic due to the intermittent operation described **Photo 3-3** No.1 and No.2 SSF Measurements of Total Iron in Treated Water (September 11, 2019)

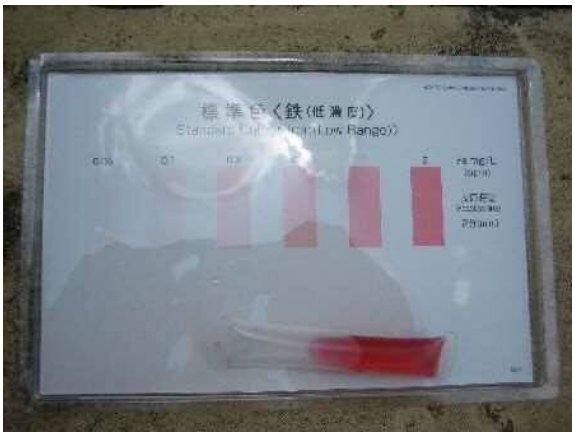
	
No. 2 SSF Treated Water	**No. 3 SSF Treated Water**

Photo 3-3 No.1 and No.2 SSF Measurements of Total Iron in Treated Water (September 11, 2019)

3-2-2 Status After Starting Continuous Operation

The following **Table 3-2** shows the operation status of the water treatment plant from September 13 to October 7, 2019, where the continuous operation of RF and SSF was carried out.

All two ponds were operated for RF, and only one out of three ponds were operated for SSF. However, since the turbidity and colour of the treated SSF water exceeded the water quality standard values in Sri Lanka, the treated SSF water was discharged back without being pumped. Therefore, the package plant and well water in the water treatment plant were sent to meet the demand.

Table 3-2 Operation status of KWTP in September 13 to October 7

Item		Operation status	Remarks
Capacity (RF+SSF)		1,128 to 2,120m^3/day, Average: 1,736m^3/day	
Amount of water withdrawal (Package Plant)		Unknown	
Water supply		259 to 512m^3/day, Average: 387m^3/day	Package plant treated water and well water in the plant are fed.
RF operating conditions		Two-pond operation	Filtration rate: 10-19, average: 15 m/day (Design value: 36 m/day)
SSF operation status		One-pond operation and two-pond suspension	Filtration rate: 3.1 to 5.9, Average: 4.8m/day (Designed values: 2.4 to 4.8m/day)
Raw Water Quality	Turbidity	22 to 43 NTU、Average: 33 NTU	
	Colour	229 unit or more	Upper limit of colour measurement: The value has exceeded 550 unit.
Treated Water Quality	Turbidity	9.9~15 NTU、Average: 12 NTU	Sri Lanka Water Quality Standards: 2 NTU
	Colour	13~212 unit、Average: 95 unit	Sri Lanka Water Quality Standard: 15 unit
	Odour	Though weak algal odour and blue grass odour were found at the beginning of the investigation, it was not felt after 9/26.	Sri Lanka Water Quality Standards: Unobjectionable

3-3 Status of O&M Manual Usage

The following **Table 3-3** shows the O&M documents prepared and submitted from July 2016, when soft components were implemented to March 2019.

Table 3-3 List of Data on O&M Manual

No.	Document Name	Date of Submission	Remarks (background, reasons etc.)
1	Text for soft components (Maintenance and management of distribution systems, connection of water supply pipes, maintenance and management of mechanical and electrical equipment, and monitoring and management of water quality)	February 2017	Distributed to NWSDB participants at implementation of the Soft-Component
2	Interim report	March 2018	Prepared temporarily because raw water in the Dry Aru became highly turbid due to drought in the Iranamadu reservoir and it became difficult to operate water treatment facilities.
3	O&M Manual (first edition)	May 2018	Prepared in October 2017 and formally submitted in response to comments from NWSDB officials.
4	O&M Manual (Revised)	March 2019	Revised based on the results of site survey in February 2019
5	O&M Manual (Final Version, Rev.2)	February 2020	Revised based on the results of Follow-up survey in February 2020

The first edition and the revised O&M manuals were kept on the bookshelf of the room of District Engineer (DE), and copies of the manuals were kept on the bookshelf of the control office in the water treatment plant, and they were inspected/referred as needed.

3-4 Results of Continuous Operation of SSF

3-4-1 Continuous Operation in No.1 SSF

(1) Purpose

Before starting the continuous operation of No.1 SSF, KWTP is operated intermittently in either No.2 SSF or No.3 SSF. It is inferred that the filtration rate is as small as 0.09m/day (designed values: 2.4 to 4 8m/day) when three SSFs are operated with the water intake amount of 1,000m^3/day. The retention time in SSF is long, so that algae contained in raw water grow particularly in the upper part of the filter layer, and that the activity of the biofilm is lowered due to the lack of the dissolved oxygen concentration and the shortage of the solar radiation amount.

Therefore, it is verified whether the odour and colour of the SSF treated water, which are particularly problematic, can be improved by continuously operation of the No.1 SSF at a filtration rate of 4.9m/day with the installation of shading net. This would enable that that the retention time is reduced, and the decrease of the dissolved oxygen concentration is avoided.

(2) Test Conditions

① Target Tank: No.1 SSF (Scratching surface sand carried out on July 29)

② Filtration Rate: 4.9m/day (0.2m/hr) *Designed value: 2.4 to 4.8m/day

③ Amount of Treated Water (Intake): 4.9m/day × 360m^2 = 1,764m^3/day (73.5m^3/hr)

**) Depending on the minimum value of the discharge volume of the intake pump*

④ Shading Net: Installed

⑤ Testing Period: September 13 to September 20, 2019

⑥ Measurement Item: Turbidity, colour, odour (sensory test), dissolved oxygen concentration, filtration rate, and filtration resistance

(3) Results and Considerations

The change in turbidity trend is shown in **Figure 3-4**. The raw water turbidity was 30 to 43 NTU and the treated water turbidity of RF was stable at 11-14 NTU. Treated water turbidity of No.1 SSF gradually decreased from the 4th day (September 17) after the beginning of the test and became below the Sri Lanka Standard: 2 NTU from the 6th day (September 19). On September 17, when the turbidity of the No. 1 SSF treated water started to decrease, this coincides with the timing when the filtration resistance started to increase and overflow, and it is considered that the turbidity of the treated water decreased due to the decrease in the filtration rate (0.08m/day at September 20).

Regarding odour, it was decreasing along with the decrease of treated water turbidity, and no odour was felt after September 18.

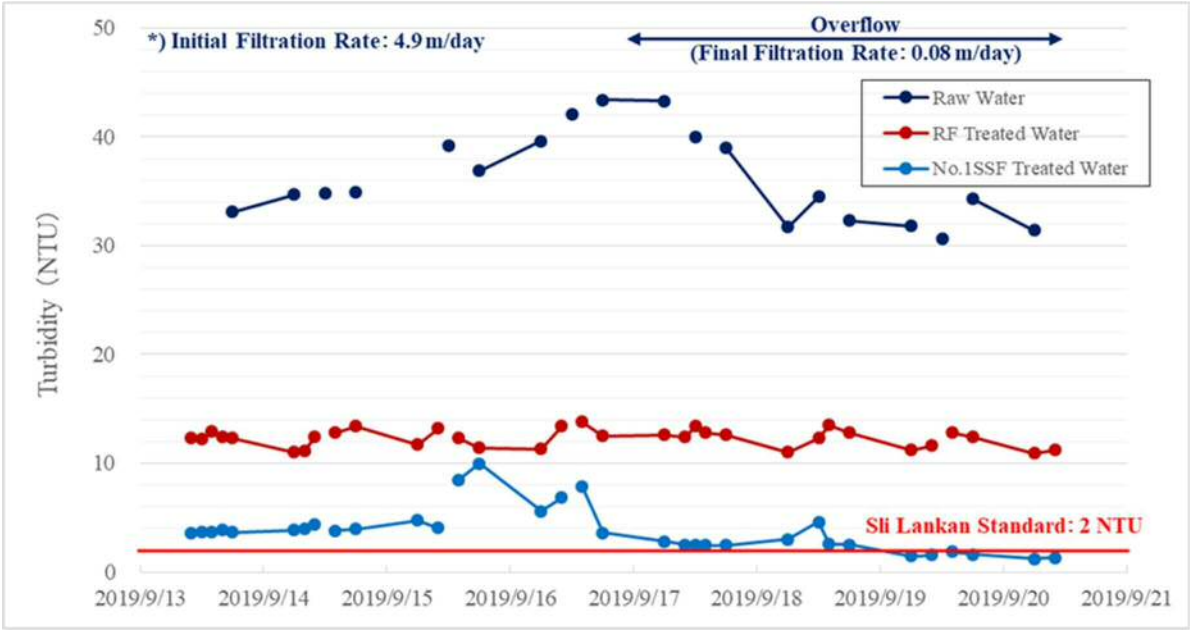


Figure 3-4 Result of Turbidity

Changes in colour trend are shown in **Figure 3-5**, and changes in dissolved oxygen (DO) and filtration resistance trend are shown in **Figure 3-6**. The colour was 50-60 unit even after the 6th day when turbidity began to satisfy the Sri Lankan standard. Although it was visually clear, it did not satisfy 15 unit of the standard water quality (see **Photo 3-4**). On September 20 of the last day of the testing, the colour of the treated water of the packaging plant was measured and showed 2 unit, and the distilled water showed 0 unit, so it is considered that there are no further problems with the colour meter used. The results of total iron and total manganese concentrations of the No. 1 SSF treated water, 0.15mg/L and 0.012mg/L respectively and

they are within the water quality standards, suggests that the remaining colour derives from the other substances except for iron and manganese.

For DO, the influent water of No. 1 SSF showed 5-8mg/L, and the treated water showed 0.2-0.5mg/L. WHO's documentation ("Slow Sand Filtration," WHO (1974)) states that DO levels in filtered water should be maintained at >3mg/L. According to this value, it suggests that the filter bed was in an anaerobic condition. The DO value in the treated water increased after September 17, but this is considered to be due to the fact that the water level in the treated water pit decreased and the treated water flowed out of the outlet valve with a drop and entrained air (see **Photo 3-4**).

Filtration resistance increased with time and overflowed after the 4th day. The surface of the No. 1 SSF filter layer could not be observed because the inside water level was too high. No biofilm was observed on the surfaces of the No. 2 and No. 3 SSF, and reddish-brown sticky substances, which seem to be ferrous oxides, were deposited (see **Photo 3-5**). It can be inferred that No. 1 SSF was in the same condition, and the main cause of the increase in the filtration resistance is the deposition of iron/ manganese oxides and the propagation of iron bacteria which derived from an anaerobic condition of surface sand layer along with the elution of iron/manganese due to the past intermittent operation. Therefore, there is a need for “continuous operation of SSF” is required to prevent from an anaerobic condition of surface sand layer.

The increase in filtration resistance is attributed to the accumulation of algae due to the deposition of iron and manganese eluted by anaerobic bio filtration, the growth of iron bacteria by dissolved iron, and the accumulation of algae due to raw water.

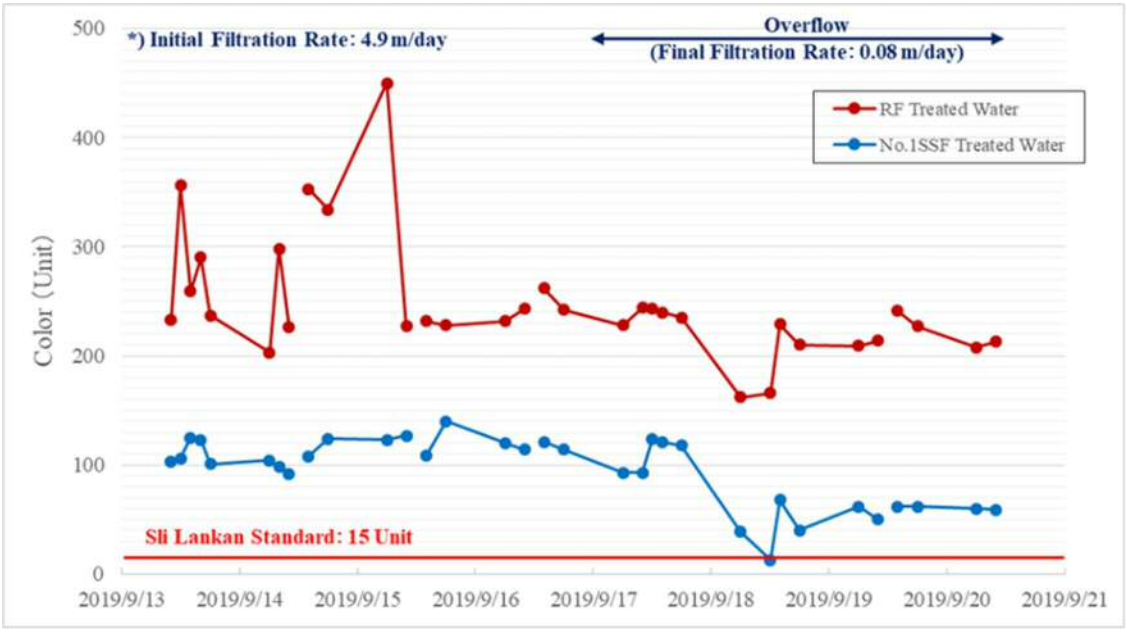


Figure 3-5 Result of Colour

Figure 3-6 Result of DO and Filtration Resistance

Table 3-4 Results of Iron and Manganese Measurements of Surface Filter Media at No. 2 SSF

Item	Density (mg/kg)
Total iron	512
Total manganese	42.4

No.1 SSF Treated Water on September 9

Status of Treater Water in the Pit

Photo 3-4 Continuous Operation in No. 1 SSF

	
Black material found on the surface of No. 2 SSF	**No. 3 SSF Filter Surfaces**

Photo 3-5 Detail Condition of No. 2 and No. 3 SSF

3-4-2 Continuous Operation in No.3 SSF

(1) Purpose

During the continuous operation of No.1 SSF performed in the first field survey, the shading nets were installed, and the filtration rate was 4.9m/day. The colour in the treated water did not satisfy the Sri Lankan water quality standard values, the filtration resistance rose with time, and the filtration rate decreased to 0.08m/day in one week after the test started. Judging from the DO values (0.2 to 0.5mg/L) in the treated water, it was suggested that the condition inside of the filter layer turned out to be anaerobic.

Therefore, it was verified that the increase in colour and filtration resistance could be reduced by removing the shading nets in the No. 3 SSF and continuously operating them to promote photosynthesis of microorganisms forming biofilms and maintaining the biofilms and filtration layers in aerobic condition.

(2) Testing Conditions

① Target Tank: No. 3 SSF (surface layer scraped prior to starting the test)

② Filtration Rate: 4.9m/day (designed values: 2.4 to 4.8m/day)

③ Amount of Treated water (Intake): 4.9m/day × 360m^2 = 1,764m^3/day (73.5m^3/hr)

** Based on the measured discharge rate of the water intake pump*

④ Shading net: None

⑤ Test period: September 23 to November 22, 2019

⑥ Measurement item: Turbidity, colour, odour (sensory test), dissolved oxygen concentration, filtration rate, filtration resistance

(3) Results and Considerations

Changes in turbidity, colour, DO, and filtration resistance are shown in **Figure 3-7** to **3-9**.

- Raw water turbidity showed 20 to 40 NTU until November 9 from the beginning of the test.
- On November 9 at 06:00 AM, after the outflow gate of the Dry Aru reservoir opened by the Department of Irrigation, there is a sudden increase in the turbidity to 48 NTU has been noticed.
- The raw water colour also rose rapidly to 549 unit with this, and both of them showed high values continuously until the test was finished on November 22.

- In addition to algae-derived turbidity and colour, it is inferred that the water flow generated by the opening of above-mentioned outflow gate caused the agitation of bottom sediments in the Dry Aru reservoir; hence the raw water turbidity and colour had increased significantly.

Few more observations from the field survey assessment:

- The treated water turbidity of RF increased with the increase of raw water turbidity since November 9, but the upper limit of SSF inlet turbidity level of below 30 NTU was maintained.
- The treated water turbidity of No. 3 SSF satisfied the Sri Lankan water quality standard value of 2 NTU for about 16 days from 18:00 on October 24 to 10:00 on November 10.
- Regarding the treated water colour, the water quality standard value of 15 unit was satisfied only for about 3 days from October 26 to 28 in which water conveyance was carried out.
- With regards to the odour in treated water, no odour was felt for 31 days, about half of the 59 days in the whole testing period.

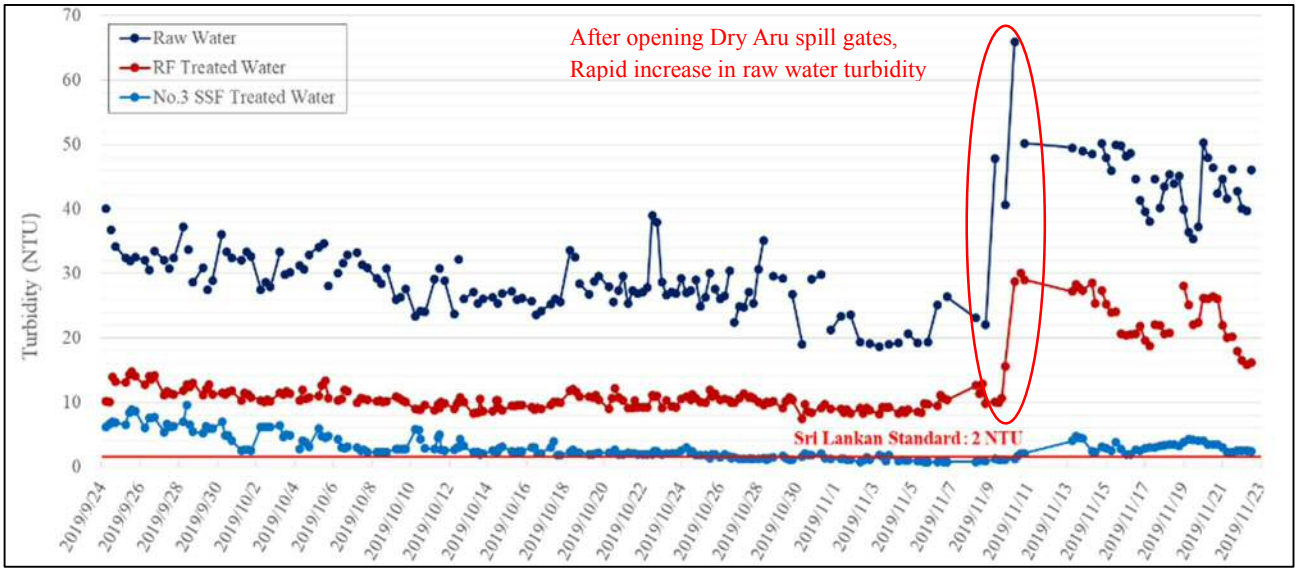


Figure 3-7 Result of Turbidity at No.3 SSF

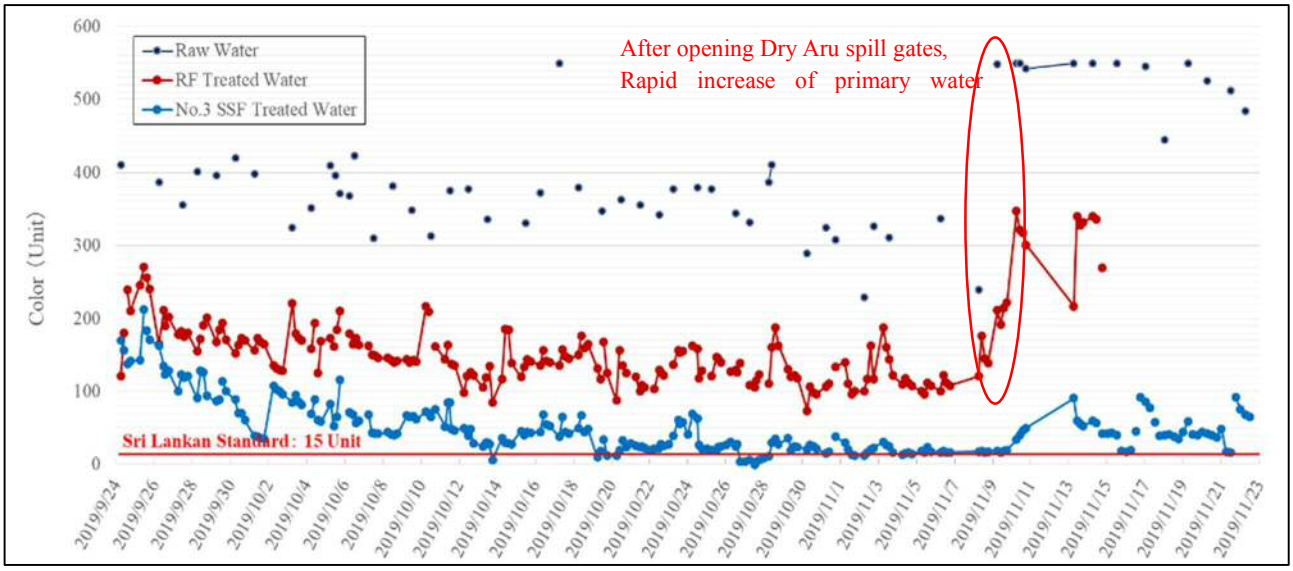


Figure 3-8 Result of Colour at No.3 SSF

Although the DO values in treated water fluctuated, they generally maintained the WHO recommended value of more than 3mg/L. There was an apparent decrease from October 26 to 28 in which the water was transmitted. During this period, since the treated water overflowed the effluent weir and flowed into the clear water reservoir, the water level in the effluent pit was sufficiently high above the spill weir. It is considered that there was no contamination of air observed previously when the same water level was low. Therefore, in order to accurately measure the DO value in the SSF treated water, it is necessary to keep the water level in the effluent pit above the effluent weir. The DO values could not be accurately measured during the period when the treated water was being drained.

On the other hand, the filtration resistance tended to increase gradually from the start of the test to October 26, although there was a fluctuation. The time of overflowing started from November 4 becomes longer, it became impossible to obtain a required amount of treated water even by fully opening the treated water valve, and the operation was stopped on November 21.

The following points were found by this test;

- It is difficult to maintain the water level in SSF at a constant level by appropriately adjusting the opening of the outflow valve during the period in which treated water of SSF is drained.
- An exposure of the filter layer surface or overflowing will occur due to the above reason.
- There is an influence on the measured value of DO in treated water during the period in which treated water of SSF is drained.
- Therefore, as described in the Improvement Plan (Measure-3) in this report, it is essential to modify the drain pipe of SSF so that water can be discharged from the downstream side of the weir in order to maintain the water level in SSF above the weir at all times.

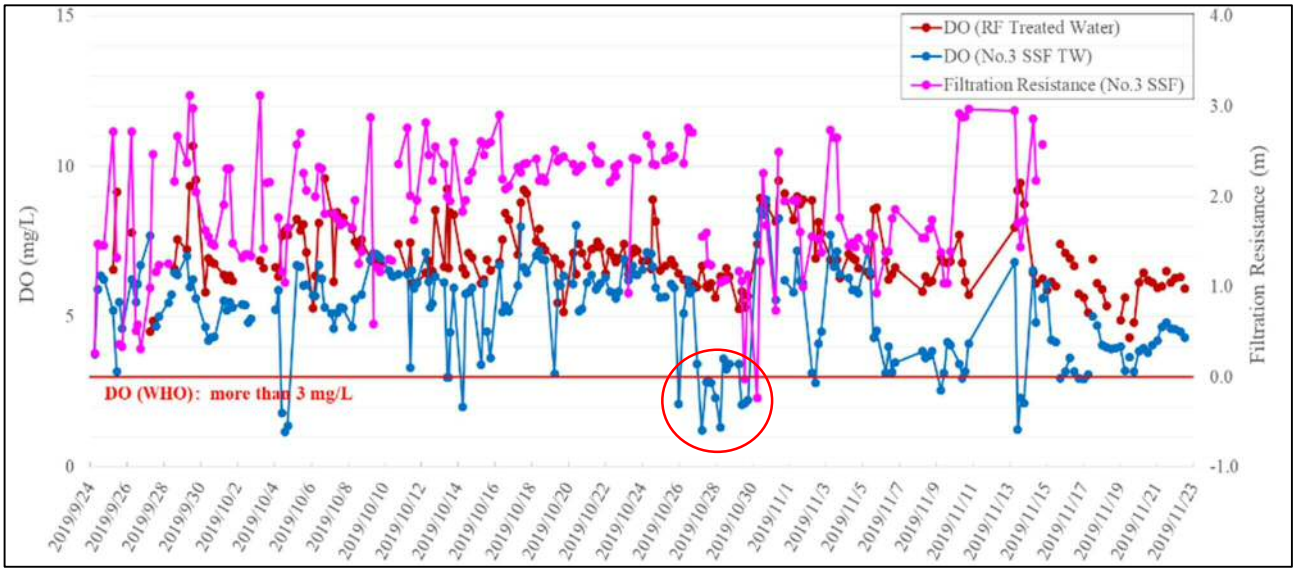


Figure 3-9 Result of DO and Filtration Resistance at No.3 SSF

Table 3-5 shows the turbidity and colour rejection rates of RF and No. 3 SSF in the dry season calculated from the above results.

Since the raw water turbidity and colour values rose rapidly from November 9, this period has been defined as the "rainy season conversion period". The turbidity and colour removal rates of RF and No.3 SSF in the

dry season from September 23 to November 8 were as shown in **Table 3-5**.

- The turbidity removal rate (mean value) of RF was 63%, the same colour removal rate was 61%
- The turbidity removal rate (mean) of No. 3 SSF was 81%, and the same colour removal rate was 78%.

As shown in **Photo 3-6**, biofilm (mainly filamentous algae) were formed on almost the entire surface of the filter layer, and the DO values of treated water were also kept at about 3mg/L or more. Therefore, it is considered that the No. 3 SSF was operating in sound condition during this consecutive test period. However, it is inferred that the existing RF+SSF cannot sufficiently treat the current raw water quality including the multiplied algae, and that the filtration duration is also limited to about two months.

Table 3-5 Turbidity and Colour Removal Rates for RF and No. 3 SSF in the Dry Season

Item	RF Removal Rate (%)			SSF Removal Rate (%)		
	Average	Maximum	Minimum	Average	Maximum	Minimum
Turbidity	63	75	46	81	94	46
Colour	61	75	32	78	97	48

No.3 Continuous Operation Status of No.3 SSF

No.3 Condition of Biofilm in No.3 SSF

Photo 3-6 Continuous Operation in No. 3 SSF

3-4-3 Investigation Related to the Increase in Filtration Resistance in a Short Period of Time Caused by Continuous Operation of No. 1 SSF

(1) Control of Algae and Turbidity in the Inflow Water of SSF

1) Purpose

Chlorophyll a in raw water and RF treated water was measured and compared in order to confirm whether live algae flowed out without being treated, or if decomposed and lost activity flowed out to some extent in the crude filter basin.

2) Results and Considerations

The results are shown in the following table. While chlorophyll a in raw water was 18 μg/L, it was reduced to 6.2 μg/L in RF treated water, and the reduction rate was about 66%. As shown in **Table 3-5** above, the turbidity removal rate of RF at this point is about 63%, which is equivalent to the above reduction rate.

Therefore, the decrease in chlorophyll a is due to the decrease in algae number due to particle removal in RF. Therefore, no change was observed such that algae were decomposed and lost their activity in the filtration layer. The **Table 3-6** shows the Chlorophyll A concentration in raw water and RF treated water.

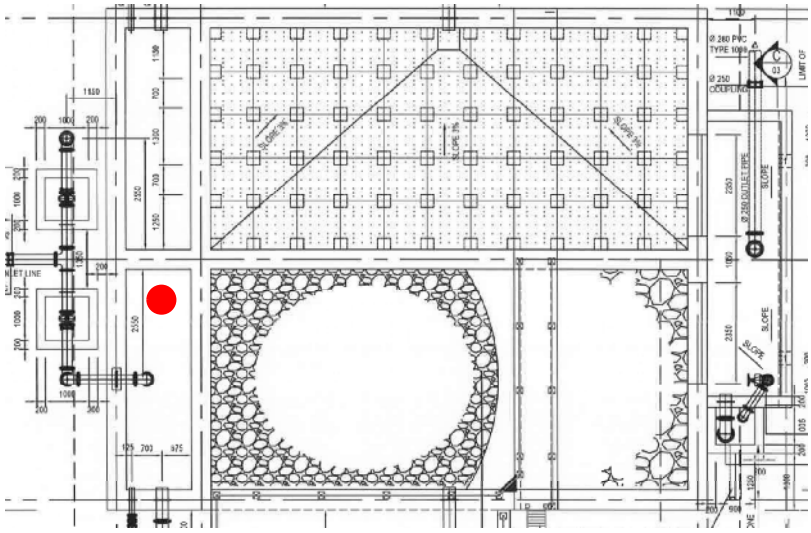


Figure 3-10 Water Sampling Points in RF

Table 3-6 Chlorophyll a Concentration in Raw Water and RF Treated Water

Water sampling point (September 27, 2019)	Chlorophyll a Concentration (µg/L)
Raw Water	18
RF Treated Water	6.2

(2) Regulation of Algal Growth in SSF

1) Purpose

Continuous testing in No.3 SSF is conducted with the shading nets removed, and the algae growth due to photosynthesis in the SSFs may occur particularly in areas prone to stagnation. For this reason, chlorophyll a was measured by sampling water from four corners in the SSF, and it was confirmed whether algal growth occurred in the SSF compared with the equivalent value in the RF treated water.

2) Results and Considerations

The results are shown in the following **Table 3-7**. Four corners in the No. 3 SSF, as opposed to the chlorophyll a of the RF-treated water being 6.2µg/L.

It showed 2.4 to 15µg/L (average value: 8.0µg/L), and no remarkable algal growth in the SSF was observed even when the shading net was removed. However, although this result was obtained at a filtration rate of 4. 9m/day and only a small portion of the algae were growing. It is highly likely that the algae would grow in a wider area at a lower filtration rate of 0.2 to 1.0m/day prior to the initiation of this FU Study.

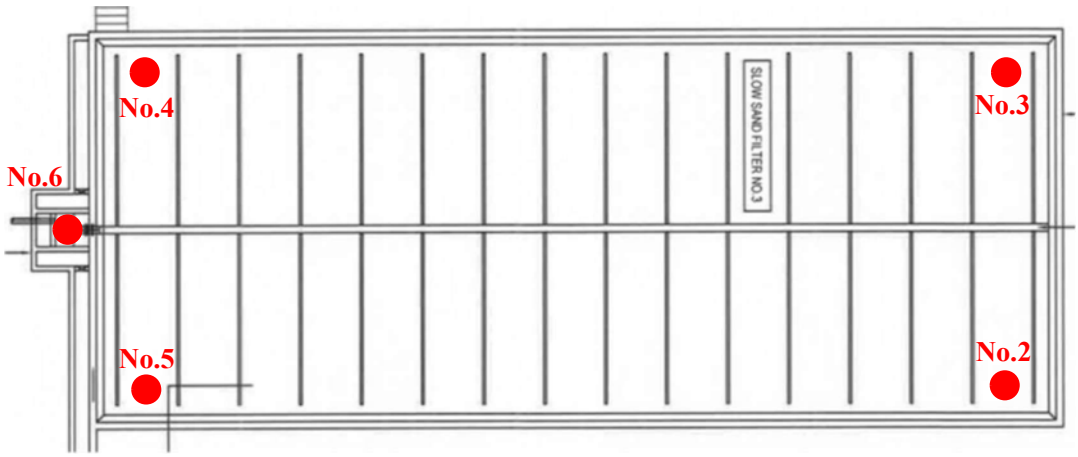


Figure 3-11 Water Sampling Point in No. 3 SSF

Table 3-7 Chlorophyll a Concentration in RF and No. 3 SSF

Water sampling point (September 27, 2019)	Chlorophyll a Concentration (µg/L)
RF Treated water	6.2
No. 2 (unfiltered water in the pond)	5.1
No.3 (unfiltered water in the pond)	9.4
No.4 (unfiltered water in the pond)	2.4
No.5 (unfiltered water in the pond)	15
No.6 (Filtered water)	0.38

Sampling status of unfiltered water in the pond (No.4)

Water sampling status of filtered water (No.6)

Photo 3-7 Water Sampling in No. 3 SSF

3-4-4 No. Filtration Test and Chlorine Addition Test of 3 SSF Treated Water

(1) Filtration test

1) Purpose

To confirm whether turbidity and colour components in No. 3 SSF treated water are soluble or suspended, turbidity and colour were measured after suction-filtration with a 1µm glass-fiber filter paper.

2) Result and Considerations

① First Test Results (September 26, 2019)

The results are shown in the following **Table 3-8**. The treated water after suction filtration with 1μm glass fiber filter paper was greatly reduced in both turbidity and colour, and the removal rates were 77% and 82%, respectively. The filter paper after filtration showed green colour, and turbidity and colour components in No. 3 SSF treated water were not soluble substances, but mainly algae in raw water leaked out.

② Results of the Second Study (October 4, 2019)

The results are shown in the following **Table 3-8**. The treated water after suction filtration with 1 μm glass fiber filter paper was greatly reduced in both turbidity and colour, and the removal rates were 76% and 74%, respectively. The filter paper after the filtration treatment showed green colour, and turbidity and colour components in No. 3 SSF treated water were not soluble substances as in the last time, but mainly algae in the raw water was found to have leaked out.

Further, it was carried out on the 11th day after starting the continuous operation test of No. 3 SSF, and since the biofilm was formed to some extent, the turbidity and colour before filtration were lower than the previous ones, but the removal rate was comparable to the previous one. In order to identify remaining turbidity and colour components, the total iron and total manganese in No. 3 treated water (before suction filtration) were measured to be 0.28mg/L (Sri Lanka water quality standard: 0.3mg/L) and 0.115mg/L (equivalent: 0.1mg/L), respectively. Therefore, it was found that the components of turbidity and colour include not only algae leaked from the SSF but also colloidal iron and manganese with a particle size of less than 1μm. In **Figure 3-9** above, it is inferred that iron and manganese oxidized and immobilized by biofilms were dissolved temporarily because the DO values decreased to about 1 mg/L due to some factor on October 4.

From the above results it was found that the turbidity and colour of the treated water from existing SSF in dry season were mainly due to algal cells derived from raw water that leaked without being trapped or removed by the biofilm. It was also suggested that iron and manganese oxidized and immobilized by biofilm could be dissolved temporarily and leaked into SSF process water when the DO value in treated water decreased.

Table 3-8 Filtration Test Results for No. 3 SSF Treated Water

Item	1st test result			2nd test result		
	Before Filtration	After Filtration	Removal Rate (%)	Before Filtration	After Filtration	Removal Rate (%)
Turbidity (NTU)	7.52	1.72	77	4.57	1.11	76
Colour (unit, Pt-Co)	125	22	82	80	21	74

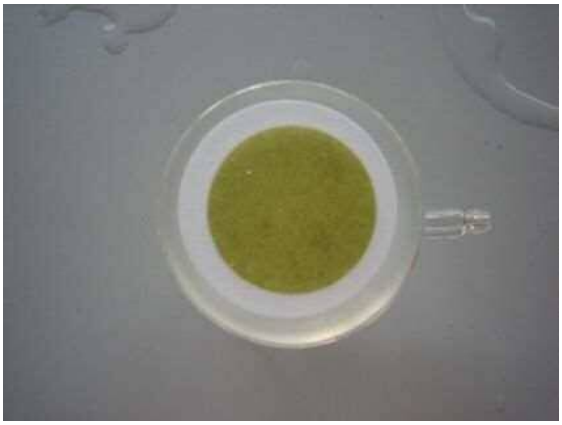
	
Test Status	**Appearance of Filter Paper after Filtration**

Photo 3-8 Filtration Test of No.3 SSF Treated Water

(2) Chlorine Addition Test

1) Purpose

In order to confirm whether turbidity and colour components in No.3 SSF treated water are oxidized and decomposed by chlorine treatment and reduced, turbidity and colour were measured after adding 1mg/L (effective chlorine concentration), which is a normal chlorine injection rate, and reacting for 30 minutes.

2) Results and Considerations

① First Test Results (September 26, 2019)

The results are shown in the following table. Turbidity and colour of No. 3 SSF treated water were hardly reduced by reacting with 1mg/L of chlorine. This result suggests that the turbidity and colour components of the treated water leaked out, and that the cell membrane/wall was not oxidized and decomposed with 1mg/L of chlorine.

② Results of the Second Study (October 4, 2019)

The results are shown in the following **Table 3-9**. When an effective chlorine concentration of 1mg/L was added to the No. 3 SSF treated water, the turbidity was almost equal but the colour is decreased by 5 units. And, the turbidity was almost equivalent, when the effective chlorine concentration of 3mg/L was added, but the colour rose 13 unit. From the results, it is considered that the turbidity and colour components in the treated water are the leaked algae and colloidal iron and manganese with particle size of 1μm or less. It is believed that the increase in colour due to the addition of chlorine was caused by the oxidation of iron and manganese with partial solubility (reduced state) by chlorine, resulting in development of colour.

From the above results, it was found that the turbidity of SSF treated water (mainly algal cells derived from raw water that leaked without being captured and removed by biofilm) was not reduced by post-chlorine treatment. And it was suggested that iron and manganese which were oxidized and immobilized by biofilm were temporarily eluted, however when DO value in process water was lowered, and then it was oxidized by post-chlorine treatment to develop colour.

Table 3-9 Chlorination Test Results of No.3 SSF Treated Water

Item	1st test result		2nd test result		
	Before addition	Chlorine addition 1 mg/L	Before addition	Chlorine addition 1 mg/L	Chlorine addition 3 mg/L
Turbidity (NTU)	8.98	7.83	4.57	4.30	4.68
Colour (Unit, Pt-Co)	136	131	80	85	93

Calcium Hypochlorite used	Test Status

Photo 3-9 Chlorination Test for No.3 SSF Treated Water

3-5 Analysis of Existing Filter Media

3-5-1 Roughing Filters

(1) Sampling of Filter Media and Confirmation of Filter Layer Conditions

On September 24, the filter layer condition checked, and filter material sampling were carried out for the RF (1 out of 2 basins) on the west side. When cleaning was carried out by opening the drain valve before starting work, the washout wastewater was yellow soil, and the turbidity was considerably high apparently. As black-green sticky algae were found on almost the entire surface of the filter layer, this was removed manually before the filter material was collected, and raw water was poured from the lower part and washed away. When we interviewed the Operator, they said that they had been removing algae and cleaning the walls in the same manner every two months (One out of two ponds was carried out once a month). No irregularities such as non-land was observed on the surface of the filter layer.

The mud-like turbidity adhering around the filter media was observed about 10 mm below the surface of the first layer (ϕ 4 to 8 mm). Since the layer thickness of the first layer is 1,000 mm, the filter material near the middle (about 500 mm from the top) was taken. Subsequently, it reached the second layer (ϕ 8 to 12 mm) and the filter material near the middle was taken in the same manner. The contamination situation of the filter material was the same for the second layer. As described above, adhesive algae were observed on the surface of the filter layer, and mud-like turbidity was observed in the first and second layers. Therefore, it is believed that that the biofilm was formed in the RF interior, resulting in upward-flow bio filtration.

Since the filter material on the wall of the dug hole collapsed and fell to the foot of the worker from the time when the second layer was started to be dug, further work was judged to be dangerous, and the sampling of the third and subsequent layers were stopped.

(2) Results of Filter Material Analysis

The results are shown in the following **Table 3-10**. The results are compared with ANSI/AWWA B 100 and JWWA A103 which are standards on new filtered sand as a reference. Acid solubility of the first and second layers (indices of inorganic substances such as metals adhered to the filter media) exceeded slightly the standard values compared to both standards, but the same cleaning turbidity (indices of turbidity adhering to the filter media) was below JWWA A103 standard values and no significant contamination was observed.

Table 3-10 Results of Filter Media Analysis in RF

Location	Point of Sampling	Acid Solubility (%)	Turbidity of Washing Wastewater (NTU)	Ignition Loss (%)
Roughing Filter (West Side)	1st layer	5.3	13	-
	2nd layer	5.8	5	-
(Reference) ANSI/AWWA B100*1)		< 5	—	—
(Reference) JWWA A103*1)		< 3.5	< 30	< 0.75

**1) These standards are applicable for new filter media.*

Surface of RF (west side)

Filter Sampling in First Layer

Contaminated First Layer of Filter Material

Sampling of Filter Material in Second Layer

Photo 3-10 Investigation in RF (West)

3-5-2 No. 2 and No. 3 SSF

(1) Sampling of Filter Media and Confirmation of Filter Layer Conditions

1) No.2 SSF

On September 25, the filter layer condition of No. 2 SSF was checked and the filter material was collected. On the surface of the filter layer, no red-brown deposit, which was considered to be an oxide of iron was observed in No.3, and a green biofilm (probably) was observed on the whole. And, small snails, dragonfly nymph, etc. which seemed to be pond snail were recognized. The fact that more than a week was required for drainage the pond and the surface layer was considerably blocked, this suggests the formation of biofilms. Some dents were found in the filter layer near the inflow pipe, but no land irregularities were found at other locations. Around 10 mm below the surface layer. Black layer was recognized which seems to be an oxide of iron or manganese in the same manner as No.3. No visible contamination was observed on the middle, lower and supported gravel surfaces of the filter layer.

Surface Layer of No. 2 SSF (whole)

No. 2 SSF Surface Layer (biofilm)

Black Material near Surface Layer of No. 2 SSF

No. 2 SSF Bearing Gravel Bed

Photo 3-11 Filter Media Condition of No.2 SSF

2) No.3 SSF

On September 19, the filter layer condition of No.3 SSF was checked and filter material was collected. Though some green algae were recognized on the surface of the filter layer, no biofilm was recognized, and small snails, dragonfly nymphs, tadpoles, etc. which seemed to be pond snail were recognized. Some dents were found in the filter layer near the inflow pipe, but no land irregularities were found at other locations. In

addition, red-brown sticky substances, which seemed to be oxides of iron, had been deposited on the surface. No visible contamination was observed on the middle, lower and supported gravel surfaces of the filter layer.

Surface Layer of No. 3 SSF (whole)

No. 3 SSF Surface Layer (partial biofilm)

No. 3 SSF Inflow (with recess)

No. 3 SSF Bearing Gravel Bed

Photo 3-12 Filter Media Condition of No.3 SSF

(2) Results of Filter Material Analysis

The results are shown in the following **Table 3-11**. The results are compared with ANSI/AWWA B 100 and JWWA A103 which are standards on new filtered sand as a reference. As an entire tendency, contamination of the filter material progressed in No. 3 SSF compared with No.2 SSF. The acid solubility and cleaning turbidity of both ponds exceeded the above-mentioned standard values. In particular, the following effects were observed in the No.3 SSF. On the other hand, the loss on ignition (the index of organic matter adhering to the filter material) almost satisfied the standard value.

- Since the acid solubility in the lower layer of sampling point A is high, anaerobic condition of biofilm by intermittent operation occurred more widely. Moreover, eluted iron and manganese reached the lower layer, and they were oxidized by touching treated water containing dissolved oxygen again and precipitated as oxides.
- Since the turbidity of washing wastewater in the middle layer at the sampling point A is high, turbid matter penetrated into the inside of the filtration layer before the biofilm filtration matured.

Regarding the No. 3 SSF in particular, attention should be paid to the quality of the treated water in the future, and when the quality of the treated water deteriorates compared with other SSFs, measures such as

replenishing washed filtered sand (or new filtered sand) are required.

Table 3-11 Results of Filter Media Analyses in No.2 and No.3 SSF

Location	Point of Sampling		Acid Solubility (%)	Turbidity of Washing Wastewater (NTU)	Ignition Loss (%)
Slow Sand Filter No 2	A	Surface*1)	5.3	39	0.28
	A	Medium*2)	4.9	54	0.26
	A	Lower*3)	7.9	57	0.22
	B	Surface*1)	6.0	44	0.26
	B	Medium*2)	4.8	39	0.27
	B	Lower*3)	7.6	43	0.73
Slow Sand Filter No 3	A	Surface*1)	6.6	50	0.38
	A	Medium*2)	7.3	379	0.22
	A	Lower*3)	10.4	46	0.26
	B	Surface*1)	6.9	171	0.91
	B	Medium*2)	7.6	40	0.72
	B	Lower*3)	7.1	77	0.77
(Reference) ANSI/AWWA B100*4)			< 5	—	—
(Reference) JWWA A103*4)			< 3.5	< 30	< 0.75

**1) Collected at approx. 200 mm below the surface of the filter layer*
**2) Collected at approx. 500 mm below the surface of the filter layer*
**3) Collected at approx. 900 mm below the surface of the filter layer*
**4) These standards are applicable for new filter media.*

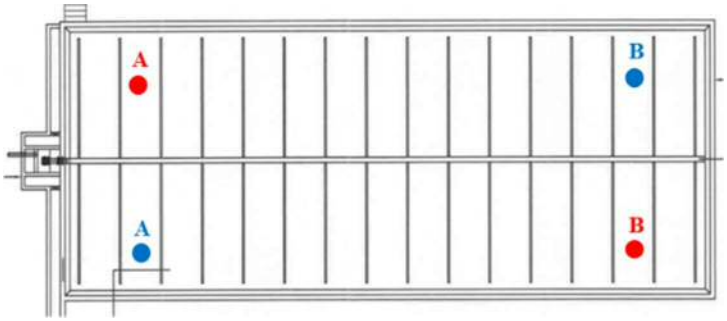


Figure 3-12 Sampling Locations at No.2 and No.3 SSF

3-6 Organization of NWSDB Kilinochchi

The Kilinochchi District Engineer's Office (hereinafter referred to as the Office), which is under the jurisdiction of the Northern NWSDB Regional Support Centre is responsible for carrying out the O&M of Kilinochchi WTP. NWSDB Regional Manager's Office functions under Regional Support Centre (North) is responsible for carrying out O&M of Kilinochchi WTP. **Figure 3-13** shows the organizational structure of the Office. This Office is composed of the head office and three branch offices. There are as few as three (3) staff members to which this Office belongs, including District Engineer (hereinafter referred to as DE), and the other 36 staff members who are assigned as O&M staff of water facilities.

12 employees under the Officer-in-Charge (OIC) are responsible for O&M of the Kilinochchi water supply system, and 10 under the Officer-in-Charge (OIC)OIC are responsible for O&M of the Kilinochchi WTP. The former is based in the main office, and the latter is based at WTP.

WTP is operated in a three (3)-shift system with Technician 1 and Operator 2. Regarding water quality control, water quality analysis specialist comes from Jaffna every month to check water quality. And the WTP operators measure turbidity and colour of raw water and treated water of each facility at an interval of four (4) times a day.

Labor, Sanitary Labor and other facilities are also located in the water purification plant, but substantially only the above-mentioned Technician 1 and Operator 2 names are used for operation control, and there are considerably few O&M personnel at the present plant as well.

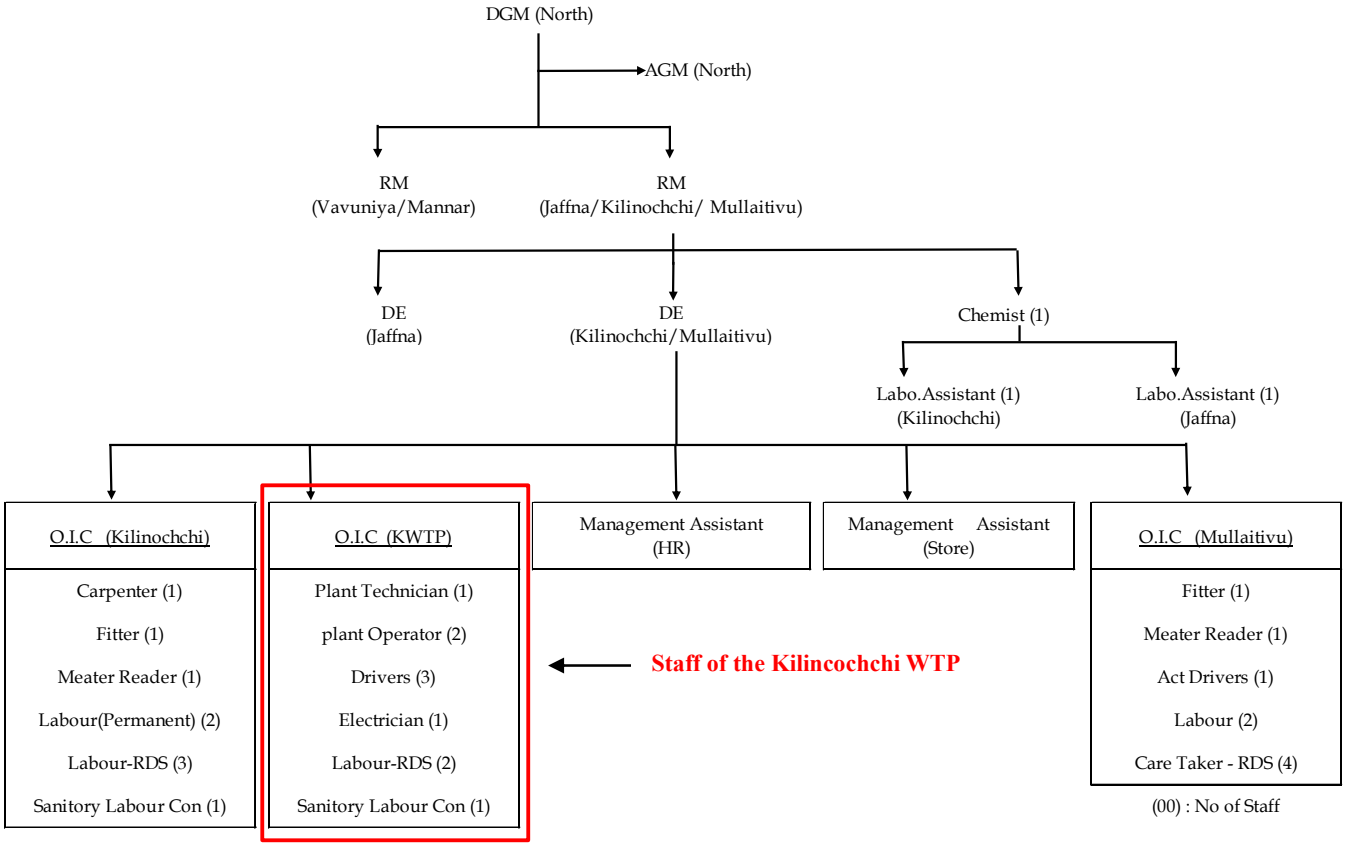


Figure 3-13 Organizational Chart of Kilinochchi Water Supply in NWSDB

4. Survey Results (Rainy Season: Second Field Survey)

4-1 Status of Dry Aru and Iranamadu Reservoirs

Turbidity of the Iranamadu reservoir in the rainy season of 2019 showed a declining tendency as rainfall increased and dam water level rose. The decreased turbidity of 10 NTU is recorded on November 15.

However, the turbidity rose up to 30 to 40 NTU due to the subsequent rainfall, and it was stable as it was.

The Dry Aru reservoir was also witnessed the algae and turbidity presence at a recorded value of 39 to 48 NTU until November 25, when there was a heavy rainfall of 50mm/hr. However, after the heavy rainfall of November 25, algae were washed away and the water surface became highly turbid with water coloured from green to yellow soil, and a significant turbidity increase to 280 NTU at some point.

Photo 4-1 and **4-2** shows the status of Iranamadu and Dry Aru reservoirs in the rainy season and the **Appendix-1** shows the results of the same quality analyses.

In addition, **Figure 4-1** shows the changes in raw water turbidity in Dry Aru reservoirs obtained to date, including the cooperative preparatory survey that was conducted by the team in 2011. Comparison of the peak value of raw water turbidity during the rainy season reveals that the peak value in 2005 was 191 NTU and turbidity is more than 250 NTU after 2017, and it can be said that the raw water quality during the rainy season (especially the turbidity) is also abnormal. Furthermore, it is inferred that the water quality of the reservoir tends to deteriorate.

Photo 4-1 Current status of Iranamadu reservoirs (Rainy Season)

Photo 4-2 Current status of Dry Aru reservoirs (Rainy Season)

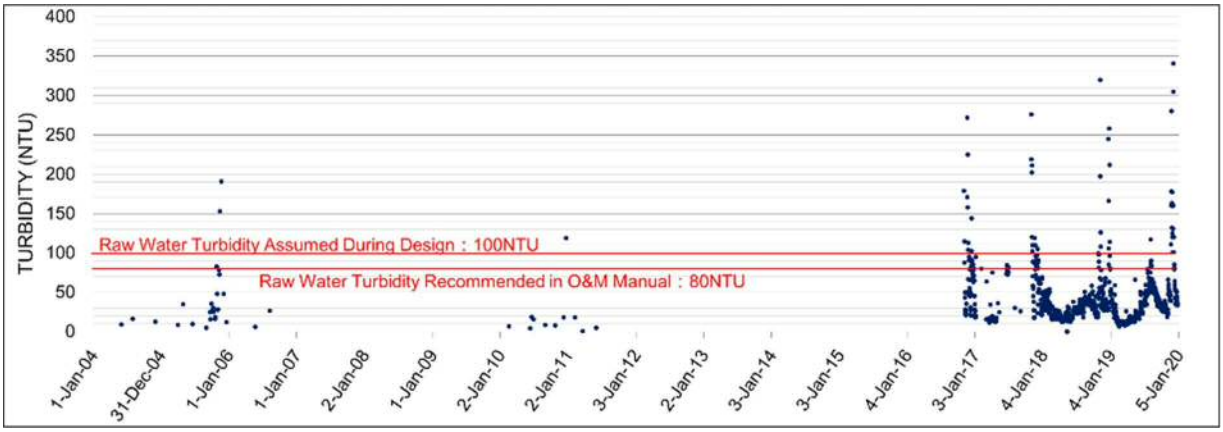


Figure 4-1 Trend of Raw Water Turbidity in Dry Aru Reservoir (2004 to 2019)

4-2 Factors of High Turbidity in Dry Aru Reservoir

In the rainy season, the outflow gates of Iranamadu reservoirs into the irrigation channels are basically closed, therefore, there is no inflow of water from Iranamadu reservoirs into Dry Aru reservoirs. In the rainy season, the inflow into Dry Aru reservoir consists of only irrigation channels and Kanagambikai reservoirs, as shown in **Figure 4-2**. Except in the rainy season, Iranamadu reservoir runoff gates are opened to send water to Dry Aru reservoir.

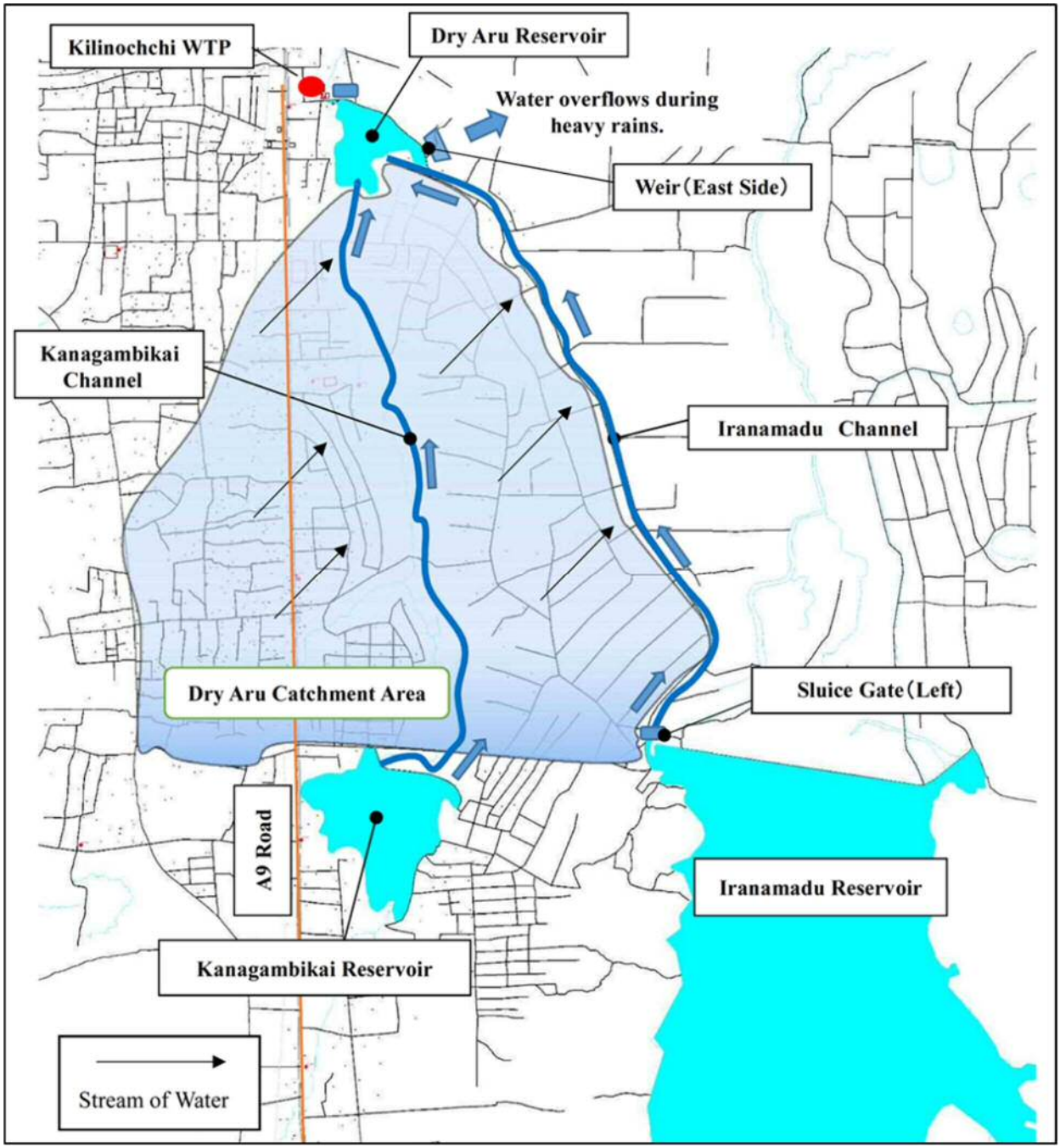


Figure 4-2 Dry Aru Reservoir Catchment Area

As a result of this study, the followings are considered as the root causes of high turbidity of the Dry Aru reservoir in rainy season.

- The left bank side outflow gate of the Iranamadu reservoir (the gate to the irrigation canal that carries water to the Dry Aru reservoir) remains closed during the rainy season. When the rainy season begins, the Iranamadu reservoir closes the gates and stores irrigation water until the water depth reaches 36 ft.
- Therefore, there is no water inflow from the Iranamadu reservoir to the Dry Aru reservoir in the rainy season.
- Water that flows into the Dry Aru reservoir in the rainy season is mainly the inflow water from the irrigation channel of the Dry Aru catchment area and the Kanagambikai reservoir effluent water only.

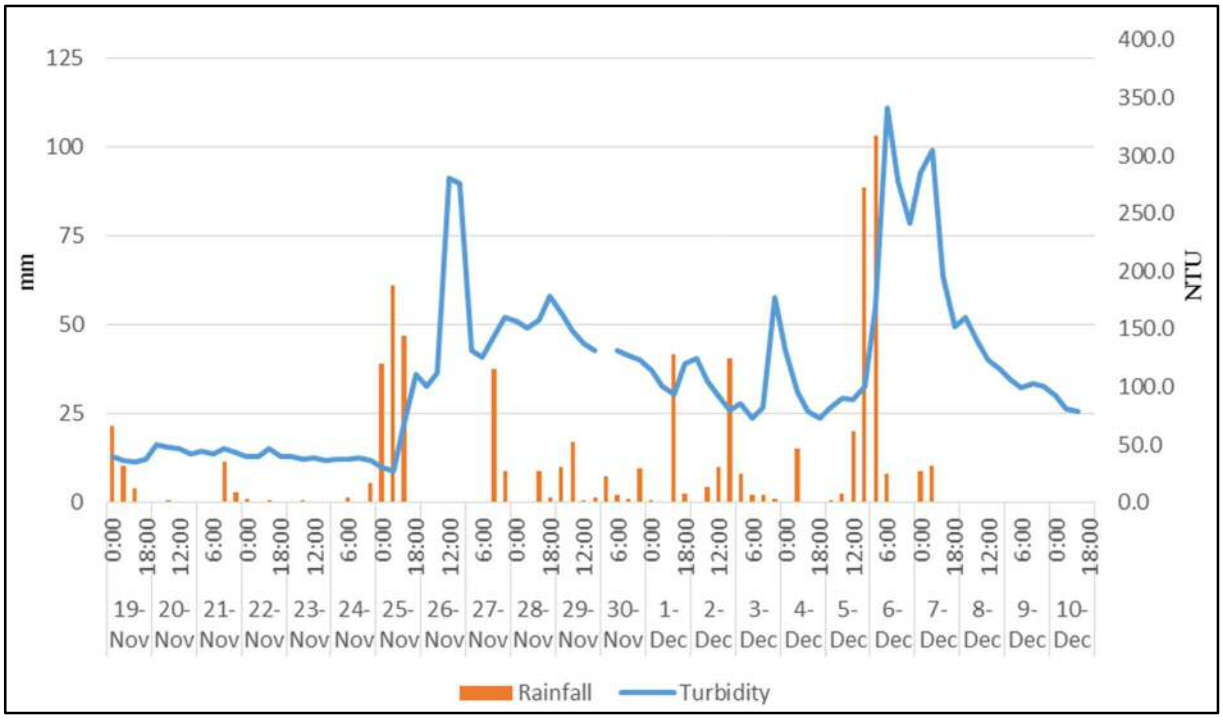
- The Dry Aru reservoir outflow gate also remain closed during the rainy season. Most of the inflow water mentioned above overflows from the weir at the eastern end of the Dry Aru reservoir.
- Therefore, the causes of the high turbidity of the Dry Aru reservoir are not from the Iranamadu reservoir but from the inflow water from the irrigation channel of the Dry Aru catchment area and from the outflow water from the Kanagambikai reservoir. After the heavy rainfall into the Dry Aru catchment, turbidity in runoff which increases with flow rate, flows through irrigation canals and ends up at Dry Aru reservoir.

4-3 Relationship between Rainfall and Turbidity

In order to assess and understand the relationship between rainfall and turbidity, the data recorded at every 6 hours interval has been extracted from the installed rain gauges and turbidity monitors. The recorded data is then plotted in graphical manner to better describe the relationship as shown in **Figure 4-3**. When the amount of rainfall exceeds a certain threshold, turbidity shows an upward trend following later, and when the amount of rainfall decreases, turbidity also decreases.

The turbidity of the Dry Aru reservoir showed the following trend:

- Right after a 60mm/hr heavy rain event on November 25, a turbidity level of 111 NTU was recorded and next day the same had been increased up to 280 NTU. Since then, the turbidity levels decreased to 65 NTU until December 4.
- After a heavy rainfall event of 100mm/hr more on December 6, a turbidity level of 341 NTU was recorded.
- Subsequently, no rainfall occurred December 8 to 12, hence the turbidity levels decreased to 55.8 NTU on December12 due to the sedimentation effects of the Dry Aru reservoir.



※ *Measuring site: Rainfall amount is rain gauge data installed in NWSDB Kilinochchi office, and turbidity is raw water data of KWTP.*

Figure 4-3 Rainfall and Turbidity of Dry Aru Reservoir

4-4 KWTP Operation Status

4-4-1 Operation Status of KWTP in Rainy Season

Table 4-1 shows the operational status of KWTP from November 10 to December 17, 2019. The operation of KWTP was significantly interrupted between November 27 and December 6 by the following reasons:

- Although the water intake pump operates continuously from September 14, electrical short circuit occurred due to the damaged power cable on November 27, and the operation was stopped.
- Although the operation was restarted from the evening of December 3 by installing a spare pump, the operation was again stopped on December 6 due to a rise in raw water turbidity that caused by heavy rainfall.

While the intake pump was in operation, Roughing Filter (hereinafter RF) operated all two basins, and Slow Sand Filter (hereinafter SSF) operated only one out of three basins. However, since the turbidity and colour of the treated SSF water exceeded the water quality standard values in Sri Lanka, the treated SSF water was discharged without being pumped to Kilinochchi Water Tower. Therefore, the treated water of packaged plants in KWTP (capacity: 500m^3/day), the wells in KWTP and the wells in the vicinity of the water intake facilities were fed in accordance with the demand.

Table 4-1 KWTP Operation Status (November 10 to December 17)

Item		Operation status	Remarks
Capacity (RF+SSF)		1,660 to 2,330m^3/day, Average: 1,880m^3/day	Continuous operation from 9/14
Moisture Collection (package plant)		Unknown	
Water Supply		270 to 870m^3/day, Average: 420m^3/day	Package plant treated water and well water in the plant are fed.
RF Operation Conditions		Two-pond operation	Filtration rate: 15-21 m/day (Design value: 36 m/day)
SSF Operation Status		One-pond operation and two-pond suspension	Filtration rate: 4.6 to 6.5m/day (Designed values: 2.4 to 4.8m/day)
Raw Water Quality	Turbidity	27 to 303 NTU、Average: 79 NTU	
	Colour	401 unit or more	Upper limit of colour measurement: Many days exceeding 550 unit
Treated Water Quality	Turbidity(No.2 SSF)	1.9 to 24 NTUs, mean: 8. 6 NTU	Sri Lanka Water Quality Standards: 2 NTU
	Turbidity(No.3 SSF)	1.1 to 8. 6 NTU, mean: 3. 1 NTU	
	Colour(No.2 SSF)	16 to 312 unit, mean: 92 unit	Sri Lanka Water Quality Standard: 15 unit
	Colour(No.3 SSF)	17 ~ 92 unit, mean: 47 unit	
	Odour	Though weak algal odour and blue grass odour were found at the beginning of the investigation, it was not felt after 11/22.	Sri Lanka Water Quality Standards: Unobjectionable

4-4-2 Cleaning the RF

Though the cleaning of RF had not been carried out once since the starting of the continuous operation of No.1 SSF from September 13 by the instruction of the investigation team, since all two ponds of RF overflowed on November 6 after the continuous operation of No.3 SSF started from September 23, the east

side one pond was cleaned on November 7 and the west side one pond was cleaned on November 8 by the judgment of NWSDB. In preparation for the anticipated increase in raw water turbidity due to the full-scale rainfall, two washings were carried out for both ponds on November 20 under the guidance of the investigation team. As shown in **Photo 4-3**, the appearance of the washout wastewater was considerably turbid, and sludge-like wastewater was confirmed at the end of the washing process. For this reason, the inflow valve was opened while the drain valve was opened at the end of cleaning, and the RF bottom was cleaned and drained. According to the interview with operators, they said that they did not completely drain the RF during the cleaning of November 7 and 8. Photo 4-3 Investigation Status of RF Cleaning

In the latest version of the O&M Manual, RF is cleaned when the filtration resistance rises, and the treated water quality deteriorates. Based on the above criteria, thorough cleaning should be carried out in preparation for high turbidity of raw water in the rainy season, cleaning should be carried out once a month even in normal times (already being carried out), and detailed procedures should be added.

	
Status of RF Washing Wastewater	**Status of RF Washing Wastewater (latter half of the washing process)**

Photo 4-3 Investigation Status of RF Cleaning

4-5 Results of Continuous Operation of SSF

4-5-1 Continuous Operation in No.1 and No.2 SSF

(1) Purpose

In order to verify the removal performance of existing RF and SSF for high turbidity raw water during the rainy season, and to confirm whether the upper limit of raw water turbidity stated in the latest version of the O&M manual: 80 NTU and SSF inflow water turbidity upper limit: 30 NTU are appropriate, a continuous operation was carried out in No. 2 SSF.

(2) Test Conditions

① Target tank: No. 2 SSF (surface layer scraped prior to starting the test)
② Filtration rate: 5.3m/day (designed values: 2.4 to 4.8m/day)
③ Treated water volume (water intake): 5.3m/day × 360 m^2 = 1,908m^3/day (79.5m/hr)
※ *The speed of the intake pumps is the same setting (minimum value) as the test in No. 3 SSF, but the discharge flow amount is increased because the water level of the Dry Aru reservoir is high.*
④ Shading net: Installed
⑤ Test period: Start on November 20, 2019

⑥ Measurement item: Turbidity, colour, odour (sensory test), dissolved oxygen concentration, filtration rate, filtration resistance

(3) Results and Considerations

Changes in turbidity, colour, DO, and filtration resistance are shown in **Figure 4-5** to **4-7.**

- Raw water turbidity ranged from 25 to 50 NTU from the start of the test to November 25.
- However, turbidity sharply increased to 178 NTU due to the heavy rainfall event that occurred on November 25, and also the turbidity was recorded as 341 NTU due to the heavy rainfall from the night of December 5 to early morning of December 6.

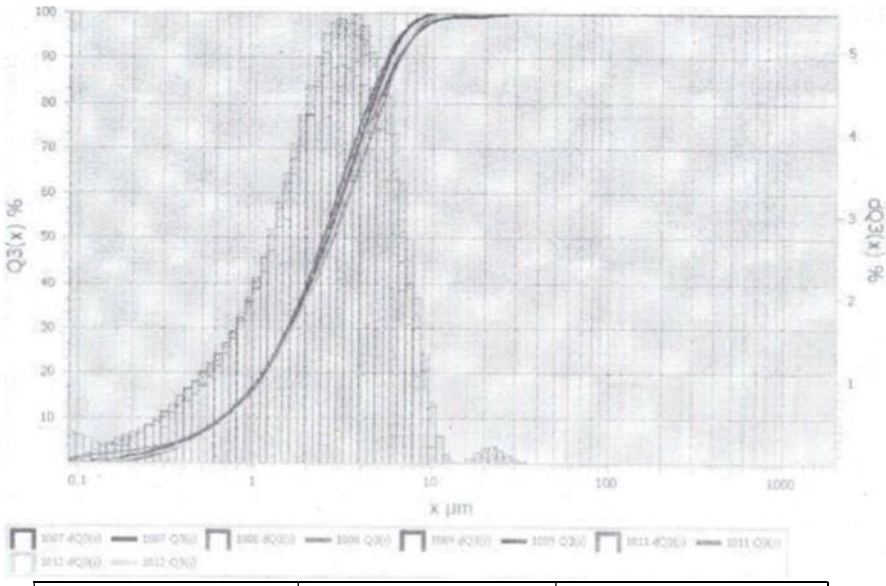
After that there was no high rainfall, and turbidity was reduced to about 40 NTU.

Regarding RF and SSF treated water turbidity, data were obtained after the evening of December 9 when the operation of the intake pump was resumed (temporarily stopped due to a decrease in the received voltage on December 7). After the raw water turbidity rose sharply due to the heavy rainfall of November 25, two RFs were cleaned one by one on December 10, since the decrease in the removal rate of RF was remarkable. However, since the turbidity removal rate was not improved, the operation of No. 1 SSF was started from December 12, and the SSF was operated in two ponds, and the filtration rate was halved from 5.3m/day to about 2.7m/day (the volume of treated water for No. 1 and No. 2 SSF could not be measured due to the runoff weir could not be overflowed at that time). The treated water turbidity of No.1 and No.2 SSF improved with the reduction of raw water turbidity and filtration rate, and the water quality standard values: the time to satisfy 2NTU increased after December 20. Photo 4-4 shows the appearance of raw water in the vicinity of the water intake facility, which is yellow soil with a whitish colour. **Figure 4-4** shows the measured particle size distributions of turbidity contained in the raw water of Dry Aru reservoir. The 10% particle size was 0.54 ± 0.30 μm, and the 50% particle size was 2.05±1.15 μm, which was very fine. About half of the particles were clay particles of size 2 μm or less (based on the definitions of the International Union of Soil Sciences).

Conditions of Raw Water in Vicinity of Water Intake Facilities

Operation Status of No. 2 SSF

Photo 4-4 Continuous Operation in No. 2 SSF



10% particle size (Average value, µm)	50% particle size (Average value, µm)	90% particle size (Average value, µm)
0.54 ±0.30	2.05 ±1.15	4.74 ±2.67

Figure 4-4 Particle Size Distribution of Turbid Matter in Raw Water in Dry Aru (water sampling date: December 6, 2019)

On the other hand, for colour, from the beginning of the test to November 25, it showed about 400 unit, but it rose sharply with heavy rainfall of November 25, and the period from November 26 to December 10 showed more than 550 unit, which is the upper limit of the colour meter measurement. As the raw water turbidity decreases, the colour also begins to decrease, and after December 14, the RF and SSF treated water colour also shows a tendency to decrease. However, the SSF treated water colour has not yet reached the water quality standard value of 15 unit. It is inferred that fine turbidity fractions described above flowed out without being captured and removed by RF and SSF and were detected as colour.

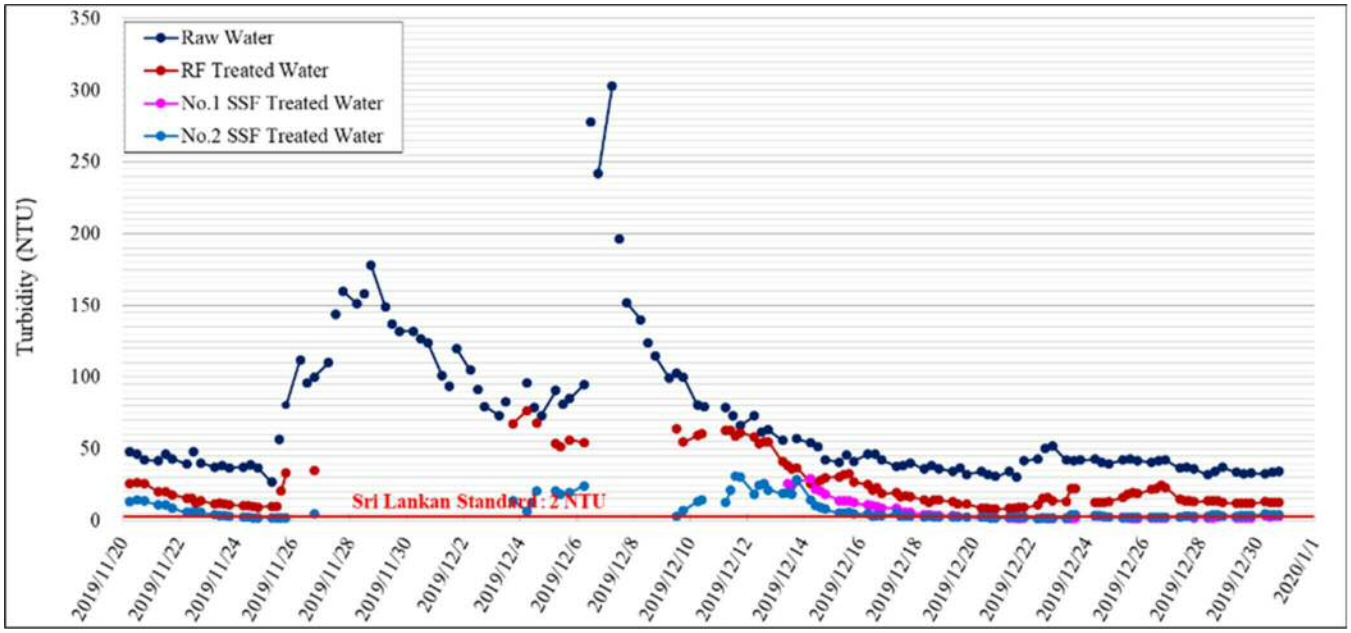


Figure 4-5 Results of Turbidity

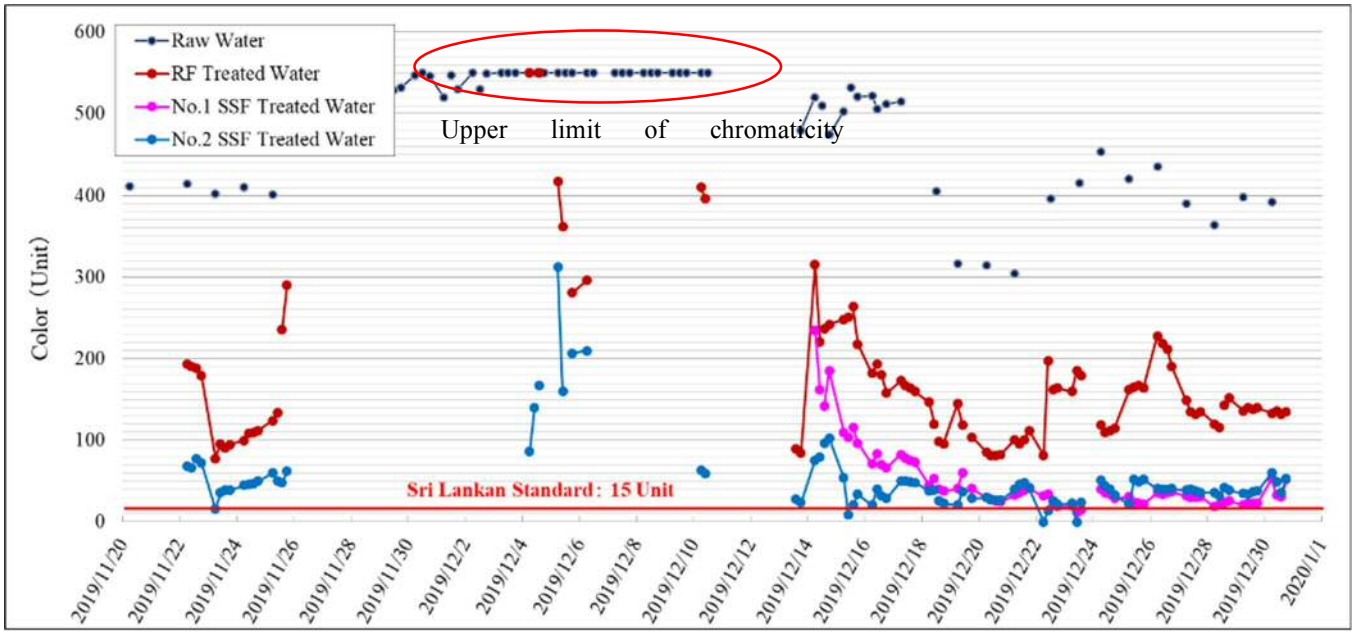


Figure 4-6 Results of Colour

For DO values (reference) in treated water, the recommended value of WHO for both No. 1 and No. 2 is 3 mg/L or higher from December 4 onwards. On the other hand, the filtration resistance is stable at around 2m in No. 2 SSF and below 1m in No. 1 SSF, and the raw water turbidity load is reduced due to the reduced rainfall. Therefore, operation can be continued for some time in the future.

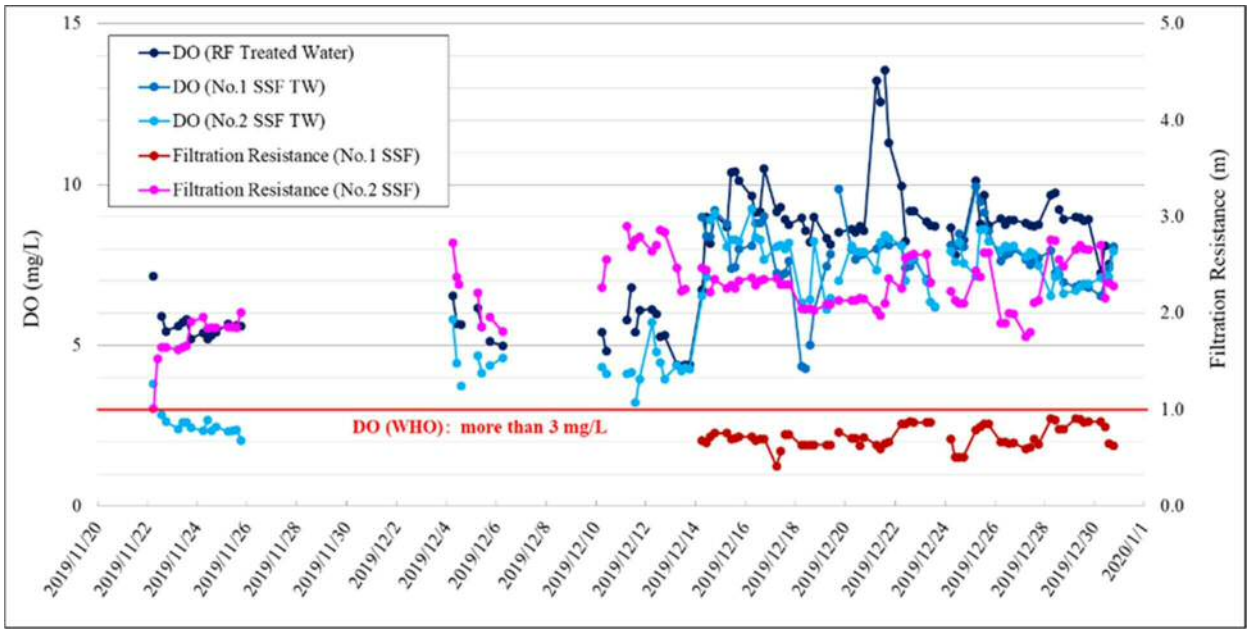


Figure 4-7 Result of DO and Filtration Resistance

Table 4-2 shows the turbidity and colour removal rates of RF, No.1 and No.2 SSF in the rainy season calculated from the above results. In calculating the turbidity and colour removal rate of SSF, the formation and acclimatization periods of biofilm at the start of operation were excluded (No. 1: December 13 to 19 data excluded and for No. 2: November 20 to December 8 data excluded). As a result, the turbidity removal rate (average value) of RF was 53% and the colour removal rate was 59%, which was a little lower than the result in the dry season. On the other hand, the turbidity and colour removal rate of SSF were improved by 13% by

reducing the filtration rate, especially for the turbidity removal rate.

From the above, it is suggested that it is effective to operate the SSF in more than one pond and to lower the filtration rate at the time of high turbidity of raw water in rainy season as a tentative countermeasure until water demand will increase. The reason why the turbidity and colour removal rate of RF showed a slightly lower value than that in the dry season is presumed to be that turbidity in raw water in the rainy season is mainly clay particles smaller than algae, and due to that the number of particles are large, they cannot be sufficiently captured and removed.

Table 4-2 Turbidity and Colour Removal Rate of RF, No.1 and No.2 SSF in Rainy Season

Item	RF Removal Rate (%)			SSF Removal Rate (%)			Remarks
	Average	Maximum	Minimum	Average	Maximum	Minimum	
Turbidity	53	78	7.3	68	95	48	SSF FR*5): 5.5 m/day
				80*4)	94*4)	62*4)	SSF FR*5): 2.7 m/day
Colour	59	82	24	85	85	85	SSF FR*5): 5.5 m/day
				73*4)	94*4)	52*4)	SSF FR*5): 2.7 m/day

** 4) Average values in No. 1 and No. 2 SSF*
** 5) Filtration Rate*

5. Future Prediction of Pollutant Load

5-1 Present Dry Aru Catchment and Population in-Catchment

(1) Current Water Supply Status

1) Water Supply Area

Kilinochchi Water Supply Scheme supplies drinking water to 4 GNDS in Kandavalai Divisional Secretariat (DS) and 14 GNDS in Karachchi DS. Within these administrative areas, Kilinochchi elevated water tank and Paranthan elevated water tank were constructed to supply water to the areas consider under above two DS areas. Further distribution network shall be extended to few more GNDS subjected to the continuous operation of KWTP. **Figure 5-1** shows the administrative areas and present water supply coverage areas.

2) Other water supply projects

Apart from the above existing Kilinochchi water supply scheme, under the World Bank funding, a new water supply scheme is being planned to serve the increasing demand of the area.

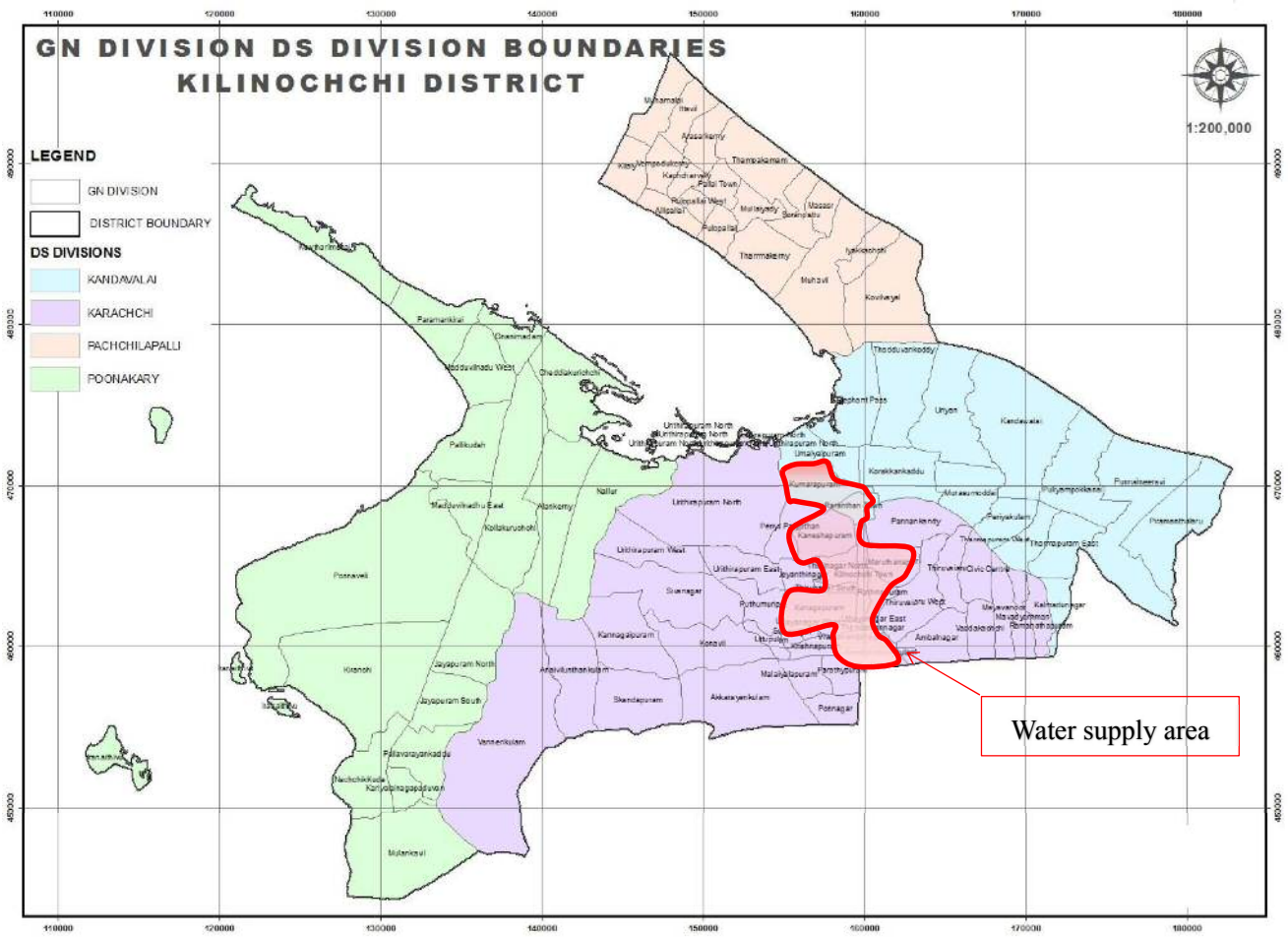


Figure 5-1 Administration Area and Water Supply Area Chart

(2) Present Dry Aru Catchment Population

The population and the number of households in the catchment area of Dry Aru reservoir are as shown in the below **Table 5-1**. The population in the last seven years shows an increasing trend. The same situation applies to the population within Kilinochchi water supply areas.

Table 5-1 Dry Aru Reservoir Catchment Population

	Year	2,011	2,012	2,013	2,014	2,015	2,016	2,017
10. Vivegananthanagar	Household(No)	515	515	483	487	568	597	622
(Area:3.51km^2)	Population	1,556	1,556	1,645	1,646	1,756	1,831	1,869
12. Uthayanagar east	Household(No)	609	613	683	678	676	688	706
(Area:1.45km^2)	Population	1,632	1,635	2,291	2,290	2,247	2,256	2,300
16. Ananthapuram	Household(No)	690	696	698	704	712	728	758
(Area:2.25km^2)	Population	1,896	1,917	1,931	1,947	2,058	2,113	2,151
17. Thondamannagar	Household(No)	303	301	278	282	303	311	319
(Area:1.62km^2)	Population	917	907	880	891	946	966	978
18. Kanakambigaikulam	Household(No)	567	569	549	550	596	603	624
(Area:4.31km^2)	Population	1,649	1,649	1,657	1,664	1,793	1,789	1,821
19. Ambalnagar	Household(No)	957	957	1,033	1,039	1,015	1,053	1,091
(Area:5.48km^2)	Population	2,887	2,894	3,085	3,107	3,278	3,359	3,403
21. Thiruvaiyaru west	Household(No)	326	331	354	353	354	363	369
(Area:4.06km^2)	Population	920	933	1,030	1,027	981	994	1,006
22. Radnapuram	Household(No)	378	378	371	377	391	412	430
(Area:2.35km^2)	Population	1,155	1,151	1,128	1,142	1,127	1,279	1,322
Dry Aru Catchment Area	Household(No)	4,345	4,360	4,449	4,470	4,615	4,755	4,919
	Population	12,612	12,642	13,647	13,714	14,186	14,587	14,850

5-2 Future Projection of Catchment Population

(1) Setting for Future Years

Next year in the future years, the Guidelines for the Design of Water Supply Facilities in Japan state that "it is desirable to set it as long as possible based on the certainty of future forecasts, the rationality of facility development, and the management status" and "about 10 to 20 years from the time of the plan formulation shall be the standard". However, due to the limited data and information available within NWSDB and the difficulties in ensuring the certainty of future projections, it has been decided to set 2040 as the future year, from the time of the FU study (2020) to a minimum of 10 years later, and from 2020 to 20 years after the implementation of the project by NWSDB. In other words, the forecast was set as the future year with 2020 as the survey time, 2030 as the short-term future year, and 2040 as the 10-year after that time as the medium-to-long term.

(2) Estimation of Catchment Population

The population in the catchment area of Dry Aru reservoir was estimated using the results of the obtained statistical data.

1) Selection of estimation method

For the estimation method of the future population projections, time series tendency analysis method was used. This can be described by the equation in which actual results and future tendency are made to be only time variables. In other words, it is a method to predict the future population by fitting a trend curve to the actual population. There are the following five tendency curves described in the Guidelines for the Design of Water Supply Facilities as the trend curves used in this method.

① Annual average increase/decrease formula: $y = ax + b$ ($a = 397.964$、$b = 12156,429$)

② Annual average rate of change: $y = y_0(1+r)^x$ (y_0= 14,850、r = 0.02760)

③ Modified exponential curve formula: $y = K - ab^x$ (K = 30680.453、a = 17,742.090、b = 0.97676)

④ Power curve: $y = Yo+A\,x^a$ (a = 2.21909、A = 69.077、Yo = 12,612)

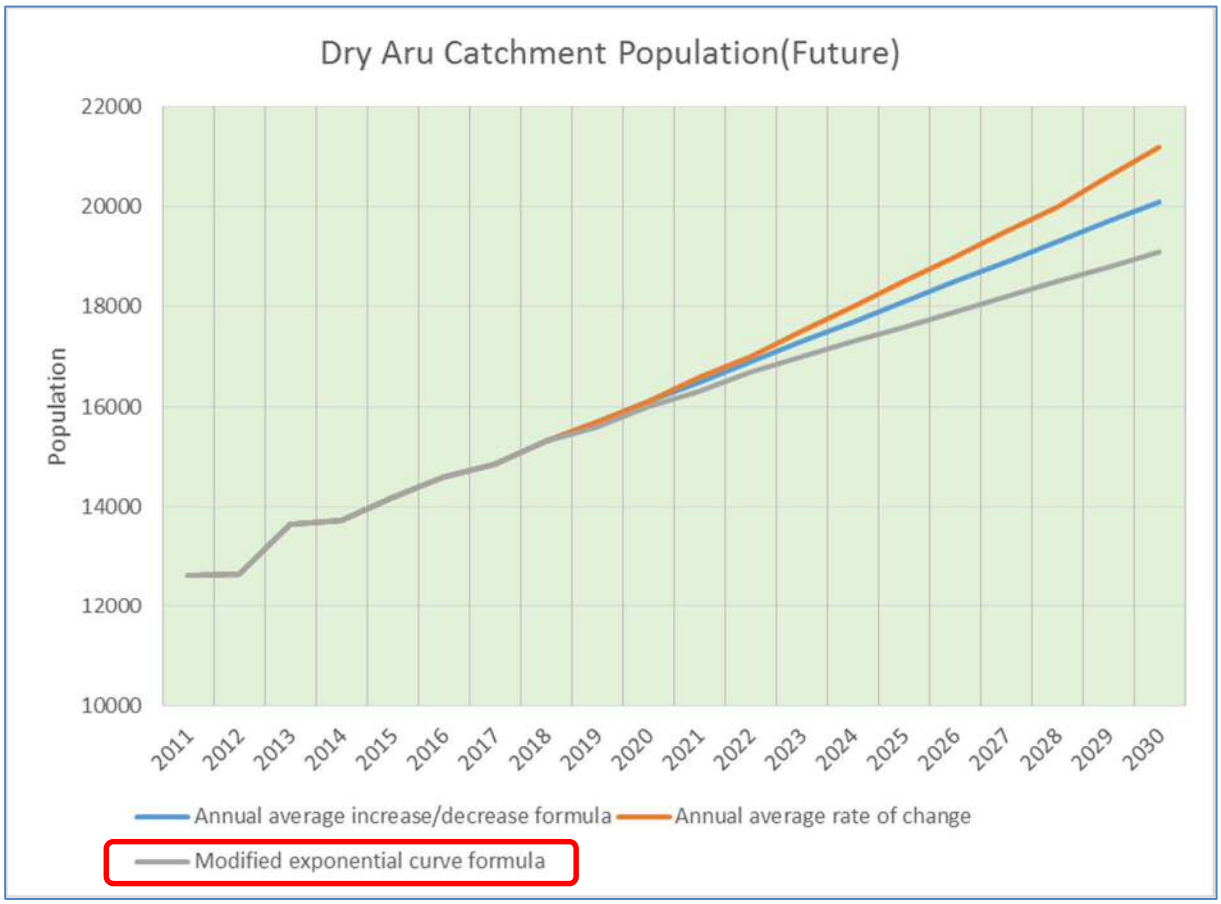
⑤ Logistic curve formula: $y = K / (1+e^{(a-bx)})$ (K = 20,000、a = -0.42326、b = 0.09286)

The power curve formula was judged to be unsuitable because it was an overestimated result of more than 60,100 in 2030.

The logistic curve equation was judged to be unsuitable too, because there was no upper planned value which was the basis of the saturation value. Among the remaining three equations, the modified exponential equation ③, which is highly correlated with past results, was adopted as the trend curve for this FU study. The results of applying these five trend curves to the actual population of Kilinochchi are shown in **Figure 5-2**.

2) Estimation Results

Table 5-2 shows the estimated population in the catchment area. As a result of the estimation, the population in the catchment area became 19,100 persons in 2030 which is the future year.



Source) FU Study Team

Figure 5-2 Projection of Population in Catchment Area (time series trend analysis)

Table 5-2 Estimation Results of Population in Catchments
(Time-Series Trend Analysis: Modified Exponential Formula)

Western calendar	Annual average change	Annual average rate of change	Modified exponential curve	Power curve	Logistic curve
2011	12,612	12,612	12,612	12,612	12,612
2012	12,642	12,642	12,642	12,642	12,642
2013	13,647	13,647	13,647	13,647	13,647
2014	13,714	13,714	13,714	13,714	13,714
2015	14,186	14,186	14,186	14,186	14,186
2016	14,587	14,587	14,587	14,587	14,587
2017	14,850	14,850	14,850	14,850	14,850
2018	15,300	15,300	15,300	17,800	15,200
2019	15,700	15,700	15,600	19,600	15,600
2020	16,100	16,100	16,000	21,700	15,900
2021	16,500	16,600	16,300	24,100	16,200
2022	16,900	17,000	16,700	26,700	16,500
2023	17,300	17,500	17,000	29,800	16,700
2024	17,700	18,000	17,300	33,100	17,000
2025	18,100	18,500	17,600	36,700	17,200
2026	18,500	19,000	17,900	40,700	17,400
2027	18,900	19,500	18,200	45,100	17,600
2028	19,300	20,000	18,500	49,700	17,800
2029	19,700	20,600	18,800	54,800	18,000
2030	20,100	21,200	19,100	60,100	18,100
Correlation coefficient	0.978106591	0.976571207	0.978969739	0.910490496	0.979316219
Adoption			○	×	× because the saturation value cannot be set

5-3 Prediction of Future Pollutant Load

(1) Current Status of Pollution from Kilinochchi General Hospitals

1) Outline of Kilinochchi General Hospital

- ✓ Name: District General Hospital – Kilinochchi (Government Hospital)
- ✓ Number of beds: 295 beds
- ✓ Number of outpatients: 600 people/day (average)
- ✓ Supply water volume: Approx. 130m^3/day
- ✓ Pipe born water source: Well water and piping connections

Photo 5-1 Overview of Kilinochchi General Hospital

2) Wastewater Treatment

Wastewater generated in hospitals is treated at a sewage treatment facility with a capacity of 110m^3/day. This facility was renewed and newly installed in July 2019, and sewage treatment is currently being carried out by sedimentation and filtration. Treated water is discharged into a small stream adjacent to hospitals, and this small stream flows from Kanagambikai reservoir to the Dry Aru reservoir.

Photo 5-2 Sedimentation Tank

Photo 5-3 Sewage filtration facility

Measurements of the quality of treated water have not been conducted regularly, and only once by NWSDB on July 18 after the commencement of operation. The outline of the measurement results is shown below. It seems that it is just after the start of operation, but from this result, it cannot be concluded that the appropriate processing is performed.

Table 5-3 Results of Measurement of Treated Water at Hospital WWTP (Measured on July 18, 2019)

Water Quality Items	Wastewater	Treated Eater	Standard *)
BOD	Not measured	56mg/L	30mg/L
COD		141mg/L	250mg/L
TSS		22mg/L	50mg/L

**) General Standards Criteria for the Discharge of Industrial Effluent into Inland Surface Waters*

Before being renewed to the current treatment facility, sewage was being treated in a septic tank, but there was a malfunction and it was often overflowing as it was untreated.

As of November 2019, the facilities had failed and had been discharged untreated, and this untreated wastewater, albeit in a small amount, had flown into the Dry Aru reservoir. The standard value as shown in **Table 5-3** is applied in case that the effluent water from hospital is diluted by at least eight times of clean water. It is inferred that this standard value will be satisfied during rainy season since the flow amount of small stream is large enough to dilute the effluent water. However, the standard value shall be reconsidered/calculated according to the actual dilution rate in dry season.

Further, canal water flow shall be measured to get confirmed that the expected dilution is occurred according to the criteria for the discharge of Industrial Effluent into Inland surface water.

Photo 5-4 Outflow of Wastewater

6. Construction Plan

6-1 Construction Company in Sri Lanka

In Sri Lanka all contractors are required to register with the Construction Industry Development Authority (CIDA); successor to the Institute of construction Training and Development (ICTAD) under the Ministry of Urban Development Water Supply and Housing Facilities. When registering, the company details such as number of employees' plants and heavy machine owned in addition to the company finance and technical capabilities are evaluated and ranked.

At the time of Grant Aid Preparatory Survey in 2011 there was a Contractor Grading Scheme according to the contract amount and it was published in the Guideline for Grading of Construction Contractors issued in September 2008 and that Grading Scheme is provided in **Table 6-1**.

Table 6-1 Contractor Grading Scheme as in year 2008

Financial Limit (Rs. Million)	Grade
X≧600.0	Grade C 1
600.0≧X>300.0	Grade C 2
300.0≧X>100.0	Grade C 3
100.0≧X>50.0	Grade C 4
50.0≧X>25.0	Grade C 5
25.0≧X>10.0	Grade C 6
10.0≧X>5.0	Grade C 7
5.0≧X>2.0	Grade C 8
2.0≧X>1.0	Grade C 9
1.0≧X	Grade C 10

※ *Source: Institute for Construction Training and Development*

The above Guideline was revised in year 2015 and the new Grading Scheme has been published. CS2 and

CS1 categories have been newly introduced into the Grading Scheme and C10 Grade was disappeared, resulting in detailed classification than earlier. A new rating table is shown in **Table 6-2**.

Table 6-2 Contractor Grading Scheme as per the revision in year 2015 by CIDA

Financial Limit (Rs. Million)	Grade	Sri Lanka Number of contractors' subject to water works	Available CIDA registered contractors in Kilinochchi District with respect to the water works
X≧3000.0	Grade CS 2	3 companies	0
3000.0≧X>1500.0	Grade CS 1	5 companies	0
1500.0≧X>600.0	Grade C 1	7 companies	0
600.0≧X>300.0	Grade C 2	8 companies	0
300.0≧X>150.0	Grade C 3	24 companies	0
150.0≧X>50.0	Grade C 4	49 companies	0
50.0≧X>25.0	Grade C 5	25 companies	0
25.0≧X>10.0	Grade C 6	Large number	0
10.0≧X>5.0	Grade C 7	Large number	29 companies
5.0≧X>2.0	Grade C 8	Large number	8 companies
2.0≧X>1.0	Grade C 9	Large number	3 companies

※ *Source: Construction Industry Development Authority(CIDA)*

Considering the construction of additional facilities in this FU Study, at least or more companies than that of enterprises participating in rehabilitation work are considered optimum. In rehabilitation work, since the companies approved by NWSDB as subcontractors were Grade C1, companies with C1 ranks or higher are considered to be subject to bidding this time as well. Companies rated Grade C1 or higher are shown in **Table 6-3**.

Table 6-3 List of CS2 and CS1 Contractors in Sri Lanka

Grade	Name of supplier	Vendor address
CS 2	Access Engineering PLC	278-Access Tower, Union place, Colombo 2
CS 2	Maga Engineering (pvt) Ltd	200, Nawala Road, Narahenpita, Colombo 5
CS 2	Sierra Construction Limited	23, Havelock Road, Colombo 5
CS 1	Hovel Construction (PVT)Ltd	245/47, Awilssawella Road, Orugodawatta
CS 1	International Construction Consortium Ltd	70, S.De S. Jayasinghe Mawatha, Kohuwala, Nugegoda
CS 1	K D A Weerasinghe & Company (PVT) LTD	8/16- Thalapathpitiya Road, Nugegoda,
CS 1	Sanken Construction (PVT) Ltd	295, Madampitiya Road, Colombo 14
CS 1	Subasinghe Contractors (PVT) LTD	294A-Kohobanwatte, Hapugala, Galle
C 1	Ceylex Engineering (PVT) LTD	Level 17, Parkland Building-No 33, Park Street-Colombo 2
C 1	CML-MTD Construction LTD	No 18, ST Michael'S Road, Colombo 3
C 1	Finite Lanka (PVT) LTD	260/1/2-1st Floor, Kandy Road-Yakkala South, Gampaha
C 1	P N D Construction (PVT) LTD	278, Moragahayata, Ratnapura
C 1	Sunpower Constructions (PRIVATE) LTD	3rdFloor-Forbes & Walker Building, 46/38-Nawam Mawatha, Colombo 2
C 1	Tudawe Brothers(PVT) LTD	505/2, Elvitigala, Mawatha, Colombo 5
C 1	V V Karunaratne & Company	579-Bulugaha Junction, Kandy Road, Kelaniya

※ *Source: Construction Industry Development Authority(CIDA)*

Many construction contractors in Kilinochchi area are small local contractors of sole proprietors. Contractors rated Grade CS 2 to C1 are based in Colombo, but there are no particular problems with executing

construction works in the Northern Province by Colombo based contractors and also, they have actually been employed as subcontractors in the rehabilitation work of WTPs.

6-2 Main Unit Price

When pre-treatment facilities are constructed as a result of FU study following products are considered. Similar to existing facilities this facility is made of ordinary concrete for civil engineering construction and machinery and electrical equipment to be installed are products made in Japan and third world country. Yard piping is done with suitable pipes as appropriately imported from Japan and third world countries.

Table 6-4 shows the tentative unit prices of civil works of the pre-treatment facilities proposed to be constructed. The unit prices were extracted form NWSDB rate book in year. Year of rate book shall be included.

Table 6-4 Tentative Unit Prices of Civil Works of the Pre-treatment Facilities Proposed to be constructed

Name	Unit	Unit price (LKR)	Unit price (yen)	Remarks
Mechanical Excavation	m^3	910	546	
Residual Soil Backfilling	m^3	603	362	
Concrete Casting	m^3	22,197	13,318	
Reinforcement Bar	ton	160,528	96,317	
Formwork	m^2	2,232	1,339	
Waterproofing Work	m^2	1,500	900	

Source: Rate Book NWSDB

6-3 Procurement of Materials and Equipment

The materials/equipment/machinery necessary for the improvement works/Pre-treatment facilities to be ordered after this FU Study will be procured locally as much as possible. However, it is desirable to procure materials/equipment/machinery which cannot be procured locally or of which quality, specifications, etc. do not conform from Japan or a third world country. All material/equipment/machinery will be procured according to the NWSDB standards and specifications.

Especially, regarding in-house piping materials, the following are considered by dividing the pipe types according to each part.

- Un plasticized vinyl chloride pipes, which have excellent workability and durability and have a good track record in NWSDB, will be adopted for on-site piping materials, while following those already adopted in the Grant Aid Project. However, the area where the piping is exposed and around the body shall be ductile iron pipes.
- Un plasticized vinyl chloride pipes are available in Sir Lanka and the procurement is easy. In addition, ductile iron pipes are easily procured in the local market because imported products (from Japan and third world countries) are on the market in Sri Lanka.

Other than piping materials, machinery and electrical equipment will be procured from Japan and other countries. These materials and equipment shall be transported by sea to Colombo Port of Sri Lanka and by land from Colombo Port to Kilinochchi.

Construction machinery can be hired locally because they are available with Sri Lankan contractors

Suppliers of major materials and equipment used in this plan are shown below.

Table 6-5 Suppliers of Construction Materials and Machinery

Procurement cost items		Supplier			Remarks
Category	Name	Sri Lanka	Japan	Third Country	
Pipe Materials	Ductile iron (DI) pipes (flanged/socket & spigot), fittings, specials and accessories		○	○	
	Valves (pressure reduction, control, partition, check, air)	○			
	Cast iron manhole lids, valves	○			
	Unplasticized polyvinyl chloride pipe	○			
Civil Work Materials	Cement, aggregate, sand and formworks	○			
	Reinforcing steel	○			
	Painting	○			
	Fuel (light oil, gasoline, oil)	○			
Mechanical/ Electrical Equipment	Pumps		○	○	
	Floc forming equipment		○	○	
	Coagulating sedimentation equipment		○	○	
	Control panel		○	○	
Construction Machinery	Leasing of excavators, cranes, dumps, etc.	○			

※ *FU Study Team*

7. Problems Possible in the Current Process and Improvement Measures

7-1 Problems to be considered in RF-SSF Process

(1) Problems at the Current Facility

i) During cleaning of the RF, it is possible to shock the filter layer and increase the cleaning effect by rapidly opening or closing the drain valve. In contrast, the above operation is difficult because the sluice valve is installed in the present state.

ii) In the current facility, when SSF treated water is drained, the water is discharged from the upstream side of the effluent weir as shown in **Figure 7-1**. In particular, during filtration and drainage operations at start-up after filter layer scraping or at the time of deterioration of treated water quality, the water level in SSF drops below the surface of the filter layer and the filter material is exposed. Under such conditions, when the filtration resistance rises and the water level in SSF is high, an air-binding phenomenon occurs near the biofilm.

(2) Problems with the Former O&M

i) With the former intermittent operation, the colour, odour and turbidity of treated water are in the following situations, and they do not satisfy the Water Quality Standard (SLS 614) of Sri Lanka.

- Colour: No record of raw water ⇒ SSF-treated water: 32 to 92 unit (SLS 614: 15 unit)
- Odour: Plant odour (algal odour, blue grass odour) is felt from SSF treated water (SLS 614: unobjectionable)
- Turbidity: raw water 28 to 46 NTU ⇒ SSF treated water: 1.1 to 12 NTU (SLS 614: 2 NTU)

ii) It is inferred that the main reason of the above situation is due to the insufficient growth of biofilm and anaerobic condition of filter layer due to intermittent operation of KWTP. The fact that total iron

concentration showed more than 2.0mg/L on September 11, 2019 supports the above points.

(3) Problems in Dry Season

i) Low water levels in the Iranamadu reservoirs and algae bloom occur, causing breeding algae to flow into the Dry Aru reservoirs through irrigation channels.

ii) According to the results of continuous operation in No. 3 SSF, bio filtration membranes (mainly algae of filtrate) were formed on almost the entire surface of the filter layer, and the DO values of treated water were also kept at about 3mg/L or more. As a result, the existing RF+SSF could not sufficiently treat the raw water quality including the multiplied algae in the dry season.

- Turbidity and odour satisfied the water quality standard values for 16 days.
- The colour satisfied the water quality standard values only for three days.

(4) Problems during Rainy Season

1) Dry Season and Rainy Season Conversion Season

i) The growth of algae continued even when the water level of the Iranamadu reservoir rose in the early rainy season, and this flowed into the Dry Aru reservoir, and the algae concentration continued to be high.

ii) Furthermore, raw water turbidity and colour had rapidly increased due to opening of the outlet gate of the Iranamadu and the Dry Aru reservoir.

2) Rainy Season

i) If the rainfall exceeds 50mm/hr, the raw water turbidity and colour of Dry Aru reservoir may increase rapidly, resulting in turbidity greater than 200 NTU and colour greater than 550 Unit.

ii) Even at times Outflow gates of the Iranamadu and the Dry Aru reservoirs are kept closed and fixed *), the Dry Aru reservoirs become highly turbid due to the inflow of high turbidity water from the Kanagambikai reservoirs and irrigation channel.

iii) When checked with the Department of Irrigation, the outflow gates to the Dry Aru reservoir are not opened to ensure and protect the storage capacity of the Iranamadu reservoir during the full rainy season.

iv) According to the continuous operation results in No.1 and No.2 SSF, the DO values of process water were more than 3mg/L and the filter bed was aerobic. However, the conditions of treated water were as follows. As a result, the existing RF+SSF could not sufficiently treat the source water of high turbidity and colour in the rainy season.

- ✓ The treated water turbidity was reduced to about 50 NTU and the water quality standard value was satisfied under the condition of lowering the filtration rate (2.7m/day).
- ✓ The colour did not satisfy the water quality standard value.
- ✓ Odour was not felt in both raw and treated water.

7-2 Presentation of Improvement Plan

Based on the results of the First Field Survey (dry season) and the Second Field Survey (rainy season), the following Measures 1 to 5 are considered as the improvement plan for algae and high turbidity at the present stage.

【Improvement Plan】

1. **Measure-1: Measures for O&M considering Colour, Odour and Turbidity**

   "Continuous operation for 24 hours" was carried out to form a sound biofilm on the surface layer of SSF, but it was clarified that the water quality standard values for turbidity and colour could not be constantly satisfied, though improvement was recognized in comparison with the former intermittent operation. Therefore, it is considered necessary to install a pre-treatment facility. However, the O&M manual should be revised and added for the period until completion of the facility and after completion, and appropriate operation management methods should be installed and described.

2. **Measure-2: Sustaining the Water Level of SSF**

   By replacing the valve related to RF cleaning with a butterfly valve from the current sluice valve, opening and closing of the valve can be made smooth, and cleaning function and effect can be improved.

3. **Measure-3: Sustaining Water Level of SSF**

   In the present facility, when the SSF treated water is drained, the water is discharged from the upstream side of the effluent weir. In particular, during filtration and drainage operation during start-up, the water level in SSF falls below the surface of the filter layer, causing problems such as exposure of the filter material. Therefore, the SSF should be modified so that water can be drained from the downstream side of the effluent weir.

4. **Measure-4: Installation of Pre-Treatment Facilities**

   Effective pre-treatment facilities will be installed as a countermeasure for algae in the dry season and high turbidity in the rainy season.

The former Measure-4: Intake pit improvement was removed from the improvement plan for the following reasons after considering the details.

Reason of exclusion of former Measure-4 (Improvement of Water Intake Pit) as Improvement Plan

Improvement of water intake pit is considered to be enable the selection of raw water with better water quality according to the change of the raw water quality of the Dry Aru reservoir.

However, since there is no significant difference in the algal concentration due to the difference of intake water depth, and it is not expected substantial effects. Then, it is judged that this improvement plan is not adopted.

7-3 Details of Improvement Plan

The outline of each improvement plan is shown below.

(1) Measure-1: Measures for O&M considering Colour, Odour and Turbidity

1) Improvement Plan

As a general rule, in order to form sound biofilms on the surface layer of SSF, it is changed from conventional intermittent operation to "24-hour continuous operation" to keep the inside of the filter layer in an aerobic state. However, the results of SSF continuous operation conducted during the dry season and rainy season confirmed that it was difficult to completely remove the turbidity and colour of treated water to below acceptable standards by continuous operation alone. Therefore, the improvement effect of colour, odour, and turbidity of treated water is limited only by the improvement of O&M, but the following O&M method is

recommended based on the knowledge obtained in this FU Study.

① O&M in Dry Season

- In principle, the frequency of RF cleaning shall be once a month and when the water level in the pond rises, it shall be cleaned appropriately by engineering judgement.
- Cleaning of the RF should be carried out once every two months (Each pond shall be cleaned once a month) by removing algae on the surface layer and cleaning the wall surface. In addition, the aerator and SSF inflow channel are cleaned regularly.
- In order to shorten the residence time in the SSF as much as possible and to prevent algal growth, the filtration rate of the SSF should be close to the design upper limit (4.8m/day).
- Shading nets shall be installed for the following reasons.
  - ✓ The effect of removing the shading nets is to promote the maturation of the biofilm and to accelerate the startup, but as seen in the No.3 SSF, many filamentous algae may propagate and cause filtration blockage.
  - ✓ Currently installed shading nets do not have enough light-shielding effect to prevent algae in biofilm from propagating at all (light-shielding ratio of about 70%), hence algae can propagate partially.
  - ✓ Wild animals such as monkey live near the water purification plant, and the installation of a light shielding net can be expected to prevent the entry of foreign substances and waste.

② O&M in Rainy Season

- In principle, the frequency of RF cleaning shall be once a month and when the water level in the pond rises, it shall be cleaned appropriately. However, if the appearance of the washing wastewater at the completion of cleaning is turbid (compared with raw water), the bottom part shall be washed by raw water with keeping open both the inlet valve and the drain valve.
- Operate more than two SSFs to close the filtration rate to the design lower limit (2.4m/day).
- Other items conform to ① above.

③ O&M in non-Dry and Rainy seasons

- Clean the inside of the intake pit where the intake pump is installed to remove sediment, etc. The frequency should be at least once a year and should be implemented prior to the rainy season.

Since the above underlined parts are not shown in the latest O&M Manual and these contents are newly added, the O&M Manual had updated and an additional training about these contents had conducted from 17th to 18th February, 2020 at Kilinochchi WTP. Details of the training and the updated O&M Manual are shown in **Appendix-5**.

2) Issues and improvement plans related to the current O&M manual

Problems and issues in the latest version of the O&M Manual (submitted in March 2019) are shown below.

① Operation methods and procedures for dealing with algae-derived colour and odour in the dry season are not described.

② The upper limit of raw water turbidity that can be handled in the rainy season was set to 80 NTU based on the operational data for 2016-2018. However, it is necessary to verify the upper limit of raw water turbidity at the time of the second survey during the rainy season and to review the current operational methods and procedures as necessary.

③ When facilities are renovated or improved, not only the contents of the added facilities/equipment may need to be added, but also modifications to the operational methods and procedures for the existing facilities/equipment may be required.
(This is not a scope of this FU Study, and it is necessary to add or modify it after completion of facility renovation and maintenance.)

Therefore, the O&M manual will be updated in this FU Study regarding the improvement measures described in ①, ② and ③ above.

3) Expected Effect

The improvement effect of colour, odour, and turbidity of treated water is limited only by the improvement of O&M as described above.

4) Necessity of Training

Especially with regard to the countermeasures against high turbidity in the rainy season, it is necessary to carry out comprehensive operation management. This would include adjustment to the water intake (filtration rate) or increasing or decreasing the number of operating basins in accordance with changes in raw water turbidity while monitoring the raw water and treated water quality. In addition, when it is impossible to treat it by operation management, temporary water intake stop (peak cut) is forced. We think that training in lecture form is insufficient and training in OJT form is necessary in order to take appropriate judgment and correspondence according to the situation which changes every moment.

In addition, it is necessary to consider the assistance/supervision with operation by the contractor depending on the contents of the facility, in case the pre-treatment facility construction is carried out. **Table 7-1** gives an overview of the assumed training.

Table 7-1 Outline of Assumed Training

No.	Item	Period	Remarks
1	WTP operation and maintenance (Consultant)	3 man-months (dry season: 1 man-month, rainy season: 2 man-months)	Simultaneous implementation of the two items on the left in OJT format
2	Water quality monitoring and management (Consultant)		
3	Assistance/supervision with operation by contractor	8 months (assuming July to February)	Specify in the contract for the construction of the pretreatment facility

(2) Measure-2: Improving of Washing Mechanism of RF

1) Improvement Plan

As an improvement plan (as an example), the existing valve is replaced with butterfly valve, so that it can be opened and closed quickly, thereby enhancing cleaning effect of filter media. Furthermore, this can increase the frequency of cleaning, especially in the rainy season.

2) Expected Effect

By increasing cleaning effect of filter media in RF, the filter media can be maintained in a proper condition, thereby it can enhance the removal rate of algae and turbidity by RF.

(3) Measure-3: Sustaining the Water Level of SSF

1) Improvement Plan

As an improvement plan, the existing effluent pit as shown in below figure should be modified to drain out from the downstream side of the effluent weir.

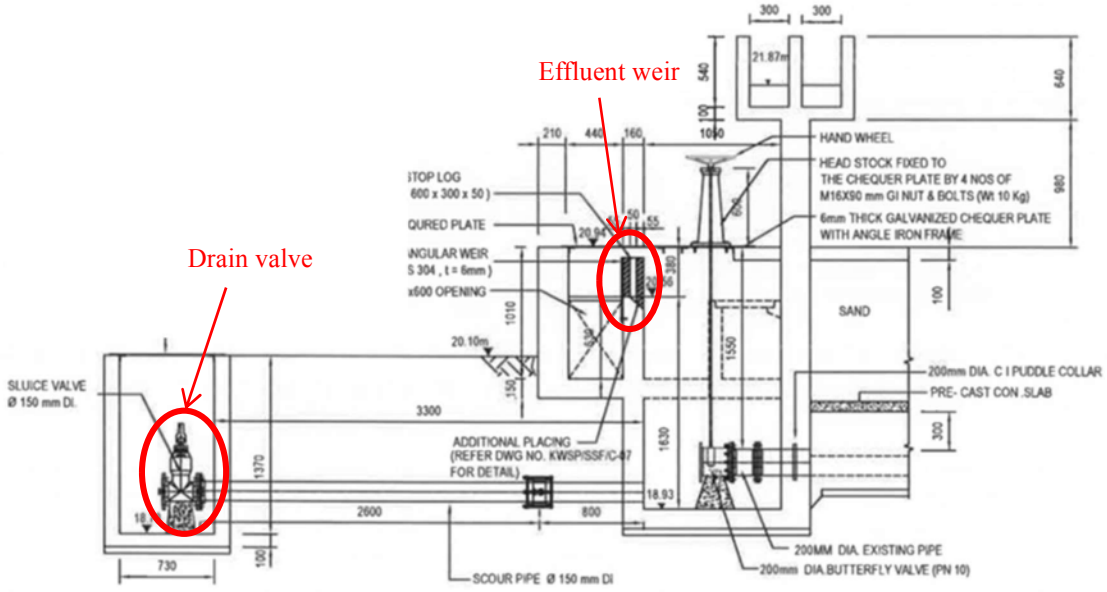


Figure 7-1 Cross-Section of current SSF Outflow Pit

2) Expected Effect

At start up after the sand scrapping procedure of SSF which is performed several times a year or at the time of deterioration of the treated water quality, it is necessary to check the water quality while draining the treated water, and to send the water to the clear water reservoir when the water quality satisfies the standard value. During this period, the SSF treated water is drained, it means wasting valuable raw water and energy for pumping. By this modification, it can be drained from the downstream side of the effluent weir so that it is possible to prevent the surface of the filter layer from being exposed, the air binding phenomenon etc. By doing so, it is expected that the biofilm in the SSF will be formed in a shorter period of time, and the treated water quality will be stabilized and improved.

In response to the changes in raw water quality in the Dry Aru reservoir, it is possible to better the quality selectively in intake raw water. It can be expected that the amount of water conveyed will be increased more than at present. However, this proposal will be finalized after all the water quality analysis results are obtained and examined comprehensively and thoroughly.

(4) Measure-4: Installation of Pre-treatment Facilities

For details, refer to "**8. Study on Pre-Treatment Method**" in the next section.

8. Study on Pre-Treatment Method

8-1 Study Results and Necessity of Pre-Treatment

(1) Result of Continuous Operation

① Water quality of the Dry Aru reservoir has been changing since 2011, and the algal concentration has been increasing from 175,000 cell/mL in 2011 to 1,010,000 cell/mL in 2019.

② As a result of SSF continuous operation for 59 days in the dry season, treated water turbidity of SSF satisfied the water quality standard value for about 16 days and the colour for about 3 days. No odour was felt for 31 days out of 59 days in the whole test period.

③ During the rainy season, the raw water turbidity increased when the rainfall was high. The colour also increased with this, and the turbidity and colour of the treated water could not satisfy the water quality standard value.

④ From the survey results, it was confirmed that it was difficult to surely remove turbidity and colour of the treated water to below the standard value by carrying out continuous operation only for the current raw water quality during dry and rainy season.

⑤ Therefore, it is considered necessary to construct a pre-treatment facility in front of the current facility and to improve the water quality to the condition where SSF can be treated.

(2) Result of Jar Test

As a result of the jar test, it was found that the coagulation sedimentation treatment was effective for algae-derived turbidity and colour in the dry season and high turbidity in the rainy season as shown in below **Table 8-1** and **Table 8-2**.

Table 8-1 Results of Jar Tests in Dry Season

Coagulant	Alum
Date	24th Oct.
Raw Water Quality	Turbidity: 26.3 NTU Colour: 350 unit pH: 7.7
Dosage (mg/L)	**70**
Supernatant Water Turbidity (NTU)	0.78
Supernatant Water Colour (unit)	**0**
Supernatant Water pH (-)	7.1

Table 8-2 Results of Jar Tests in Rainy Season

Coagulant	Alum	PACl	Alum	PACl
Date	15th Nov.		11th Dec.	
Raw Water Quality	Turbidity: 54.8 NTU Colour: >550 Unit pH: 7.2 Chlorophyll-a: 45.3 µg/L		Turbidity: 74.4 NTU Colour: - unit*) pH: 7.6 Chlorophyll-a: -	
Dosage (mg/L)	**70**	**50**	**80**	**50**
Supernatant Water Turbidity (NTU)	4.2	1.5	7.7	1.1
Supernatant Water Colour (unit)	**56**	**9**	- *)	- *)

Coagulant	Alum	PACl	Alum	PACl
Supernatant Water pH (-)	6.2	6.8	7.0	7.5
Supernatant Water Chlorophyll-a (μg/L)	14.7	1.6	-	-
Supernatant Water Aluminium (mg/L)	-	-	0.07	0.14

**) Measurement was not possible due to the maintenance of the colourimeter.*

(3) Survey Results of the Kitayamada WTP

The operation data of Kitayamada WTP in Japan, which has "Coagulation-Sedimentation" facility as a pre-treatment for "RF + SSF", is shown below.

Turbidity Raw Water: max.150 NTU ⇒After Coagulation-Sedimentation: ave.**0.8 NTU** ⇒After RF: ave. **0.1 NTU**
Colour Raw Water: max.22.8 unit ⇒ After SSF: max. **0.9 unit**
Algae Concentration (Raw Water): **5,000 cell/mL** (at highest period)

- Raw Water Turbidity of 150 NTU (Maximum) is sufficiently treated to 0.8 NTU by Coagulation-Sedimentation process.
- Colour of 22.8 unit (Maximum), which is lower than KWTP, is treated to 0.9 unit by SSF and its removal ratio is up to 96%.
- With proper O&M, high turbidity and algae can be treated with "Coagulation-Sedimentation + RF + SSF".
- However, it is uncertain whether high concentration of algae can be treated, because the Kitayamada WTP has a lower algal concentration of raw water than that of Kilinochchi.
- Further, NWSDB is in the opinion that due to high coagulant dosing such as PACL or Alum, residual coagulant in the effluent water of sedimentation unit will disturb the bio film in SSF.

(4) Survey Results of the WTP in Ampara

The operation of the Konduwatuwana WTP in Ampara, which uses the DAF-system as a pre-treatment for rapid sand filters (RSF), is shown below. The WTP consists of two types of WTPs, ECTAD Plant (72,000m^3/day) and KfW Plant (6,800m^3/day), located next to each other.

Turbidity	
ECTAD WTP	Raw Water: max.13.5 NTU ⇒After DAF & RSF : ave. **1.0 NTU**
KfW WTP	Raw Water: max.12.5 NTU ⇒After DAF : ave. **5.23 NTU** ⇒After RSF: ave. **0.93 NTU**
Colour	
ECTAD WTP	Raw Water: max.185 unit ⇒After DAF & RSF: max. **12 unit**
KfW WTP	Raw Water: max.185 unit ⇒After DAF: max. **61 unit** ⇒After RSF: max. **8 unit**
Algae Concentration (Raw Water): **72,000 cell/mL** (at highest period)	

- Raw water turbidity 12.5 NTU has been treated by DAF up to 5.23 NTU.

- Raw water colour of 185 unit has been treated up to 61 unit by the DAF (removal rate of 67%). However, powdered activated carbon is injected.
- As a result of this operation, it was confirmed that turbidity and colour mainly derived from algae could be treated by DAF, if appropriate O&M was carried out.
- However, since turbidity, colour and algae concentrations in Konduwatuwana WTPs are lower than those in KWTP, it was not possible to confirm whether these can be reliably removed by the introduction of DAF.

(5) Necessity of Pre-Treatment Facilities

Table 8-3 shows the upper limit values of raw water turbidity and colour in case a coagulation sedimentation tank is introduced upstream of the existing RF+SSF. Based on the above-mentioned survey results, the turbidity and colour removal rate of RF and SSF are obtained as shown below. The removal rate of coagulation-sedimentation is also calculated by the jar test results (see **Table 8-1** and **Table 8-2**) as shown below.

Table 8-3 Turbidity and Colour Removal Rate and Calculated Upper Limit in Case Coagulation Sedimentation Treatment is introduced

Item	Conditions	Coagulation Sedimentation Removal Rate (%)	Existing RF Removal Rate (%)	Existing SSF Removal Rate (%)	**Upper Limit Values of Raw Water**[*1]	Raw Water Quality during Test
Turbidity	Dry Season (Alum)	97	63	81	**948 NTU**	40 NTU
	Rainy Season (Alum)	91	53	80	**236 NTU**	341 NTU
	Rainy season (PACl)	98			**1,064 NTU**	
Colour	Dry Season (Alum)	99. 8[*2]	61	78	**87,413 unit**	> 550 unit
	Rainy Season (Alum)	> 90 *[3]	59	73	**> 1,355 unit** [*3]	> 550 unit
	Rainy Season (PACl)	> 98 *[3]			**> 6,775 unit** [*3]	

**1) For example, the upper limit of raw water turbidity in dry season, 948 NTU, can be calculated as follows;*
Standard value: 2 NTU / (1- 81%) / (1-63%) / (1-97%) = 948 NTU

**2) The colour removal rate was calculated using the treated water colour as a 1 unit.*

**3) Since the raw water colour value exceeded the measurement range of colour meter, the upper limit was calculated using the raw water colour as 550 unit.*

According to the above results, the upper limit of raw water turbidity is 948 NTU and that of colour is 87,413 unit in case coagulation/flocculation/sedimentation treatment is performed using Alum as a flocculant in the dry season. The calculated upper limit value of raw water turbidity: 948 NTU is approx. 24 times larger than the actual raw water turbidity: 40 NTU. Hence, these values mean that the deteriorated raw water quality during dry season confirmed in this FU Study can be treated sufficiently, and the same thing can be said for rainy season.

However, considering the actual condition of jar test, the removal rate of turbidity and colour as shown in **Table 8-3** are excessive and these values will be less in the site by the following reasons;

- Floating microflocs were observed on water surface in the beaker during the jar test.

- Water quality of the supernatant water was measured by excluding these floating microflocs.

For this reason, the upper limit values of raw water turbidity and colour in the dry season were evaluated using the algae removal rate (average value): 60%*3 by coagulation/flocculation/sedimentation process as shown in a Japanese literature.

**3) Removal rate of Anacystis and Chroococcus which are dominant species detected in the treated water of KWTP is unknown. Therefore, removal rate of Microcystis which is shown in "Guidance for Water Treatment to Prevent Biological Fouling" (Japan Water Works Association, March 2006), since Anacystis, Chroococcus and Microcystis are categorized in cyanobacteria.*

Table 8-4 Upper Limits based on Algae Removal Rate in Dry Season

Item	Coagulation Sedimentation Removal Rate (%)	Existing RF Removal Rate (%)	Existing SSF Removal Rate (%)	Sedimentation Inflow Upper Limit	Raw Water Quality during Test
Turbidity	60 *3)	63	81	**75 NTU**	40 NTU
Colour	60 *3)	61	78	**435 unit**	**> 550 unit**

According to **Table 8-4** above, since the raw water colour during the test period exceeded the upper limit of sedimentation tank inflow, only coagulation/flocculation/sedimentation treatment is considered to be insufficient as a pretreatment. However, the coagulation-sedimentation removal rate used for the examination: 60% is the value on the safe side, and on the other hand, in case the removal rate based on the jar test results is used, both turbidity and colour can be treated sufficiently. Therefore, it is necessary to verify the reasonable value by the additional verification test.

From the above, the following are candidates for the pre-treatment facilities:

- "Coagulation-Sedimentation" based on jar test results and operation results at Kitayamada WTP; and
- "DAF" based on operation results at Konduwatuwana WTP. However, since "DAF" alone cannot treat high turbidity in the rainy season, the following two methods will be examined.

Alternative-1: "Coagulation-Sedimentation"
Alternative-2: "Coagulation-Sedimentation" with "DAF"

8-2 Outline and Features of the Pre-Treatment Method

8-2-1 Coagulation-Sedimentation

(1) Outline

Algae and suspended particles contained in raw water of the Dry Aru reservoir and coagulants are rapidly mixed and formed microflocs are grown in flocculation tank. The grown floc sediments and separates in the sedimentation tank of the subsequent stage, and the sediment floc is discharged out of the system periodically through the de-sludge valve.

At the moment, the mechanical stirring is adopted for coagulation and flocculation tank so that the stirring strength can be adjusted for the fluctuation of the treated water quantity, and in addition, it is a policy to

install plate settler or tube settler from the viewpoint of space saving.

Further, the period in which the coagulation-sedimentation treatment is not required except in the dry season and the rainy season, stops the chemical injection and mechanical stirring, it is possible to reduce the operation cost. Examples of the introduction of coagulation-sedimentation facility are shown in **Photo 8-1**.

	
Baffling Type Coaguration-Sedimentation Tank (Narok, Kenya)	**Mechanical Stirring Type Flocculation Tank (Vavuniya, Sri Lanka)**

Photo 8-1 Introduction Example

(2) Features

<Advantages>

- ✓ Stable algae removal is possible (80-90% removal of plankton algae according to Water Facility Design Guidance 2012).
- ✓ It is also effective as a measure against high turbidity in the rainy season.

<Disadvantages>

- ✓ Algae such as Synedra, Melosira, and Microcystis cannot be sufficiently removed.

8-2-2 Coagulation-Sedimentation with DAF

(1) Outline

The DAF (Dissolved Air Flotation) is a method in which, after air is injected into raw water, fine bubbles generated by decompression are attached to suspended particles contained in raw water, and they are forcibly floated and removed by lowering the apparent density. In particular, it is effective for poorly settling particles such as algae.

This system is also effective for suspended particles other than algae and can handle raw water turbidity to some extent (according to the manufacturer's recommendation, the upper limit is about 70 NTU). However, the results of past and present investigations also show that the raw water turbidity of the Dry Aru reservoir rose to about 300 NTU in the rainy season, and it may not be possible to deal with the situation when DAF is installed independently. Therefore, the coagulation-sedimentation tank and DAF are integrated, and it is operated as a coagulation- sedimentation tank in the rainy season when the raw water turbidity is high, and DAF is stopped. In the dry season, on the other hand, it is effective to operate only DAF during algae bloom, and to pass the coagulation- sedimentation tank as it is.

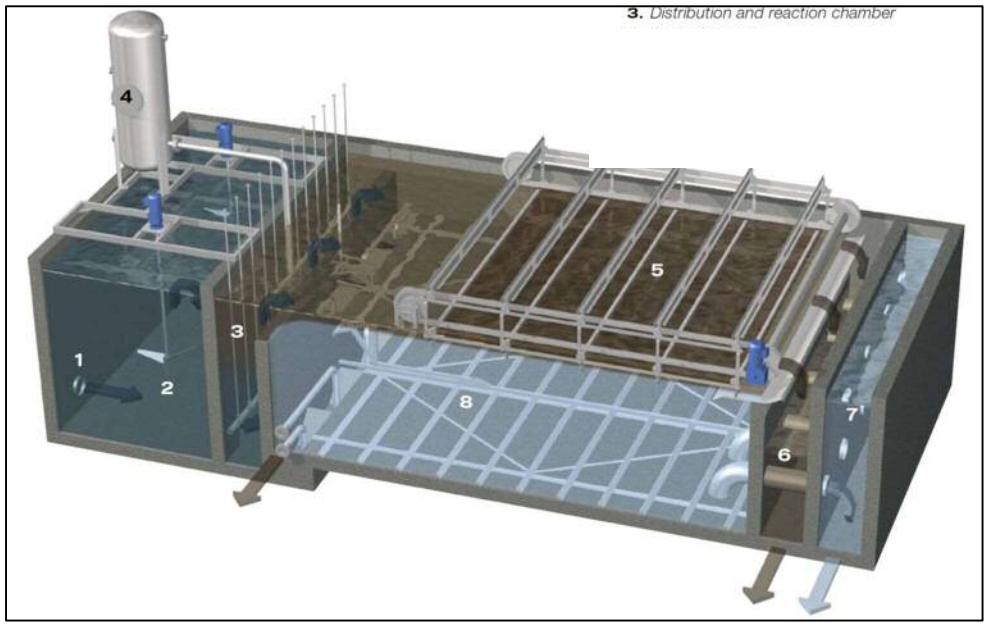


Figure 8-1 Reference Diagram of the Dissolved Air Flotation Unit (DAF) alone

(2) Features

<Advantages>

- ✓ Raw water including algae and high turbidity can be treated stably. (DAF alone can only handle up to about 70 NTU of raw water turbidity, but coagulation-sedimentation can accommodate high turbidity.)

<Disadvantages>

- ✓ The installation area is large.
- ✓ Construction and O&M costs are expensive.

8-2-3 Outline of Pre-Treatment Facility

(1) Proposed Pre-Treatment Facility Layout and Water Treatment Flow

The site for construction of the pre-treatment facility is supposed to be a pipe yard on the back side of the existing Electrical & Generator House in KWTP site as shown in **Figure 8-2**.

The outline plan of the pretreatment facility and the water purification flow are shown below.

In addition, the following layout drawings and the water purification flow may be changed due to the results of the examination of the necessity of additional pumps and the ability of appropriate water intake pumps, etc. in accordance with the progress of verification tests and detailed designs to be conducted in the future.

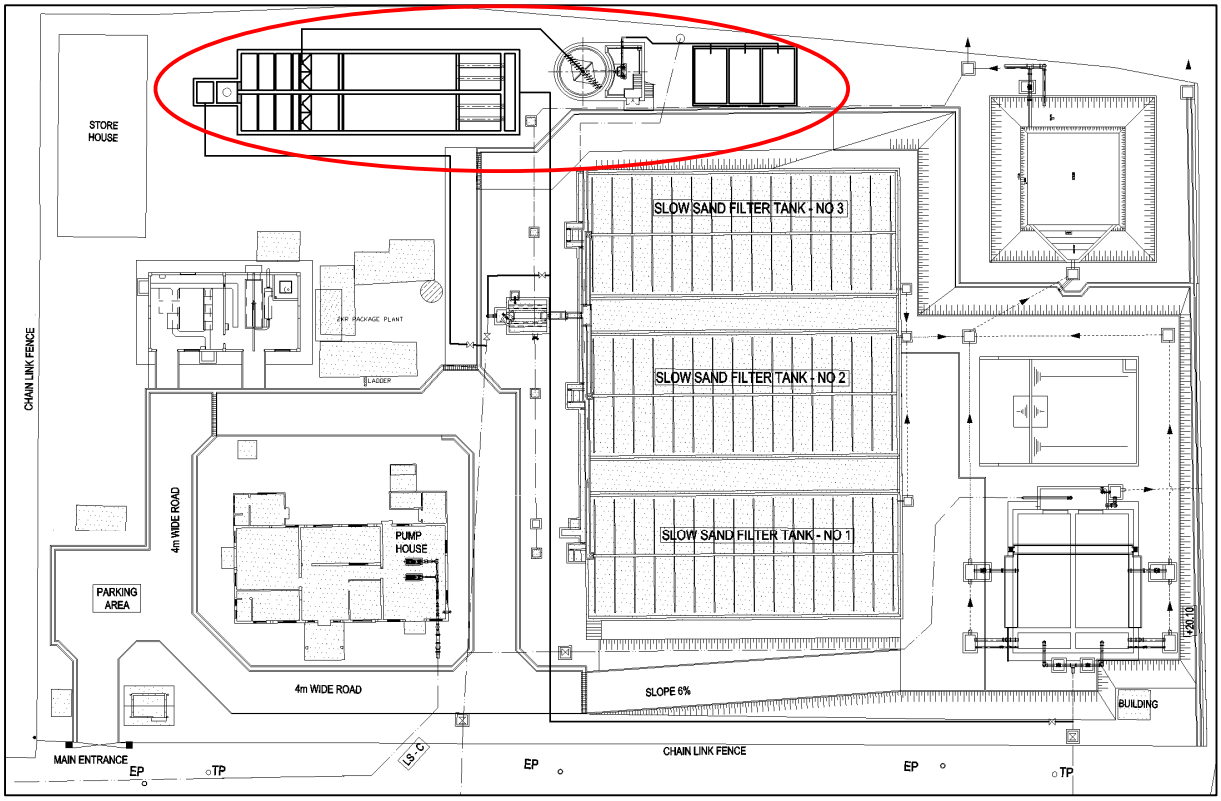


Figure 8-2 Layout Plan of Pre-Treatment Facilities

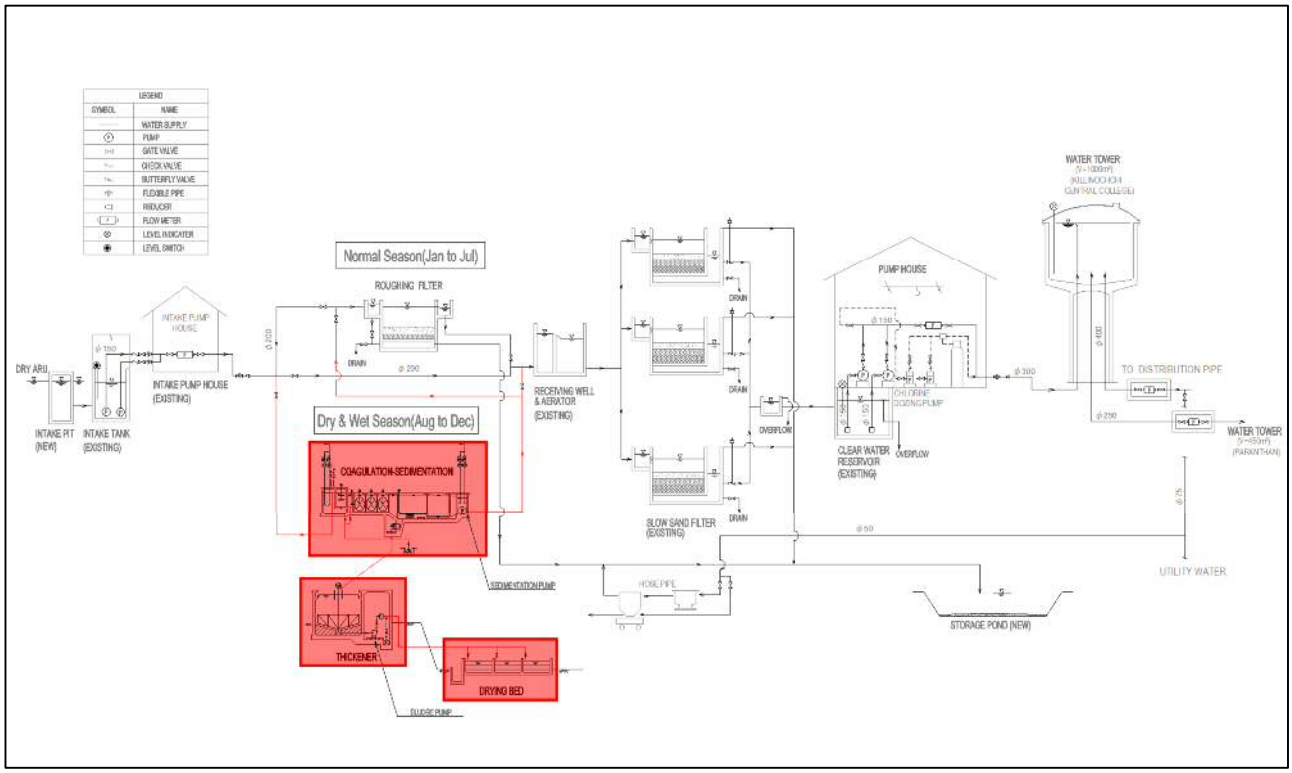


Figure 8-3 Water Treatment Flow Diagram

(2) Proposal for Installation of Plate Settler/Tube Settler in Coagulation-Sedimentation Tank

The plate settler/tube settler is considered for the pre-treatment facility because construction area in KWTP

is limited. By installing the plate settler/tube settler in a sedimentation tank, a multi layered sedimentation tank is formed, and flocks which are difficult to settle are surely captured and settled.

Photo 8-2 Tube Settler in Coagulation-Sedimentation Tank

8-3 Comparative Study

Table 8-5 shows a comparative study of algae and turbidity removal effects, operation & maintenance aspects, construction costs, O&M costs, etc. for the two methods described above.

Table 8-5 Comparison of Pre-Treatment Methods

Item		<Alternative-1> Coagulation-Sedimentation		< Alternative-2> Coagulation-Sedimentation with DAF	
1	Outline	Algae and turbidity are reduced and removed by coagulation sedimentation.		Turbidity is reduced and removed by flocculation sedimentation and algae by DAF.	
2	Effect of Algae Removal	✓ Generally, 80-90% of algae can be removed in Japan. ✓ *Synedra, Melosira, Microcystis* detected in Dry Aru may not be sufficiently removed. ✓ According to the operation record of Kitayamada WTP, raw water turbidity of 150 NTU (max.) including algae has been treated to 0.8 NTU by coagulation sedimentation treatment.	△	✓ The removal effect for algae is highest. ✓ According to the operation record of Konduwatuwana WTP in Anpara, raw water turbidity of 12. 5 NTU, including algae, was treated by DAF to 5.23 NTU, and raw water colour of 185 unit was removed by DAF to 61 unit (although powdered activated carbon was injected).	◎
3	Effect of Turbidity Removal	✓ High turbidity can be treated by coagulation-sedimentation process.	◎	✓ Same as left.	◎
4	Reliability of Treatment	✓ Since only coagulation-sedimentation facility is installed, if a malfunction occurs in the facility, it may not be possible to remove algae and turbidity as specified.	△	✓ Regarding the removal of algae, the reliability of the treatment is higher than that of Alternative-1, because coagulation-sedimentation is in the subsequent stage even when a failure occurs in the DAF.	○
5	Operation and Maintenance	✓ Since chemical injection management based on jar tests is the main activity, O&M is easier than Alternative-2.	○	✓ In addition to chemical injection management based on jar tests, there are many daily monitoring, inspection, and maintenance works due to the large number of equipment, and skill and labor are required. ✓ NWSDB has O&M experience of DAF. ✓ DAF is no experience in Japan. Support from Japan side is difficult.	○
6	**Estimated Construction Cost** (Pre-treatment facility only) (In case of an inclined plate is installed)	Approx. **145 million LKR (**Approx. **90 million JPY)** ✓ Since one facility is constructed, the construction cost can be kept low compared with Alternative -2.	○	Approx. 27**0 million LKR (**Approx. **170 million JPY)** *(Construction cost in case coagulation sedimentation tank and DAF are built in one structure)* ✓ Construction cost is higher than Alternative-1 because of the construction of the two facilities and the high construction costs of the DAF itself. ✓ Since coagulation-sedimentation tank and DAF are built in one structure, the construction cost can be reduced as described above in comparison with the case of constructing two facilities separately. ✓ Concerning DAF. There are about six plants in Sri Lanka, but no experience in Japan. Support from Japan side is difficult.	○
7	**O&M Cost** Pre-Treatment facility only) (electricity and chemicals cost only)	Approx. **500 thousand LKR/month (**Approx. **320 thousand JPY/month)**	○	Approx. **600 thousand LKR/month (**Approx. **380 thousand JPY/month)**	○

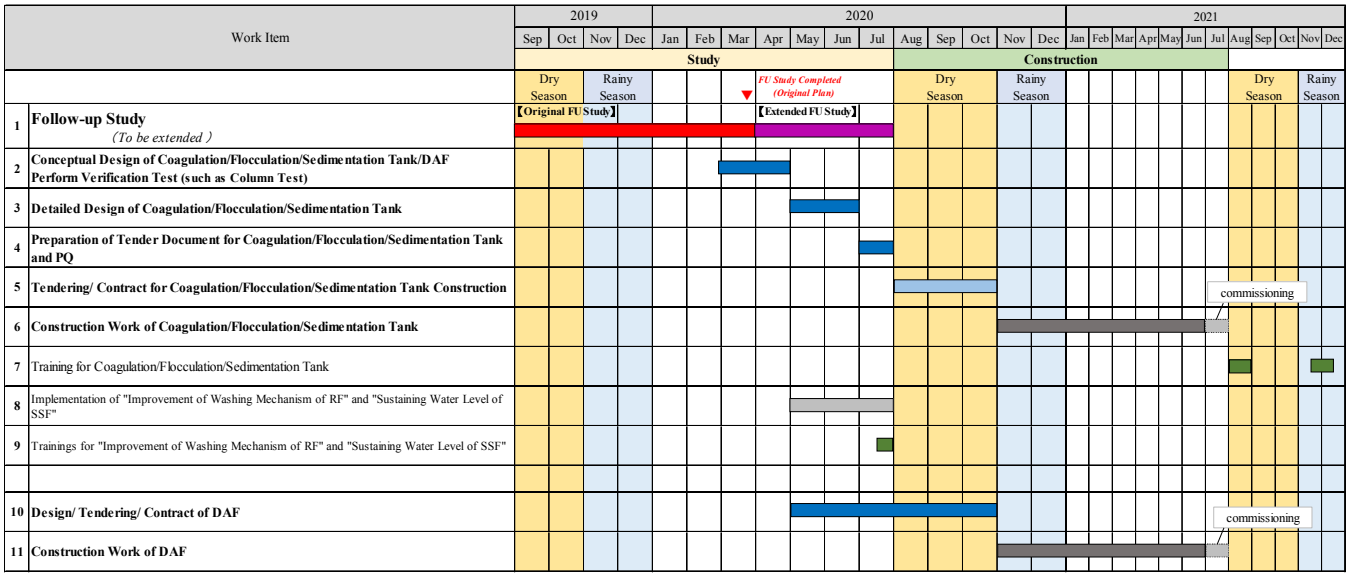
◎ : Very Good、 ○: Good、 △: Fair、 ×: Not Good

8-4 Future Countermeasures

As shown in "8-1 (5) Necessity of Pretreatment Facilities" and **Table 8-5** above, it is impossible to determine at the moment whether **<Alternative-1> Coagulation-Sedimentation** or **<Alternative-2> Coagulation-Sedimentation with DAF**.

As of March 2020, FU Study Team will not draw up any conclusions and propose to continue this FU study as follows.

i) This FU study will be extended to July 2020.
ii) Conduct conceptual design on Coagulation-Sedimentation and DAF in March and April 2020 during the extended period of the FU study.
iii) Detailed design and tendering/ contract of Coagulation Flocculation/Sedimentation Tank will also be conducted from May to July 2020.
iv) Tentative Schedule of Kilinochchi Follow-up Study (Draft) is shown below.



Remarks

1. *The above tentative schedule will be carried out if JICA's cooperation is approved.*
2. *Coagulation Sedimentation Tank is planned to construct for turbidity countermeasures in rainy season.*
3. *Coagulation Sedimentation Tank can remove some of the algae, but not totally.*
4. *Decision of combine or separate structure of "Coagulation Sedimentation" and "DAF" will be studied at the Conceptual Design period.*
5. *Construction period of Coagulation/Flocculation/Sedimentation Units is set as 9 months including commissioning.*

Figure 8-4 Tentative Schedule of Kilinochchi Follow-up Study (Draft)

9. Suggestion

i) Reducing Grazing of Livestock (particularly cattle) in Catchments in Iranamadu and Dry Aru Reservoirs

Specially during the dry season, a large number of livestock (in particular catmint) were randomly grazed around Iranamadu reservoir (catchment area) as shown in **Photo 9-1**, and their manure flow into Iranamadu

reservoir. This is one of the causes for high growth of Algae in the reservoir. These algae flow into Dry Aru reservoir through the irrigation channel as shown in **Photo 9-2**.

Hence the public who owns the cattle should be made aware, in order to reduce the pollution effect due to grazing and relevant regulations should be established to restrict grazing. This will help to control high growth of Algae and consequently improve the water quality of reservoirs.

Photo 9-1 Grazing of Cattle in Iranamadu Reservoir (Rainy Season)

Photo 9-2 Abnormal Growth of Algae in Dry Aru Reservoir

ii) KWTP O&M System

KWTP is operated under a three-shift system consisting of three members; 1 Technician and 2 operators. During the operation turbidity and color of raw and treated water are measured. Although Labor, etc. are also arranged, operation control is not carried out, and only cleaning of facilities such as filters and cleaning of the inside of the water treatment plant, etc. are carried out.

Problems with the O&M system in water treatment plants and response proposals are shown below.

- At the moment, there is insufficient Operator.
- The system is operated and managed 24 hours a day, including holidays, by only three people including Technician.
- In addition, the operation and management of the packaged plant was also carried out under this system, and it was found that some management, such as appropriate injection of coagulants, was neglected.
- We propose to perform 24-hour continuous operation in four shifts, even if it is small. For this reason, as shown in Table 9-1, Operator needs to be increased from the current activities, two to four.
- This is considered necessary because the number of management and inspection items also increases when a pretreatment facility is newly constructed.

Table 9-1 Proposals for increasing O&M Staff at KWTP

In charge		Number of staffing	
		Current status	Proposal
①	OIC (field length)	1	1
②	Plant Technician	1	1
③	**Plant Operator**	**2**	**4**

In charge		Number of staffing	
		Current status	Proposal
④	Driver	3	3
⑤	Electrician	1	1
⑥	Labor	2	2
⑦	Sanitary Labor Con (cleaner)	1	1
Total		11	**13**

iii) Coordination between NWSDB and the Department of Irrigation

The results of this FU Study showed that the opening and closing operations of the runoff gates of Iranamadu reservoir and Dry Aru reservoir, which affect the raw water quality of the Kilinochchi Water treatment plant, will be carried out at the judgment of the Department of Irrigation mainly on the request of farmers, but there is no information provided to NWSDB. In the rainy season in particular, it was found that the turbidity and colour of the raw water increased rapidly when the outflow gates of Dry Aru reservoirs installed near the existing intake facilities were opened.

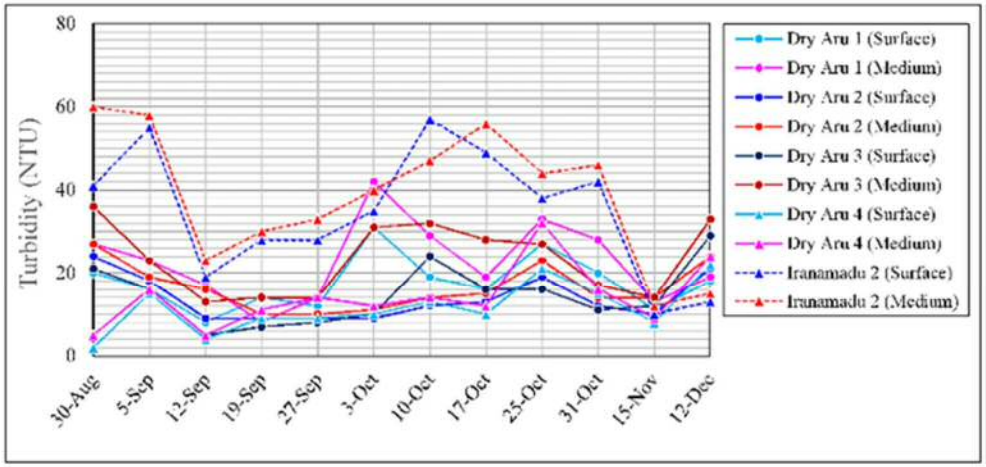
Accordingly, the Department of Irrigation should consult with NWSDB in the future, and when opening and closing the spill gates, the Department of Irrigation should establish a coordination system to communicate with NWSDB in advance. It is also recommended that both sides cooperate and work together to exchange necessary information including rainfall, etc. possessed by the Department of Irrigation, and to improve the water quality of Iranamadu reservoir and Dry Aru reservoir proposed in (i) above.

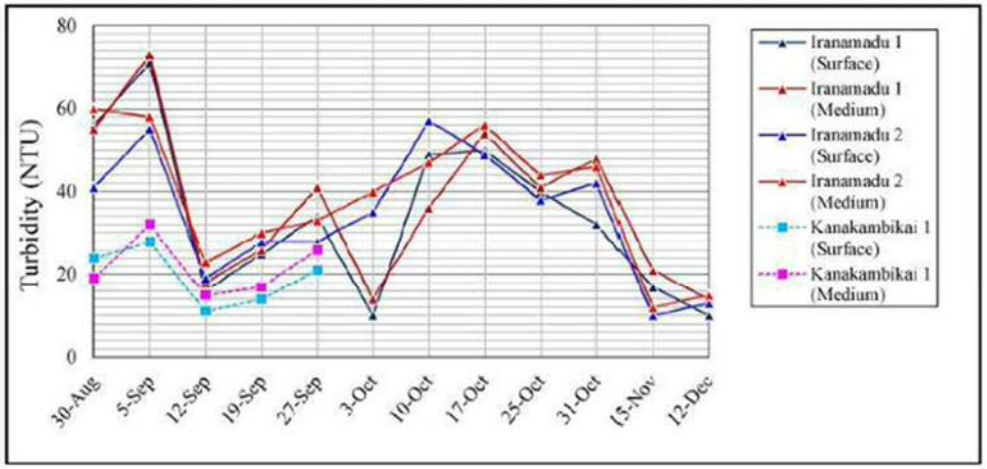
Appendix

Appendix-1: Results of Water Quality Analysis of the Reservoirs

1. Turbidity/ NTU

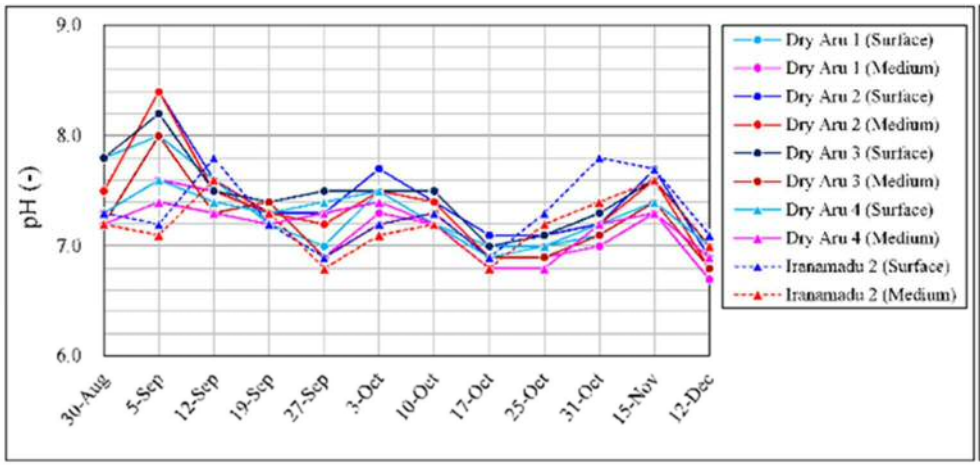
Date of Sampling			Average	Max.	Min.	30-Aug	5-Sep	12-Sep	19-Sep	27-Sep	3-Oct	10-Oct	17-Oct	25-Oct	31-Oct	15-Nov	12-Dec
Dry Aru	01-Canal from Iranamadu	Surface	18	31	8	20	16	8	14	12	31	19	16	27	20	11	18
		Medium*1	23	42	8	27	23	17	8	14	42	29	19	33	28	13	19
	02-Center of the tank	Surface	14	24	9	24	18	9	9	9	9	12	13	19	12	10	21
		Medium*2	16	27	10	27	19	16	10	10	11	14	15	23	14	14	24
	03-Near Water Board Intake	Surface	15	29	5	21	16	5	7	8	10	24	16	16	11	12	29
		Medium*3	24	36	13	36	23	13	14	14	31	32	28	27	17	14	33
	04-Canal from Kanakambikai	Surface	12	22	2	2	15	4	9	9	10	13	10	21	15	8	22
		Medium*4	14	32	5	5	16	5	11	14	12	14	12	32	16	9	24
Iranamadu	01-Center of the reservoir	Surface	34	71	10	56	71	16	25	34	10	49	50	40	32	17	10
		Medium*5	37	73	14	55	73	18	26	41	14	36	54	41	48	21	14
	02-Near Irrigation Office	Surface	35	57	10	41	55	19	28	28	35	57	49	38	42	10	13
		Medium*6	39	60	12	60	58	23	30	33	40	47	56	44	46	12	15
Kanakambikai	01-Near Spill	Surface	20	28	11	24	28	11	14	21	-	-	-	-	-	-	-
		Medium*7	22	32	15	19	32	15	17	26	-	-	-	-	-	-	-

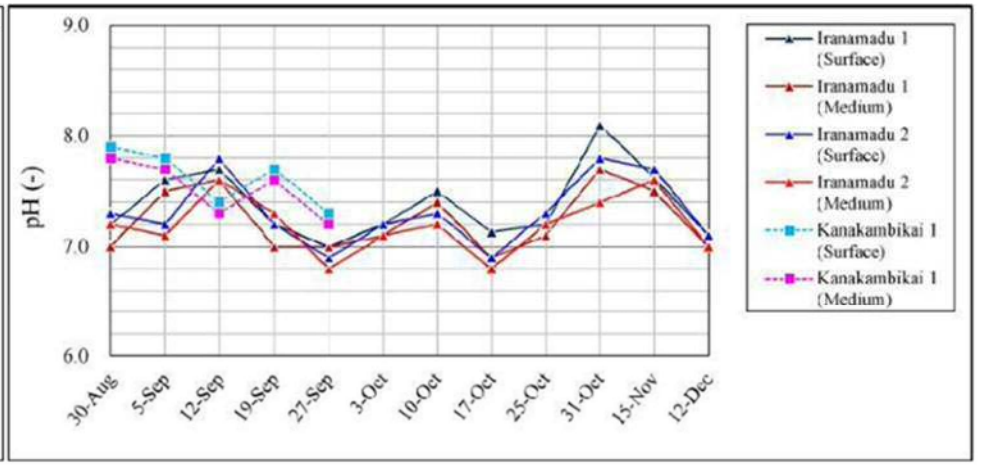




2. pH

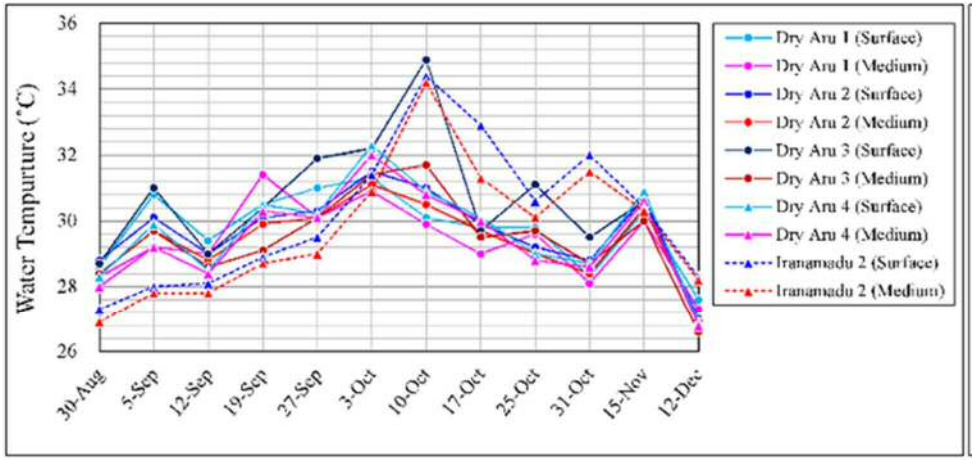
Date of Sampling			Average	Max.	Min.	30-Aug	5-Sep	12-Sep	19-Sep	27-Sep	3-Oct	10-Oct	17-Oct	25-Oct	31-Oct	15-Nov	12-Dec
Dry Aru	01-Canal from Iranamadu	Surface	7.3	8.0	6.8	7.8	8.0	7.6	7.2	7.0	7.5	7.2	7.0	7.0	7.1	7.4	6.8
		Medium*1	7.2	7.6	6.7	7.3	7.6	7.5	7.4	6.9	7.3	7.2	6.9	6.9	7.0	7.3	6.7
	02-Center of the tank	Surface	7.4	8.4	6.9	7.5	8.4	7.6	7.3	7.3	7.7	7.4	7.1	7.1	7.2	7.7	6.9
		Medium*2	7.4	8.4	6.8	7.5	8.4	7.5	7.3	7.2	7.5	7.4	6.9	7.0	7.2	7.6	6.8
	03-Near Water Board Intake	Surface	7.5	8.2	7.0	7.8	8.2	7.5	7.4	7.5	7.5	7.5	7.0	7.1	7.3	7.6	7.0
		Medium*3	7.2	8.0	6.8	7.2	8.0	7.3	7.4	6.9	7.2	7.3	6.9	6.9	7.1	7.4	6.8
	04-Canal from Kanakambikai	Surface	7.3	7.6	6.9	7.3	7.6	7.4	7.3	7.4	7.5	7.2	6.9	7.0	7.2	7.4	7.0
		Medium*4	7.2	7.4	6.8	7.2	7.4	7.3	7.2	7.3	7.4	7.2	6.8	6.8	7.2	7.3	6.9
Iranamadu	01-Center of the reservoir	Surface	7.4	8.1	7.0	7.2	7.6	7.7	7.2	7.0	7.2	7.5	7.1	7.2	8.1	7.6	7.1
		Medium*5	7.2	7.7	6.9	7.0	7.5	7.6	7.0	7.0	7.1	7.4	6.9	7.1	7.7	7.5	7.0
	02-Near Irrigation Office	Surface	7.3	7.8	6.9	7.3	7.2	7.8	7.2	6.9	7.2	7.3	6.9	7.3	7.8	7.7	7.1
		Medium*6	7.2	7.6	6.8	7.2	7.1	7.6	7.3	6.8	7.1	7.2	6.8	7.2	7.4	7.6	7.0
Kanakambikai	01-Near Spill	Surface	7.6	7.9	7.3	7.9	7.8	7.4	7.7	7.3	-	-	-	-	-	-	-
		Medium*7	7.5	7.8	7.2	7.8	7.7	7.3	7.6	7.2	-	-	-	-	-	-	-

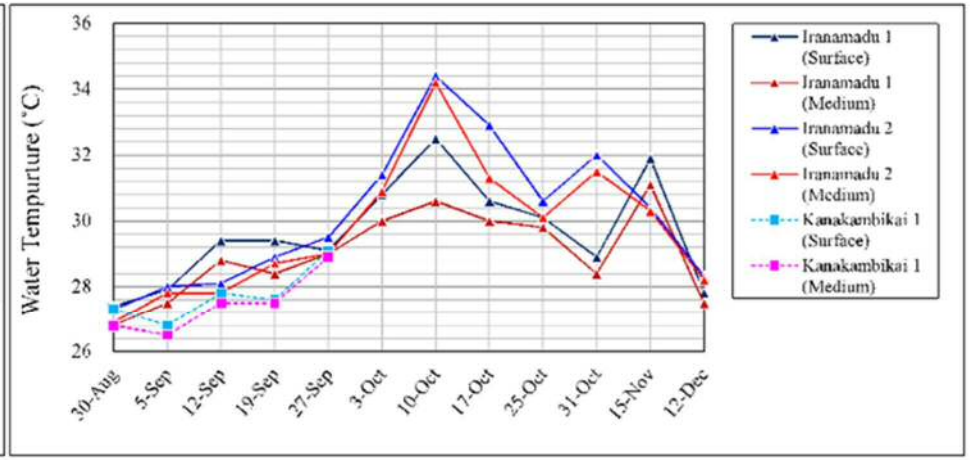




3. Water Tempurture /℃

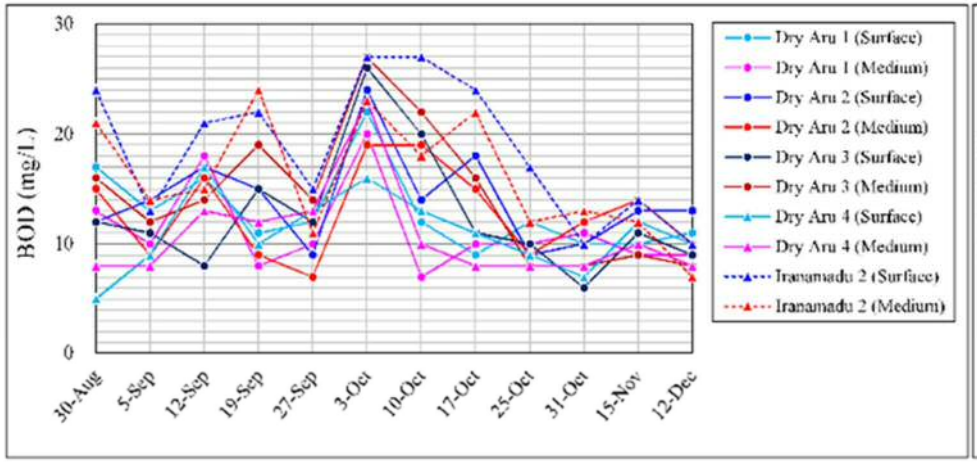
Date of Sampling			Average	Max.	Min.	30-Aug	5-Sep	12-Sep	19-Sep	27-Sep	3-Oct	10-Oct	17-Oct	25-Oct	31-Oct	15-Nov	12-Dec
Dry Aru	01-Canal from Iranamadu	Surface	29.8	31.3	27.6	28.6	30.8	29.4	30.5	31.0	31.3	30.1	29.8	29.8	28.3	30.3	27.6
		Medium*1	29.4	31.4	27.3	28.3	29.2	29.0	31.4	30.1	30.9	29.9	29.0	29.6	28.1	30.0	27.3
	02-Center of the tank	Surface	29.7	31.5	27.0	28.8	30.1	29.0	30.1	30.3	31.5	31.0	29.9	29.2	28.8	30.7	27
		Medium*2	29.4	31.1	26.9	28.4	29.7	28.8	29.9	30.1	31.1	30.5	29.7	29.0	28.4	30.4	26.9
	03-Near Water Board Intake	Surface	30.5	34.9	26.8	28.7	31.0	29.0	30.4	31.9	32.2	34.9	29.7	31.1	29.5	30.6	26.8
		Medium*3	29.5	31.7	26.6	28.4	29.7	28.6	29.1	30.1	31.4	31.7	29.5	29.7	28.7	30.0	26.6
	04-Canal from Kanakambikai	Surface	29.7	32.3	26.9	28.3	29.9	28.5	30.5	30.2	32.3	30.9	30.1	29.0	28.7	30.9	26.9
		Medium*4	29.5	32.0	26.8	28.0	29.2	28.4	30.3	30.1	32.0	30.8	30.0	28.8	28.6	30.6	26.8
Iranamadu	01-Center of the reservoir	Surface	29.7	32.5	27.4	27.4	27.9	29.4	29.4	29.1	30.8	32.5	30.6	30.1	28.9	31.9	27.8
		Medium*5	29.0	31.1	26.8	26.8	27.5	28.8	28.4	29.0	30.0	30.6	30.0	29.8	28.4	31.1	27.5
	02-Near Irrigation Office	Surface	30.2	34.4	27.3	27.3	28.0	28.1	28.9	29.5	31.4	34.4	32.9	30.6	32.0	30.4	28.3
		Medium*6	29.7	34.2	26.9	26.9	27.8	27.8	28.7	29.0	30.9	34.2	31.3	30.1	31.5	30.3	28.2
Kanakambikai	01-Near Spill	Surface	27.7	29.1	26.8	27.3	26.8	27.8	27.6	29.1	-	-	-	-	-	-	-
		Medium*7	27.4	28.9	26.5	26.8	26.5	27.5	27.5	28.9	-	-	-	-	-	-	-

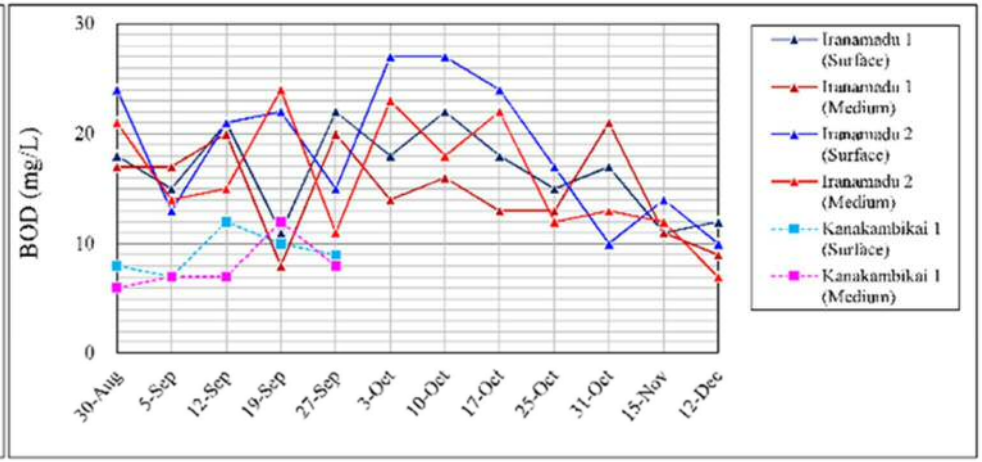




4. BOD/mg/L

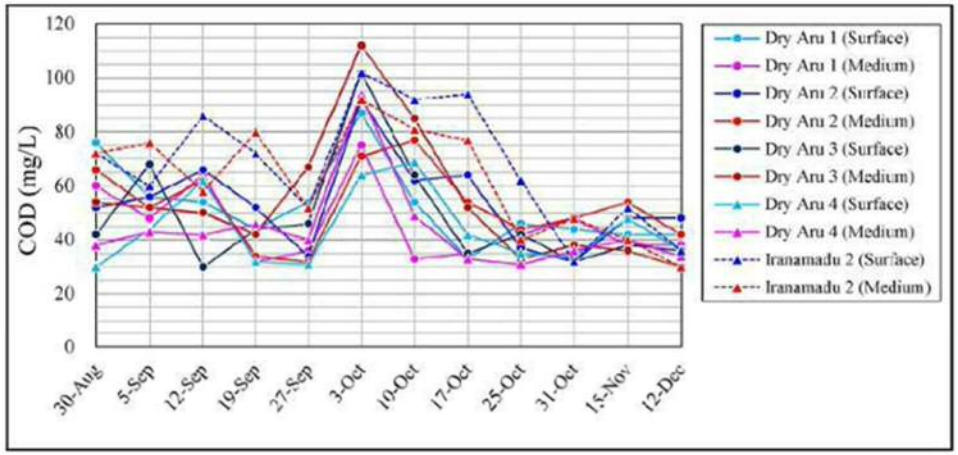
Date of Sampling			Average	Max.	Min.	30-Aug	5-Sep	12-Sep	19-Sep	27-Sep	3-Oct	10-Oct	17-Oct	25-Oct	31-Oct	15-Nov	12-Dec
Dry Aru	01-Canal from Iranamadu	Surface	13	22.0	9.0	17	13	16	11	12	22	12	9	12	10	10	11
		Medium*1	11	20.0	7.0	13	10	18	8	10	20	7	10	10	11	9	9
	02-Center of the tank	Surface	14	24.0	9.0	12	14	17	15	9	24	14	18	9	10	13	13
		Medium*2	13	19.0	7.0	15	9	16	9	7	19	19	15	9	12	14	10
	03-Near Water Board Intake	Surface	13	26.0	6.0	12	11	8	15	12	26	20	11	10	6	11	9
		Medium*3	14	27.0	8.0	16	12	14	19	14	27	22	16	8	8	9	8
	04-Canal from Kanakambikai	Surface	11	17.0	5.0	5	9	17	10	13	16	13	11	9	7	12	10
		Medium*4	11	23.0	8.0	8	8	13	12	13	23	10	8	8	8	10	8
Iranamadu	01-Center of the reservoir	Surface	17	22.0	11.0	18	15	21	11	22	18	22	18	15	17	11	12
		Medium*5	15	21.0	8.0	17	17	20	8	20	14	16	13	13	21	11	9
	02-Near Irrigation Office	Surface	19	27.0	10.0	24	13	21	22	15	27	27	24	17	10	14	10
		Medium*6	16	24.0	7.0	21	14	15	24	11	23	18	22	12	13	12	7
Kanakambikai	01-Near Spill	Surface	9	12.0	7.0	8	7	12	10	9	-	-	-	-	-	-	-
		Medium*7	8	12.0	6.0	6	7	7	12	8	-	-	-	-	-	-	-

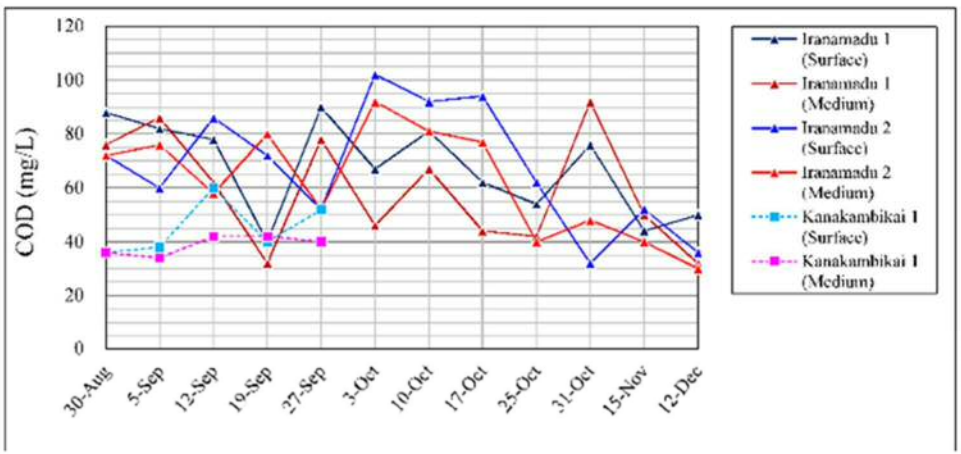




5. COD/mg/L

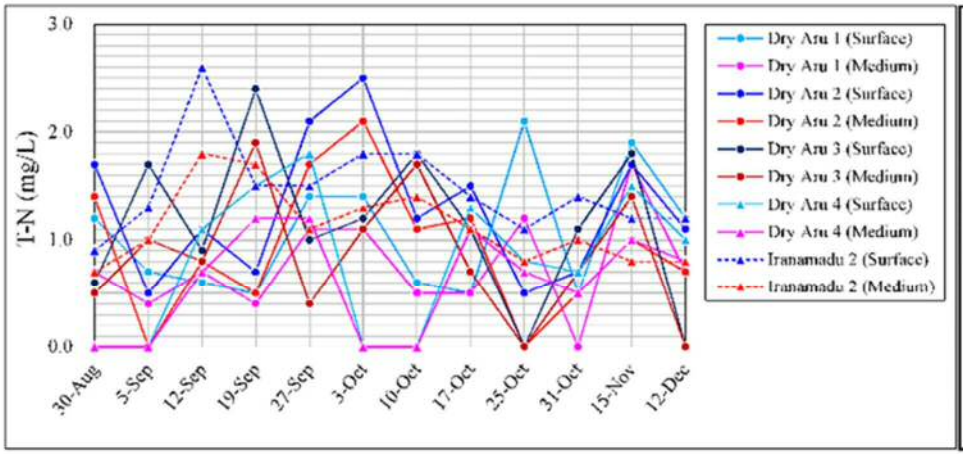
Date of Sampling			Average	Max.	Min.	30-Aug	5-Sep	12-Sep	19-Sep	27-Sep	3-Oct	10-Oct	17-Oct	25-Oct	31-Oct	15-Nov	12-Dec
Dry Aru	01-Canal from Iranamadu	Surface	53	87.0	33.0	76	56	54	44	54	87	54	33	46	44	42	42
		Medium*1	46	75.0	32.0	60	48	64	32	36	75	33	35	42	48	38	38
	02-Center of the tank	Surface	54	92.0	32.0	52	56	66	52	34	92	62	64	37	32	48	48
		Medium*2	53	77.0	32.0	66	52	62	34	32	71	77	54	44	48	54	42
	03-Near Water Board Intake	Surface	48	102.0	30.0	42	68	30	44	46	102	64	35	42	32	38	36
		Medium*3	54	112.0	30.0	54	52	50	42	67	112	85	52	33	38	36	30
	04-Canal from Kanakambikai	Surface	44	69.0	30.0	30	44	62	32	31	64	69	42	35	34	48	36
		Medium*4	44	94.0	31.0	38	43	42	46	40	94	49	33	31	36	40	34
Iranamadu	01-Center of the reservoir	Surface	68	90.0	40.0	88	82	78	40	90	67	81	62	54	76	44	50
		Medium*5	59	92.0	32.0	76	86	62	32	78	46	67	44	42	92	50	32
	02-Near Irrigation Office	Surface	68	102.0	32.0	72	60	86	72	52	102	92	94	62	32	52	36
		Medium*6	62	92.0	30.0	72	76	58	80	52	92	81	77	40	48	40	30
Kanakambikai	01-Near Spill	Surface	45	60.0	36.0	36	38	60	40	52	-	-	-	-	-	-	-
		Medium*7	39	42.0	34.0	36	34	42	42	40	-	-	-	-	-	-	-

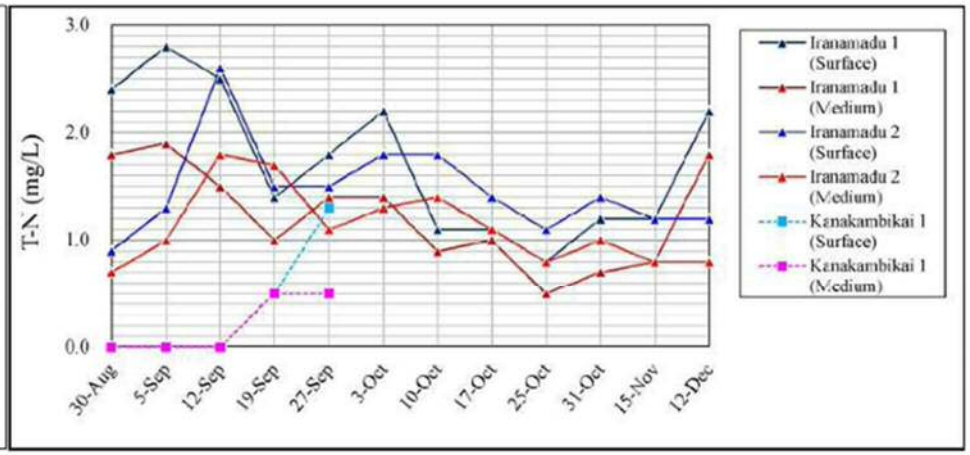




6. Total Nitrogen (as N)mg/L

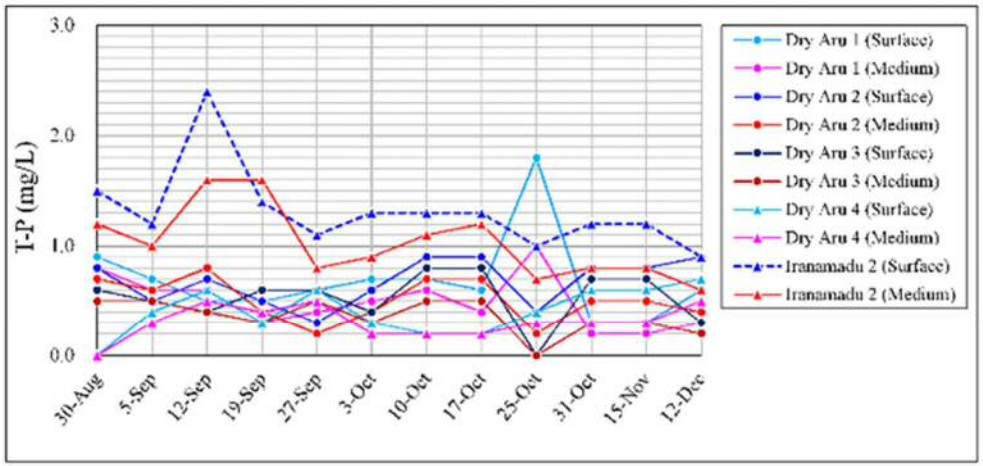
Date of Sampling			Average	Max.	Min.	30-Aug	5-Sep	12-Sep	19-Sep	27-Sep	3-Oct	10-Oct	17-Oct	25-Oct	31-Oct	15-Nov	12-Dec
Dry Aru	01-Canal from Iranamadu	Surface	1.1	2.1	0.5	1.2	0.7	0.6	0.5	1.4	1.4	0.6	0.5	2.1	0.5	1.9	1.2
		Medium*1	0.8	1.7	0.4	0.7	0.4	0.7	0.4	1.1	1.1	0.5	0.5	1.2	<0.5	1.7	0.7
	02-Center of the tank	Surface	1.3	2.5	0.5	1.7	0.5	1.1	0.7	2.1	2.5	1.2	1.5	0.5	0.7	1.7	1.1
		Medium*2	1.1	2.1	0.5	1.4	<0.5	0.8	0.5	1.7	2.1	1.1	1.2	<0.5	0.5	1.0	0.7
	03-Near Water Board Intake	Surface	1.4	2.4	0.6	0.6	1.7	0.9	2.4	1.0	1.2	1.8	1.1	<0.5	1.1	1.8	< 0.5
		Medium*3	1.0	1.9	0.4	0.5	1.0	0.8	1.9	0.4	1.1	1.7	0.7	<0.5	0.7	1.4	< 0.5
	04-Canal from Kanakambikai	Surface	1.2	1.8	0.7	<0.5	<0.5	1.1	1.5	1.8	<0.5	<0.5	1.3	0.8	0.7	1.5	1.0
		Medium*4	0.9	1.2	0.5	<0.5	<0.5	0.7	1.2	1.2	<0.5	<0.5	1.1	0.7	0.5	1.0	0.8
Iranamadu	01-Center of the reservoir	Surface	1.7	2.8	0.8	2.4	2.8	2.5	1.4	1.8	2.2	1.1	1.1	0.8	1.2	1.2	2.2
		Medium*5	1.2	1.9	0.5	1.8	1.9	1.5	1.0	1.4	1.4	0.9	1.0	0.5	0.7	0.8	1.8
	02-Near Irrigation Office	Surface	1.5	2.6	0.9	0.9	1.3	2.6	1.5	1.5	1.8	1.8	1.4	1.1	1.4	1.2	1.2
		Medium*6	1.1	1.8	0.7	0.7	1.0	1.8	1.7	1.1	1.3	1.4	1.1	0.8	1.0	0.8	0.8
Kanakambikai	01-Near Spill	Surface	0.9	1.3	0.5	<0.5	<0.5	<0.5	0.5	1.3	-	-	-	-	-	-	-
		Medium*7	0.5	0.5	0.5	<0.5	<0.5	<0.5	0.5	0.5	-	-	-	-	-	-	-

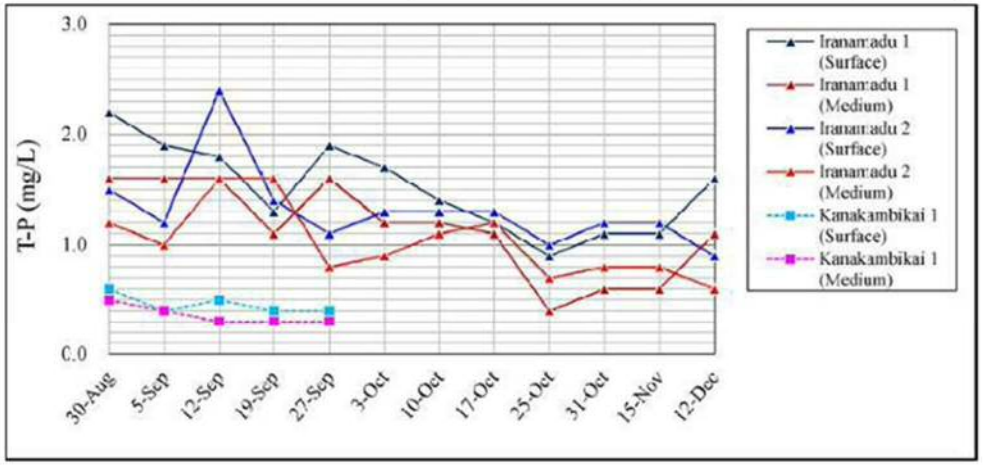




7. Total Phospate (as P)mg/L

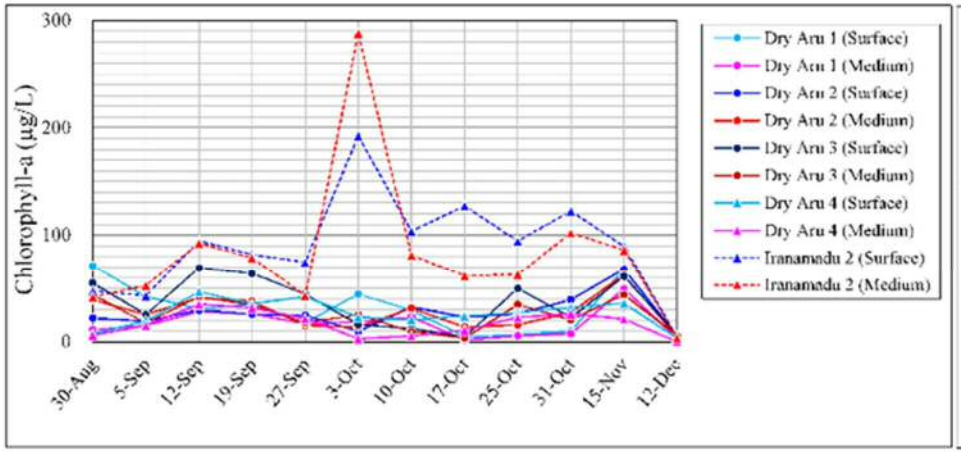
Date of Sampling			Average	Max.	Min.	30-Aug	5-Sep	12-Sep	19-Sep	27-Sep	3-Oct	10-Oct	17-Oct	25-Oct	31-Oct	15-Nov	12-Dec
Dry Aru	01-Canal from Iranamadu	Surface	0.7	1.8	0.3	0.9	0.7	0.5	0.5	0.6	0.7	0.7	0.6	1.8	0.3	0.3	0.6
		Medium*1	0.5	1.0	0.2	0.8	0.6	0.6	0.3	0.4	0.5	0.6	0.4	1.0	0.2	0.2	0.3
	02-Center of the tank	Surface	0.7	0.9	0.3	0.8	0.5	0.7	0.5	0.3	0.6	0.9	0.9	0.4	0.8	0.8	0.9
		Medium*2	0.5	0.8	0.2	0.7	0.6	0.8	0.4	0.2	0.4	0.7	0.7	0.2	0.5	0.5	0.4
	03-Near Water Board Intake	Surface	0.6	0.8	0.3	0.6	0.5	0.4	0.6	0.6	0.4	0.8	0.8	<0.1	0.7	0.7	0.3
		Medium*3	0.4	0.5	0.2	0.5	0.5	0.4	0.3	0.5	0.3	0.5	0.5	<0.1	0.3	0.3	0.2
	04-Canal from Kanakambikai	Surface	0.4	0.7	0.2	<0.1	0.4	0.6	0.3	0.6	0.3	0.2	0.2	0.4	0.6	0.6	0.7
		Medium*4	0.3	0.5	0.2	<0.1	0.3	0.5	0.4	0.5	0.2	0.2	0.2	0.3	0.3	0.3	0.5
Iranamadu	01-Center of the reservoir	Surface	1.5	2.2	0.9	2.2	1.9	1.8	1.3	1.9	1.7	1.4	1.2	0.9	1.1	1.1	1.6
		Medium*5	1.1	1.6	0.4	1.6	1.6	1.6	1.1	1.6	1.2	1.2	1.1	0.4	0.6	0.6	1.1
	02-Near Irrigation Office	Surface	1.3	2.4	0.9	1.5	1.2	2.4	1.4	1.1	1.3	1.3	1.3	1.0	1.2	1.2	0.9
		Medium*6	1.0	1.6	0.6	1.2	1.0	1.6	1.6	0.8	0.9	1.1	1.2	0.7	0.8	0.8	0.6
Kanakambikai	01-Near Spill	Surface	0.5	0.6	0.4	0.6	0.4	0.5	0.4	0.4	-	-	-	-	-	-	-
		Medium*7	0.4	0.5	0.3	0.5	0.4	0.3	0.3	0.3	-	-	-	-	-	-	-

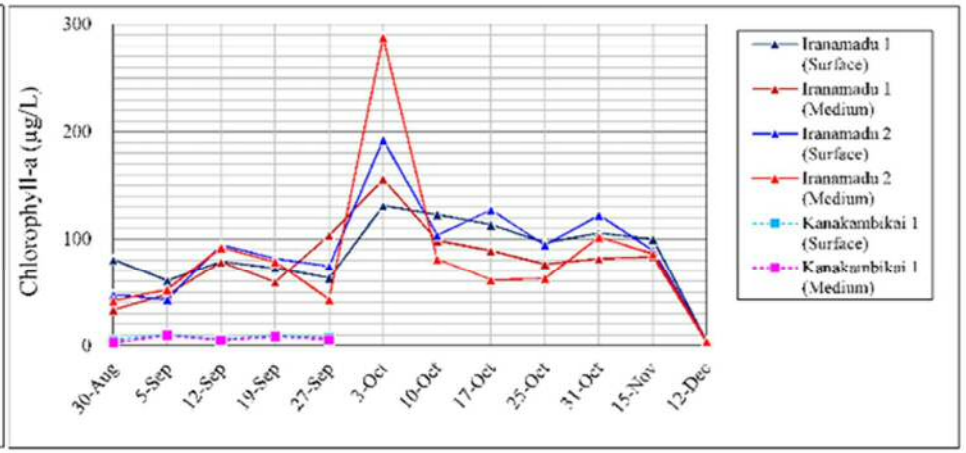




8. Chlorophyll a µg/L

Date of Sampling			Average	Max.	Min.	30-Aug	5-Sep	12-Sep	19-Sep	27-Sep	3-Oct	10-Oct	17-Oct	25-Oct	31-Oct	15-Nov	12-Dec
Dry Aru	01-Canal from Iranamadu	Surface	30	71.0	3.3	71	42	31	35	18	44	29	4.8	7	10	68	3.3
		Medium*1	17	49.2	1.8	11	15	28	26	17	18	23	1.8	6	7	49	3.00
	02-Center of the tank	Surface	27	67.8	5.8	22	19	29	25	25	10	32	23	26	39	68	5.8
		Medium*2	27	62.2	4.3	39	25	41	38	15	14	31	14	16	27	62	4.3
	03-Near Water Board Intake	Surface	36	69.1	4.4	55	25	69	64	44	16	13	4.4	50	22	61	6.5
		Medium*3	25	43.9	3.5	44	18	42	34	18	25	9.5	3.5	35	21	44	5.9
	04-Canal from Kanakambikai	Surface	26	46.7	3.4	7.3	19	47	35	42	23	21	24	27	32	36	3.4
		Medium*4	17	34.9	0.2	6.3	15	35	32	22	2.7	6	11	23	26	21	0.2
Iranamadu	01-Center of the reservoir	Surface	86	131.2	3.7	81	60	79	73	63	131	123	113	97	106	100	3.7
		Medium*5	76	156.0	2.7	33	48	78	59	103	156	98	89	76	82	83	2.7
	02-Near Irrigation Office	Surface	90	192.5	4.4	47	43	95	82	75	192	104	127	95	122	90	4.4
		Medium*6	83	288.0	4.1	42	52	92	79	43	288	81	62	63	102	86	4.1
Kanakambikai	01-Near Spill	Surface	8	10.6	5.4	5.4	11	6.5	9.9	7.6	-	-	-	-	-	-	-
		Medium*7	6	9.5	2.8	2.8	9.5	5.2	8.4	5.9	-	-	-	-	-	-	-



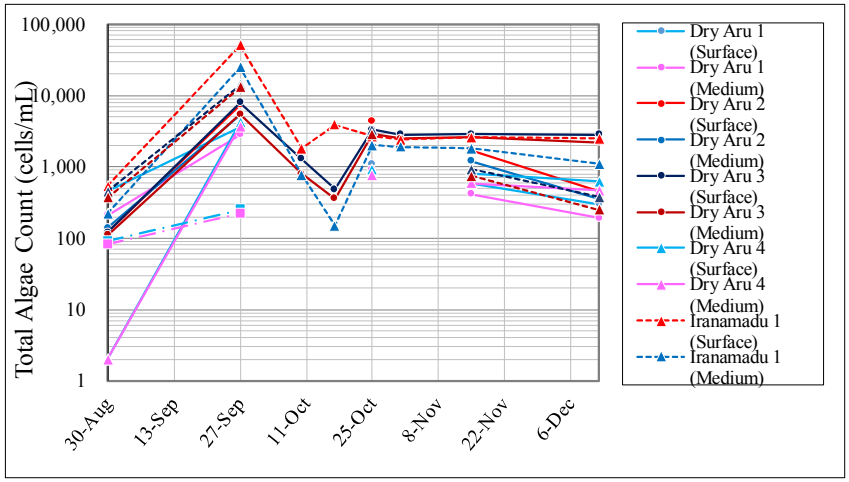


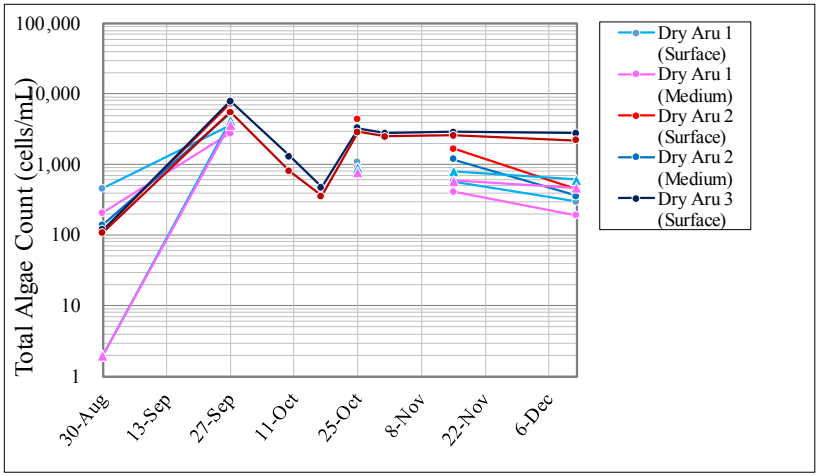
Sampling Depth

*1 : 0.6 m (up to 17th Oct), 1.5 m (from 25th Oct)
*2 : 0.6 m (up to 17th Oct), 1.5 m (from 25th Oct)
*3 : 1.5 m
*4 : 0.6 m (up to 17th Oct), 1.5 m (from 25th Oct)
*5 : 1.5 m (up to 17th Oct), 5.0 m (from 25th Oct)
*6 : 0.6 m (up to 17th Oct), 5.0 m (from 25th Oct)
*7 : 0.4 m (up to 27th Sep)

9. Total Algae Count(cells/ml)

Sampling Location			Average	Max.	Min.	30-Aug	27-Sep	10-Oct	17-Oct	25-Oct	31-Oct	15-Nov	12-Dec
Dry Aru	01-Canal from Iranamadu	Surface	1,208	3,600	300	460	3,600			1,100		580	300
		Medium*1	902	2,800	190	210	2,800			900		410	190
	02-Center of the tank	Surface	2,814	7,400	120	120	7,400			4,400		1,700	450
		Medium*2	2,060	5,400	140	140	5,400			3,200		1,200	360
	03-Near Water Board Intake	Surface	2,700	7,900	120	120	7,900	1,300	480	3,300	2,800	2,900	2,800
		Medium*3	2,121	5,500	110	110	5,500	800	360	2,900	2,500	2,600	2,200
	04-Canal from Kanakambikai	Surface	1,304	4,200	2	2	4,200			900		800	620
		Medium*4	1,106	3,700	2	2	3,700			770		590	470
Iranamadu	01-Center of the reservoir	Surface	8,430	51,000	540	540	51,000	1,800	3,900	2,700	2,400	2,600	2,500
		Medium*5	4,118	25,000	150	220	25,000	770	150	2,000	1,900	1,800	1,100
	02-Near Irrigation Office	Surface	3,810	14,000	380	450	14,000			3,300		920	380
		Medium*6	3,432	13,000	250	370	13,000			2,800		740	250
Kanakambikai	01-Near Spill	Surface	170	250	90	90	250						
		Medium*7	151	220	82	82	220						





Sampling Depth

*1 : 0.6 m (up to 17th Oct), 1.5 m (from 25th Oct)
*2 : 0.6 m (up to 17th Oct), 1.5 m (from 25th Oct)
*3 : 1.5 m
*4 : 0.6 m (up to 17th Oct), 1.5 m (from 25th Oct)
*5 : 1.5 m (up to 17th Oct), 5.0 m (from 25th Oct)
*6 : 0.6 m (up to 17th Oct), 5.0 m (from 25th Oct)
*7 : 0.4 m (up to 27th Sep)

Appendix-2: Measurement Results of Turbidity and Flow Rate by Irrigation Channel Measuring Point

Measurements of turbidity and flow rate in the irrigation channel connecting Iranamadu reservoir with Dry Aru reservoir are shown in the following tables. The measurement was carried out after the observation of the rainfall to some extent, before the stop of the rainfall was stopped.

Date	a		b					c		d		e		Remarks
	Time	Turbidity (NTU)	Time	Turbidity (NTU)	Flow Velocity (m/s)	Water Depth (m)	Flow Amount (m^3/s)	Time	Turbidity (NTU)	Time	Turbidity (NTU)	Time	Turbidity (NTU)	
2019/11/25	9:00	414	9:10	560				9:15	500			9:25	42.8	Heavy rain starts in morning
2019/11/28	16:20	185	16:30	180				16:35	110	16:40	171	16:45	138	After a momentary heavy rain
2019/11/29	10:40	200	10:50	200	0.116	0.45	0.52	11:00	153	11:05	109	11:10	126	Heavy rain
2019/12/3	10:15	66	10:24	130	0.205	0.48	0.98	10:30	150	10:34	128	10:39	63	
2019/12/4	10:55	104	11:06	113	0.134	0.42	0.56	11:12	43.8	11:16	84	11:20	65.5	
2019/12/6	9:40	159	10:15	180				10:35	173	10:38	190	10:47	223	b Inflow turbidity near 135NTU
	11:46	116	11:56	165	0.396	0.76	3.01	12:03	165	12:06	177	12:12	257	
	13:30	97	13:40	153	0.266	0.62	1.65	13:45	155	13:49	173	13:51	265	
	15:29	87	15:37	142	0.24	0.57	1.37	15:43	147	15:47	167	15:50	206	
	17:45	93	17:54	119				17:56	142	18:00	151	18.05	161	
2019/12/7	9:17	196	9:25	225				9:30	183	9:33	122	9:38	148	
	13:26	73	13:35	152				13:37	162	13:40	111	13:45	135	
	17:25	57	17:32	108				17:36	134	17:39	120	17:43	125	
2019/12/8												9:10	110	
2019/12/9												8:30	89	
												17:00	74.2	
2019/12/10												8:30	71.3	
	14:13	35	14:20	31				14:25	29	14:30	63	14:35	69	
2019/12/12												8:30	55.8	
												17:00	51.7	
2019/12/13												8:30	47.3	
												17:00	42.4	
2019/12/16												8:30	33.3	
												17:00	26.6	
2019/12/17												8:30	33.1	

※ *The measurement points are: a: measured upstream of the irrigation channel; b: irrigation channel bifurcation in front of Dry Aru, c: Immediately before the entrance of Dry Aru d: before the east end weir of Dry Aru e: around the water intake*

Next, the results of the measurement of turbidity of the irrigation channel connecting Kamagambikai reservoir and Dry Aru reservoir are shown in the following tables. The measurement was carried out after the observation of the rainfall to some extent, before the stop of the rainfall was stopped.

Date	f		g		h		Remarks
	Time	Turbidity (NTU)	Time	Turbidity (NTU)	Time	Turbidity (NTU)	
2019/11/25					9:45	700	Heavy rain starts in morning
2019/12/3	10:00	77					
2019/12/6	9:15	104	9:20	143	10:55	149	Iranamadu WL:31.4ft
			17:32	116	18:15	133	
2019/12/7	8:57	97	9:00	107	9:50	136	Iranamadu WL:35.6ft Turbidity:41.5NTU
	13:12	101	13:14	105	13:50	132	
	17:12	97			17:52	120	
2019/12/10	13:45	76	13:50	73	14:54	52	Iranamadu WL:35.3ft

※ *The measurement point is f: the effluent Weir of Kamagambikai Reservoir, g: upstream of irrigation channel, h: just before the entry point of Dry Aru (near the kilinochchi Water Tower).*

Appendix-3: Turbidity and Rainfall

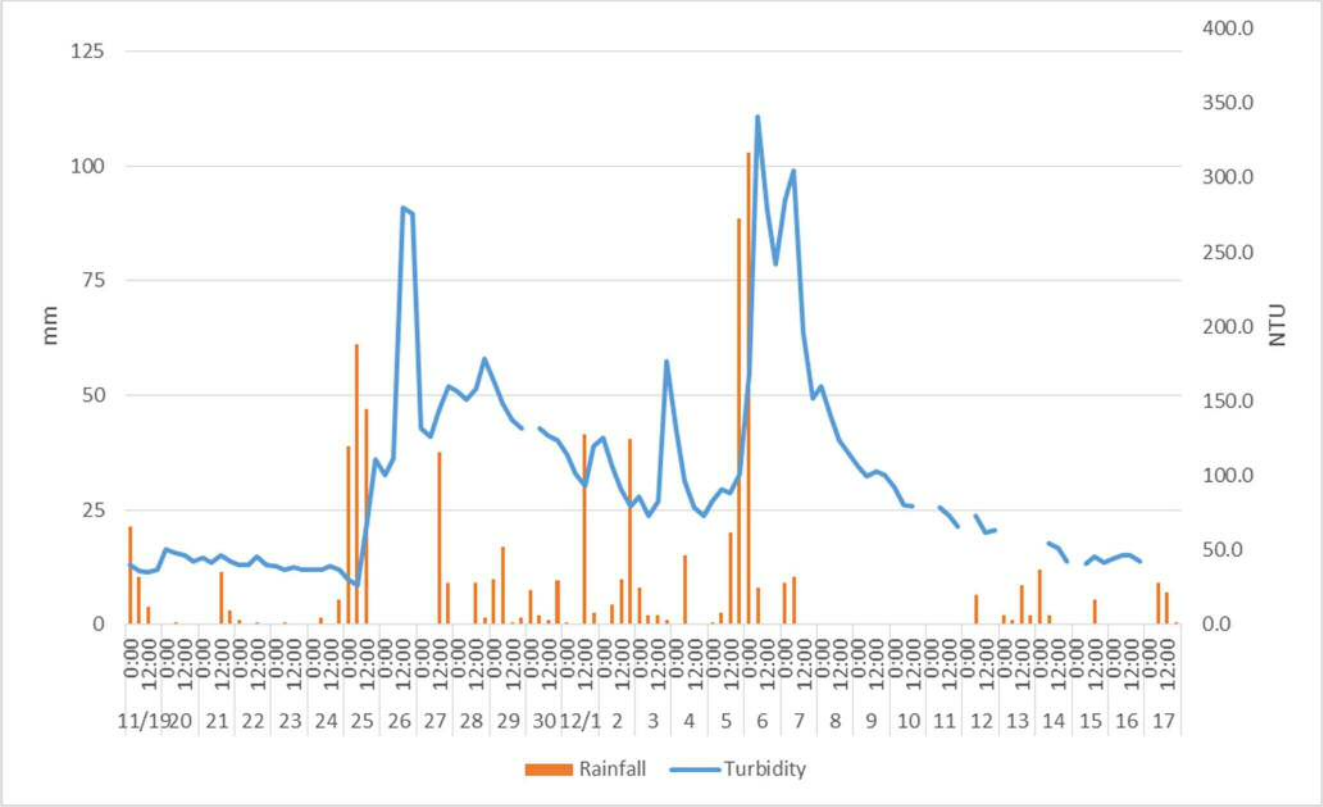
This paper summarizes turbidity and rainfall at the same time in the following tables and figures in order to investigate the relation between rainfall data by an integrating rain gauge installed in this FU Study and turbidity data measured in a water treatment plant.

Date	Time	Turbidity	Rainfall	Date	Time	Turbidity	Rainfall	Date	Time	Turbidity	Rainfall
19-Nov	0:00	40	21.5	1-Dec	0:00	114	0.5	13-Dec	0:00		2
	6:00	36.4	10.5		6:00	101	0		6:00	55.8	1
	12:00	35.4	4		12:00	93.4	41.5		12:00		8.5
	18:00	37.2	0		18:00	120	2.5		18:00	56.9	2
20-Nov	0:00	50.3	0	2-Dec	0:00	125	0	14-Dec	0:00		12
	6:00	47.9	0.5		6:00	105	4.5		6:00	54.3	2
	12:00	46.4	0		12:00	91.1	10		12:00	51.4	0
	18:00	42.4	0		18:00	79.6	40.5		18:00	42.1	0
21-Nov	0:00	44.7	0	3-Dec	0:00	85.6	8	15-Dec	0:00		0
	6:00	41.6	0		6:00	73.4	2		6:00	40.7	0
	12:00	46.2	11.5		12:00	82.6	2		12:00	45.5	5.5
	18:00	42.8	3		18:00	177	1		18:00	41.4	0
22-Nov	0:00	40.1	1	4-Dec	0:00	131	0	16-Dec	0:00	44.3	0
	6:00	39.7	0		6:00	96.2	15		6:00	46.3	0
	12:00	46.1	0.5		12:00	78.8	0		12:00	46.9	0
	18:00	40.1	0		18:00	73.2	0		18:00	42.3	0
23-Nov	0:00	39.6	0	5-Dec	0:00	82.7	0.5	17-Dec	0:00		0
	6:00	37.1	0.5		6:00	90.6	2.5		6:00	36	9
	12:00	38.4	0		12:00	88.5	20		12:00		7
	18:00	36.9	0		18:00	101	88.5		18:00		0.5
24-Nov	0:00	37	0	6-Dec	0:00	169	103				
	6:00	37	1.5		6:00	341	8				
	12:00	38.9	0		12:00	278	0				
	18:00	36.7	5.5		18:00	242	0				
25-Nov	0:00	30.2	39	7-Dec	0:00	285	9				
	6:00	26.8	61		6:00	305	10.5				
	12:00	68.9	47		12:00	196	0				
	18:00	111	0		18:00	152	0				
26-Nov	0:00	100	0	8-Dec	0:00	160	0				
	6:00	112	0		6:00	140	0				
	12:00	280	0		12:00	124	0				
	18:00	276	0		18:00	115	0				
27-Nov	0:00	132	0	9-Dec	0:00	106	0				
	6:00	126	0		6:00	99.6	0				
	12:00	144	37.5		12:00		0				
	18:00	160	9		18:00		0				
28-Nov	0:00	157	0	10-Dec	0:00	92.1	0				
	6:00	151	0		6:00	80.5	0				
	12:00	158	9		12:00	79.3	0				
	18:00	178	1.5		18:00		0				
29-Nov	0:00	163	10	11-Dec	0:00		0				
	6:00	149	17		6:00	78.9	0				
	12:00	137	0.5		12:00	73.4	0				
	18:00	132	1.5		18:00	66	0				
30-Nov	0:00		7.5	12-Dec	0:00		0				
	6:00	132	2		6:00	73.1	6.5				
	12:00	127	1		12:00	61.9	0				
	18:00	124	9.5		18:00	63.4	0				

*) Turbidity was measured at the intake of the Kilinochchi, and rainfall was measured by an accumulated rain meter placed in NWSDB office.

When turbidity and rainfall are shown in the figure, it was found that turbidity also rises when there is a

certain amount of rainfall. Especially, turbidity rose rapidly after two times of heavy rainfall from November 25 and December 5 to 6. After that, turbidity was also found to decrease even if rainfall was intermittent.



※ *Preparation of FU Study Team*

Appendix -4: Water Quality Standard in Sri Lanka（SLS 614: 2013 Specification for Portable Water）

No.	Parameters	Unit	Requirement
Physical and organoleptic requirements			
1	Color	units	15
2	Odor	---	unobjectionable
3	Taste	---	unobjectionable
4	Turbidity	NTU	2
5	pH (at 25°C ± 2°C)	---	6.5 to 8.5
Chemical requirements			
6	Aluminium (as Al)	mg/L	0.2
7	Free ammonia (as NH_3)	mg/L	0.06
8	Albuminoid ammonia	mg/L	0.15
9	Anionic detergents (as MBAS)	mg/L	0.2
10	Calcium (as Ca)	mg/L	100
11	Chloride (as Cl)	mg/L	250
12	Chemical oxygen demand (COD)	mg/L	10
13	Copper (as Cu)	mg/L	1.0
14	Fluoride (as F)	mg/L	1.0
15	Free residual chlorine (as Cl_2)	mg/L	1.0
16	Iron (as Fe)	mg/L	0.3
17	Magnesium (as Mg)	mg/L	30
18	Manganese (as Mn)	mg/L	0.1
19	Nitrate (as NO_3^-)	mg/L	50
20	Nitrite (as NO_2^-)	mg/L	3
21	Nickel (as Ni)	mg/L	0.02
22	Oil and Grease	mg/L	0.2
23	Phenolic compounds (as C_6H_5OH)	mg/L	0.001
24	Sodium (as Na)	mg/L	200
25	Sulphate (as SO_4^{2-})	mg/L	250
26	Total alkalinity (as $CaCO_3$)	mg/L	200
27	Total dissolvec solids	mg/L	500
28	Total hardness (as $CaCO_3$)	mg/L	250
29	Total phosphates (as PO_4^{3-})	mg/L	2.0
30	Zinc (as Zn)	mg/L	3.0
31	Pesticide residue	mg/L	WHO requirements
Toxic substances			
32	Arsenic (as As)	mg/L	0.01
33	Cadmium (as Cd)	mg/L	0.003
34	Chromium (as Cr)	mg/L	0.05
35	Cyanide (as CN)	mg/L	0.05
36	Lead (as Pb)	mg/L	0.01
37	Mercury (as Hg)	mg/L	0.001
38	Selenium (as Se)	mg/L	0.01
Bacteriological requirements			
39	*E.coli* or thermotolelant coliform bacteria	-	shall not be detectable in any 100 ml sample.
40	Total coliform bacteria	-	・shall not exceed 3 in any 100 ml sample. ・shall not be detectable in 100 ml of any two consecutive samples.

Appendix -5: Details of the Training about the Updated O&M Manual

i) Date

17th to 18th February, 2020

ii) Attendance List

The First Day（17th Feb, 2020）		The Second Day（18th Feb, 2020）	
Name	Designation	Name	Designation
S. Sarankan	DE	S. Sarankan	DE
S. Balakumar	OIC	B. Jeevarasa	EA(Mechanical)
B. Jeevarasa	EA(Mechanical)	H.W.K.R. Seneviratne	Plant Technician
U.L.D. Rafeek	Pump Operator	U.L.D. Rafeek	Pump Operator
S. Wigneswaran	Pump Operator	S. Wigneswaran	Pump Operator
T. Tharshiya	Local Staff (FU Study Team)	T. Tharshiya	Local Staff (FU Study Team)

iii) Photos

Explanation of the updated contents (The First Day)

Training of RF washing (The Second Day)

Training of RF washing (The Second Day)

Q&A (The Second Day)

iv) Updated O&M Manual

See the attached document.

DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA
MINISTRY OF WATER SUPPLY AND DRAINAGE
NATIONAL WATER SUPPLY AND DRAINAGE BOARD (NWSDB)

THE PROJECT FOR REHABILITATION OF KILLINOCHCHI WATER SUPPLY SCHEME IN SRI LANKA

OPERATION AND MAINTENANCE MANUAL (FINAL VERSION, Rev.2)

FEBRUARY 2020

NJS CONSULTANTS CO., LTD.

Revision History

Revision	Month/Year	History
0	October, 2017	The final version had been issued.
1	March, 2019	The contents had been revised and updated based on the site survey result.
2	February, 2020	The contents had been revised and updated based on the Follow Up Survey result.

Table of Contents

OPERATION AND MAINTENANCE MANUAL

1. General

The purpose of this manual is to acquaint engineers and/or plant operators with the overall plant capabilities, to instruct them the purpose and intended operation of each treatment process and facility/equipment, and to provide the necessary instruction for the proper operation and maintenance of the facilities/equipment. This manual shall be utilized as a reference book for engineers and/or plant operators to understand not only the entire water supply system including transmission pipe but also the major O&M activities of each facility/equipment.

Detail information which will be needed for major maintenance, part replacement and overhauling of the equipment are available in the As Built Document and As Built Drawings under the Contract. This manual can also be utilized as a reference and/or training tool for new personnel.

1.1 Requirements

Engineer and/or Operator engaged in O&M of water supply system are required to improve your knowledge, abilities and skills as mentioned below:

1.2 Why Water Treatment is Necessary?

> The purpose of water treatment plant is to produce clean, safe and sufficient amount of drinking water.

The main purpose of water treatment is to provide clean, safe and sufficient amount of drinking water continuously. Drinking water must be free of disease-causing organisms and toxic substances. And also, the water should not have disagreeable taste, odor or appearance.

1.3 Water Quality Standards

> Water treatment plant is to produce safe water that meets the drinking water quality standards.

Basically, the water quality standard is established by the water quality regulations. The water quality standards in Sri Lanka are based on the SLS 614 (2013) as shown in **Table 1-1**. These standards should always be applied with all water supply schemes.

Table 1-1 Drinking Water Standards

(Sri Lanka Standards for potable water: SLS 614, 2013)

No.	Parameters	Unit	Requirement
Physical and organoleptic requirements			
1	Color	units	15
2	Odor	---	unobjectionable
3	Taste	---	unobjectionable
4	Turbidity	NTU	2
5	pH (at 25°C ± 2°C)	---	6.5 to 8.5
Chemical requirements			
6	Aluminium (as Al)	mg/L	0.2
7	Free ammonia (as NH_3)	mg/L	0.06
8	Albuminoid ammonia	mg/L	0.15
9	Anionic detergents (as MBAS)	mg/L	0.2
10	Calcium (as Ca)	mg/L	100
11	Chloride (as Cl)	mg/L	250
12	Chemical oxygen demand (COD)	mg/L	10
13	Copper (as Cu)	mg/L	1.0
14	Fluoride (as F)	mg/L	1.0
15	Free residual chlorine (as Cl_2)	mg/L	1.0
16	Iron (as Fe)	mg/L	0.3
17	Magnesium (as Mg)	mg/L	30
18	Manganese (as Mn)	mg/L	0.1
19	Nitrate (as NO_3^-)	mg/L	50
20	Nitrite (as NO_2^-)	mg/L	3
21	Nickel (as Ni)	mg/L	0.02
22	Oil and Grease	mg/L	0.2
23	Phenolic compounds (as C_6H_5OH)	mg/L	0.001
24	Sodium (as Na)	mg/L	200
25	Sulphate (as SO_4^{2-})	mg/L	250
26	Total alkalinity (as $CaCO_3$)	mg/L	200
27	Total dissolvec solids	mg/L	500
28	Total hardness (as $CaCO_3$)	mg/L	250
29	Total phosphates (as PO_4^{3-})	mg/L	2.0
30	Zinc (as Zn)	mg/L	3.0
31	Pesticide residue	mg/L	WHO requirements
Toxic substances			
32	Arsenic (as As)	mg/L	0.01
33	Cadmium (as Cd)	mg/L	0.003
34	Chromium (as Cr)	mg/L	0.05
35	Cyanide (as CN)	mg/L	0.05
36	Lead (as Pb)	mg/L	0.01
37	Mercury (as Hg)	mg/L	0.001
38	Selenium (as Se)	mg/L	0.01
Bacteriological requirements			
39	*E.coli* or thermotolelant coliform bacteria	-	shall not be detectable in any 100 ml sample.
40	Total coliform bacteria	-	・shall not exceed 3 in any 100 ml sample. ・shall not be detectable in 100 ml of any two consecutive samples.

1.4 Responsibility of Plant Operators

> Plant Operators have the responsibility of producing clean, safe and sufficient amount of drinking water from the water treatment plant.

Plant Operators should monitor the raw water entering the plant and keep an eye on the water as it flows through all of the treatment process. The water flow into the plant shall be adjusted according to conditions of the raw water and system demands. Equipment and facilities shall be maintained and repaired as necessary in order to keep the water treatment plant in sound condition. Typical duties of Plant Operators are summarized in **Table 1-2**.

Table 1-2 Typical Duties of Plant Operators

1） Start, shut down and perform daily inspection of each equipment, such as pump, mixer, chemical feeder and monitoring/control systems.
2） Perform preventive maintenance activities, such as lubrication, cleaning and part replacement.
3） Prepare/carry necessary chemicals, such as chlorine cylinders and/or bagged chemicals either by hand or using handling equipment such as forklifts and/or hoists.
4） Perform corrective maintenance for mechanical/electrical equipment.
5） Check/monitor the operating condition, such as flow rate, pressure, water levels and water quality.
6） Collect representative water samples and check/measure turbidity, color, odor, residual chlorine and other parameters as required.
7） Keep O&M records of the above mentioned items/activities.
8） Procure necessary chemicals, fuel, repair parts and tools.

Plant Operators must pay attention to the conditions of all facilities/equipment including the water supply system in daily and periodical inspections. Especially, the following activities shall performed by Plant Operators in daily inspection.

- Listen for abnormal noises.
- Look for leaks of water, oil, and/or fuel.
- Pay attention to smells and/or abnormal vibration.
- Observe the operation (temperatures, pressures, levels, valves) of plant equipment for appropriate operating ranges and positions.

1.5 Necessary Knowledge and Skills

a) Basic knowledge of total water treatment system and process;
b) Basic knowledge of civil structure and mechanical/electrical equipment;
c) Basic knowledge of manual/automatic operation and maintenance of all equipment;

d) Basic knowledge of water quality and laboratory equipment/instrument;
e) Basic knowledge of safety work;
f) Basic knowledge and skills of trouble shooting.
g) Skills to perform necessary O&M activities including water quality tests:
h) Skills to keep records and prepare reports;

1.6 Outline of the Project

This project aims to supply stable and safe drinking water to residents in Killinochchi town with a population of about 21,000 people in the area (planned maximum daily water supply of 3,800 m^3/day) in the target year of 2020 by rebuilding the water supply system with the Dry Aru reservoir as the water source.

In order to achieve the above objectives, rehabilitation works was conducted for the existing intake facility, intake pump station, water treatment plant facilities, the works for establishment of new machinery and electric facilities and establishment / expansion of transmission / distribution water systems. Furthermore, procurement of equipment for O&M and provision of support for training personnel necessary for the operation and management of water supply projects were also conducted.

Table 1-3 Outline of the Project

Projected population of water supply area	16,558
Projected population supplied in each ward	20,996 (79%)
Rate of non-revenue water (%)	20.0
Variation coefficient	1.25
Estimated average daily water supply	2,981 (m^3/d)
Estimated maximum daily water supply	3,726 (m^3/d)
Designed production volume	**3,800 (m^3/d)**
Designed distribution water supply	3,800 (m^3/d)

1.7 Water Service Area

The planning area consists of 14 Grama Niladhari (GN); i.e. 2 GNs in Kandawalai Division and 12 GNs in Karachchi Division as shown in the following table.

Table 1-4 Outline of the Planning Area

Sr	P-Codes	Divisional Secretary	Grama Niladhari
1	4506043	Kandawalai	Kumarapuram
2	4506044	-ditto-	Paranthan
3	4509010	Karachchi	Vivegananthanagar
4	4509012	-ditto-	Uthayanagar East
5	4509016	-ditto-	Ananthapuram
6	4509017	-ditto-	Thondarmannagar
7	4509018	-ditto-	Kanagambikaikulan
8	4509022	-ditto-	Ratnapuram
9	4509023	-ditto-	Killinochchi Town
10	4509024	-ditto-	Maruthanagar
11	4509026	-ditto-	Kanagapuram

Sr	P-Codes	Divisional Secretary	Grama Niladhari
12	4509027	-ditto-	Thirunagar South
13	4509028	-ditto-	Thirunagar North
14	4509029	-ditto-	Kaneshapuram

1.8 Design Pressure

Pipe line: 1.0 MPa (10 kg/cm^2)

1.9 Treatment Process and Each Facility's Function

Figure 1-1 shows a flow diagram of the water treatment plant processes and the purpose or function of each process. After taking water from Dry Aru, the water has to undergo a step-by-step treatment to produce safe drinking water. The first step, roughing filters, concentrates on the removal of solids. The second step, slow sand filters and disinfection (chlorination), is used especially to remove/catch the remaining microorganisms and the last traces of solid matter.

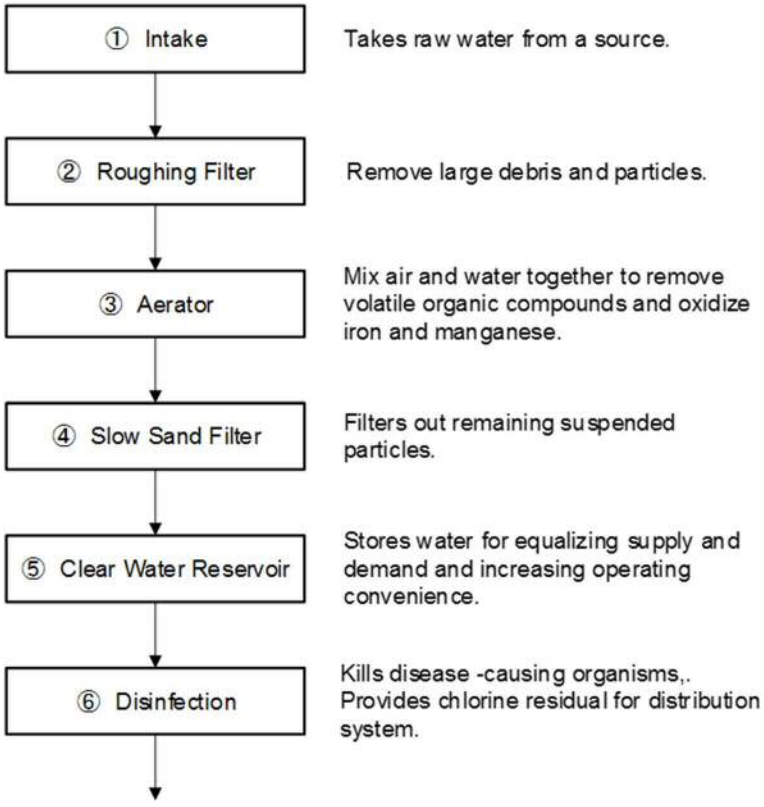


Figure 1-1 Flow Diagram of the Water Treatment Plant

(1) Intake

Raw water enters the water treatment plant through the intake structure. The main purpose of the intake structure is to draw in water and supply it to roughing filters.

(2) Roughing filter

Roughing filters are used to pretreat water by removing large suspended solids from the water that could rapidly clog a slow sand filter. Roughing filters can also reduce the number of pathogens in the water, as well as the amount of iron and manganese.

The roughing filters have a few layers of gravel of different sizes. The water passes through the gravel and suspended matter is trapped. The accumulated material trapped in the gravel must be removed periodically by cleaning. Cleaning is achieved by rapidly draining down the media through a fast-opening valves on draining pipes.

(3) Aerator

Next the water goes through aerators. Aeration is the process of mixing air and water together to remove volatile compounds to reduce objectionable odors and destroy some compounds by oxidation.

(4) Slow sand filter

After the aerators, the water passes through the slow sand filters to remove the remaining suspended impurities.

As its names implies, slow sand filtration is accomplished by passing the water at a relatively low rate through a sand medium. The water is treated primarily through biological activity taking place in a layer on the surface of the sand bed. The layer on the sand surface is an accumulation of organic and inorganic debris and particulate matter in which biological activity is stimulated.

The layer removes bacteria, organic matter and reduces turbidity of the water.

When the sand bed becomes clogged, the bed must be dewatered, and the upper layer of the sand is removed, washed, and replaced.

(5) Clear water reservoir

The treated water is stored in a large tank during low demand periods until it is pumped to the water tower.

(6) Disinfection

The water is disinfected by the chlorination process. The purpose of disinfection is to kill the remaining disease-causing organisms in the water.

(7) Transmission Pipe

Treated water from Water Treatment Plant is transmitted to the new elevated tank with New HDPE pipe OD

355mm. From New Elevated Tank (1,000m3) to New Elevated Tank (450m3) water is also supplied with new pipe HDPE pipe of OD 280 mm. All the new HDPE pipes are connected by butt fusion joints.

(8) Distribution Pipe

Pipe lines from New Elevated Tank are laid to the market area with using Ductile Iron Pipe lined with cement mortar. The size of pipes varies from Dia 400mm to Dia300mm and at lower demand area PVC pipe of OD 150 mm has been used. There are no any public supply connection from new water supply line between Water Treatment Plant and New Elevated Tank however supply to public from existing line is not affected.

(9) Valves

Valves are provided at different locations for specific purposes such as air valve to release trapped air, gate and butterfly valves to control flow of water at different line and all these valves shall be used as its purpose.

(10) Washout and drain

Washout drains are provided to keep the pipelines free from clogging. It shall be washed out at least once in 3 months in dry season and once a month in rainy season with enough water to flush deposited soil and until clear water observed at washout.

(11) Fire Hydrant

These fire hydrants are used in case of fire.

(12) Air Valve

These are the valves located at higher elevations of longitudinal slop of pipe lines to release trapped air.

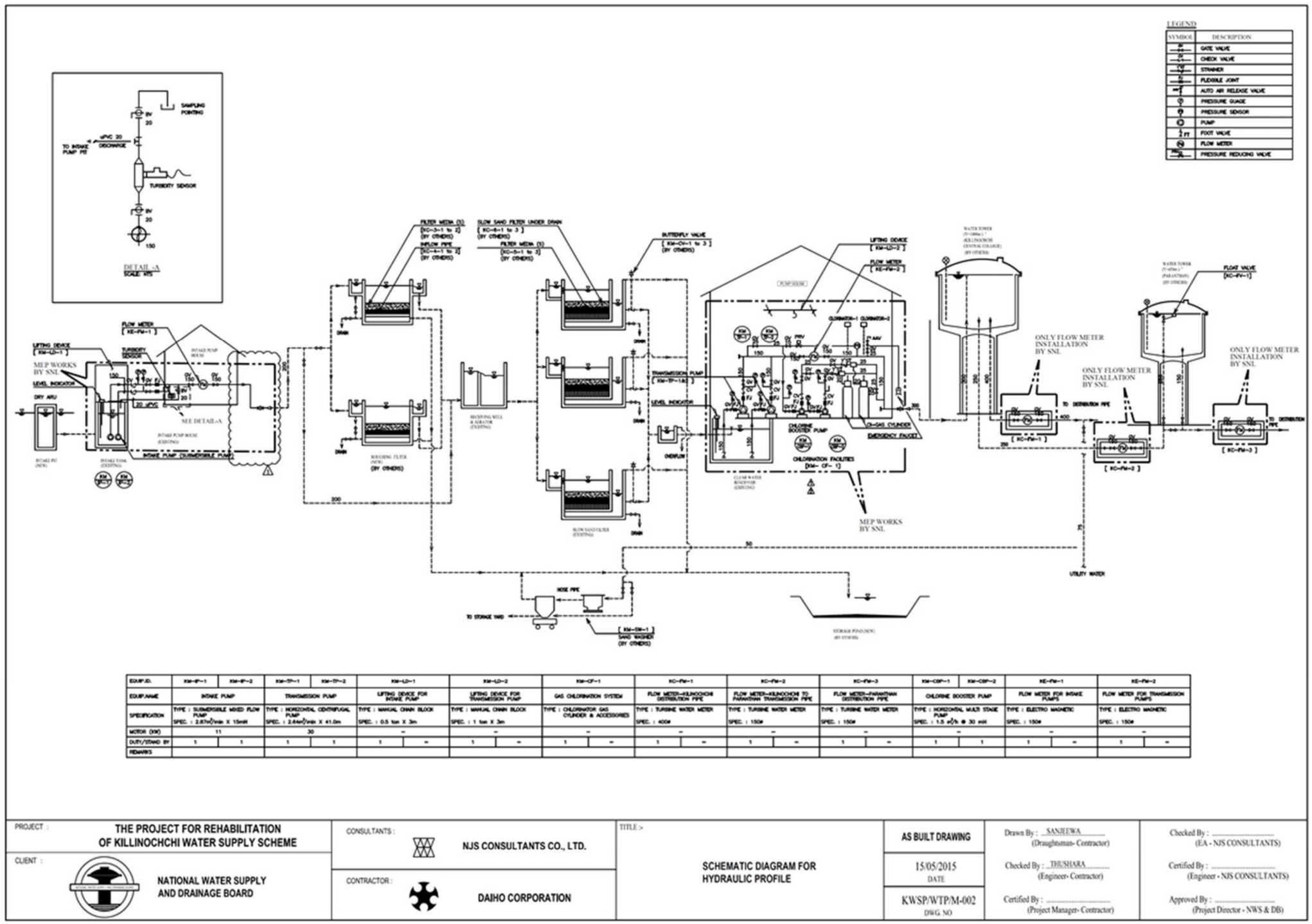
Outline of the water treatment plant is shown in **Table 1-5** and general layout, hydraulic profile and schematic flow diagram of the water treatment plant is shown in **Figure 1-2** to **Figure 1-4** accordingly.

Table 1-5 Outline of the Water Treatment Plant

Item	Specification
Plant Capacity	Q = 3,800m^3/day ×1.05 = 3,990m^3/day = 166.3 m^3/hr. = 2.77m^3/min = 0.046 m^3/sec
Daily Production	Q = 3,800 m^3/day
Intake Tank (Existing)	
Number	N = 1
Dimension	Width =3.0 m, Length = 6.0 m, Effective Depth =2.3 m
Effective Capacity	V = 3.0 × 6.0 × 2.3 × 1 = 41.4 m^3
Retention Time	T = 41.4 / 2.77 = 14.9 min
Receiving Well (Existing)	
Number	N = 1
Dimension	Width =1.2 m, Length =0.9 m, Effective Depth =2.07 m

Item	Specification
Effective Capacity	V = 1.2×0.9×2.07×1 = 2.24 m^3
Retention Time	T = 2.24 / 2.77 = 0.81 min
Aerator (Existing)	
Type	Cascade Type
Number	N = 1
Dimension	Width B =3.0 m, Length L =3.6 m
Roughing Filter (Newly constructed)	
Type	Up Flow Type
Number	N = 2
Filtration Rate	V = 1.5 m/hr. = 36 m/day
Dimension	Width =5.1 m, Length =11.0 m
	Filtration Area = 5.1 × 11.0 = 56.1 m^2/tank
Filtration Media	Effective Thickness = 3.0 m, Three Layers
	φ12–16mm × 1,000 mm φ8–12mm × 1,000 mm φ4–8mm × 1,000 mm
Slow Sand Filter (Rehabilitated, Existing)	
Type	Down Flow Type
Number	N = 3
Filtration Rate	V = 2.4 to 4.8m/day (0.1 – 0.2m/hr.)
Dimension	Width =12.0m, Length = 30.0m
	Filtration Area = 12.0 × 30.0 × 3 = 1,080.0m^2
Filtration Rate	V' = 3,990 / 1,080 = 3.69 m/day < 4.8m/day
Effective Depth	H = 1.00m
Filtration Sand	Effective Diameter: 0.15-0.35 mm
	Equalizing Co-efficient: Less than 3.0
	Sand Layer Thickness 102.5 cm
Clear Water Reservoir (Existing)	
Number	N = 1
Dimension	Width = 6.0 m, Length = 9.0 m
	Effective Depth = 2.30m
Effective Capacity	V = 6.0 × 9.0 × 2.3×1 = 124.2m^3
Retention Time	T = 124.2 / 166.3 = 0.75 hr.
Storage Pond (Newly constructed)	
Number	N = 1
Dimension	Width (Top) = 16.0 m, Width (Bottom) = 8.8 m
	Length (Top) = 16.0 m, Length (Bottom) = 8.8 m
	Effective Depth = 1.3 m
Effective Capacity	V = $\{14^2+(14^2\times8.8^2)^{1/2}+8.8^2\}$ / 3 ×1.3 = 171.9m^3
Killinochchi Water Tower (Newly constructed)	
Number	N = 1
Dimension	Cylinder Part Diameter = 15.00m, Effective Depth = 4.00m Corn-Shape Part Diameter = 15.00 to 9.00m, Effective Depth = 3.00m Cylinder Center Part (Deduct) Diameter = 2.10m, Depth = 7.00m
Effective Capacity	V = 1,028.97m^3 say 1,000m^3

Item	Specification
Retention Time	T = 1,028.97 / 158.3 = 6.5hr
Pharantan Water Tower (Newly constructed)	
Number	N = 1
Dimension	Cylinder Part Diameter = 11.00m, Effective Depth = 3.00m Corn-Shape Part Diameter = 11.00 to 7.40m, Effective Depth = 3.00m Cylinder Center Part (Deduct) Diameter = 2.10m, Depth = 6.00m
Effective Capacity	V = 466.29m^3 say 450m^3
Retention Time	T = 466.29 / 158.3 = 2.95hr



EQUIP.ID.	KM-IP-1	KM-IP-2	KM-TP-1	KM-TP-2	KM-LD-1		KM-LD-2		KM-CF-1		KC-FM-1		KC-FM-2		KC-FM-3		KM-CBP-1	KM-CBP-2	KE-FM-1		KE-FM-2	
EQUIP.NAME	INTAKE PUMP		TRANSMISSION PUMP		LIFTING DEVICE FOR INTAKE PUMP		LIFTING DEVICE FOR TRANSMISSION PUMP		GAS CHLORINATION SYSTEM		FLOW METER-KILINOCHCHI DISTRIBUTION PIPE		FLOW METER-KILINOCHCHI TO PARANTHAN TRANSMISSION PIPE		FLOW METER-PARANTHAN DISTRIBUTION PIPE		CHLORINE BOOSTER PUMP		FLOW METER FOR INTAKE PUMPS		FLOW METER FOR TRANSMISSION PUMPS	
SPECIFICATION	TYPE : SUBMERSIBLE MIXED FLOW PUMP SPEC. : 2.67m³/min X 15mH		TYPE : HORIZONTAL CENTRIFUGAL PUMP SPEC. : 2.64m³/min X 41.0m		TYPE : MANUAL CHAIN BLOCK SPEC. : 0.5 ton X 3m		TYPE : MANUAL CHAIN BLOCK SPEC. : 1 ton X 3m		TYPE : CHLORINATOR GAS CYLINDER & ACCESSORIES		TYPE : TURBINE WATER METER SPEC. : 400ø		TYPE : TURBINE WATER METER SPEC. : 150ø		TYPE : TURBINE WATER METER SPEC. : 150ø		TYPE : HORIZONTAL MULTI STAGE PUMP SPEC. : 1.5 m³/h @ 30 mH		TYPE : ELECTRO MAGNETIC SPEC. : 150ø		TYPE : ELECTRO MAGNETIC SPEC. : 150ø	
MOTOR (KW)	11		30		-		-		-		-		-		-		-		-		-	
DUTY/STAND BY	1	1	1	1	1	-	1	-	1	-	1	-	1	-	1	-	1	1	1	-	1	-
REMARKS																						

PROJECT : THE PROJECT FOR REHABILITATION OF KILLINOCHCHI WATER SUPPLY SCHEME	CONSULTANTS : NJS CONSULTANTS CO., LTD.	TITLE > SCHEMATIC DIAGRAM FOR HYDRAULIC PROFILE	AS BUILT DRAWING	Drawn By : SANJEEWA (Draughtsman- Contractor)	Checked By : ..... (EA - NJS CONSULTANTS)
CLIENT : NATIONAL WATER SUPPLY AND DRAINAGE BOARD	CONTRACTOR : DAIHO CORPORATION		15/05/2015 DATE	Checked By : THUSHARA (Engineer- Contractor)	Certified By : ..... (Engineer - NJS CONSULTANTS)
			KWSP/WTP/M-002 DWG NO	Certified By : ..... (Project Manager- Contractor)	Approved By : ..... (Project Director - NWS & DB)

Figure 1-2 Flow Diagram of Killinochchi Water Treatment Plant

①	Intake	Takes raw water from a source.
②	Roughing Filter	Remove large debris and particles.
③	Aerator	Mix air and water together to remove volatile organic compounds and oxidize iron and manganese.
④	Slow Sand Filter	Filters out remaining suspended particles.
⑤	Clear Water Reservoir	Stores water for equalizing supply and demand and increasing operating convenience.
⑥	Disinfection	Kills disease -causing organisms,. Provides chlorine residual for distribution system.

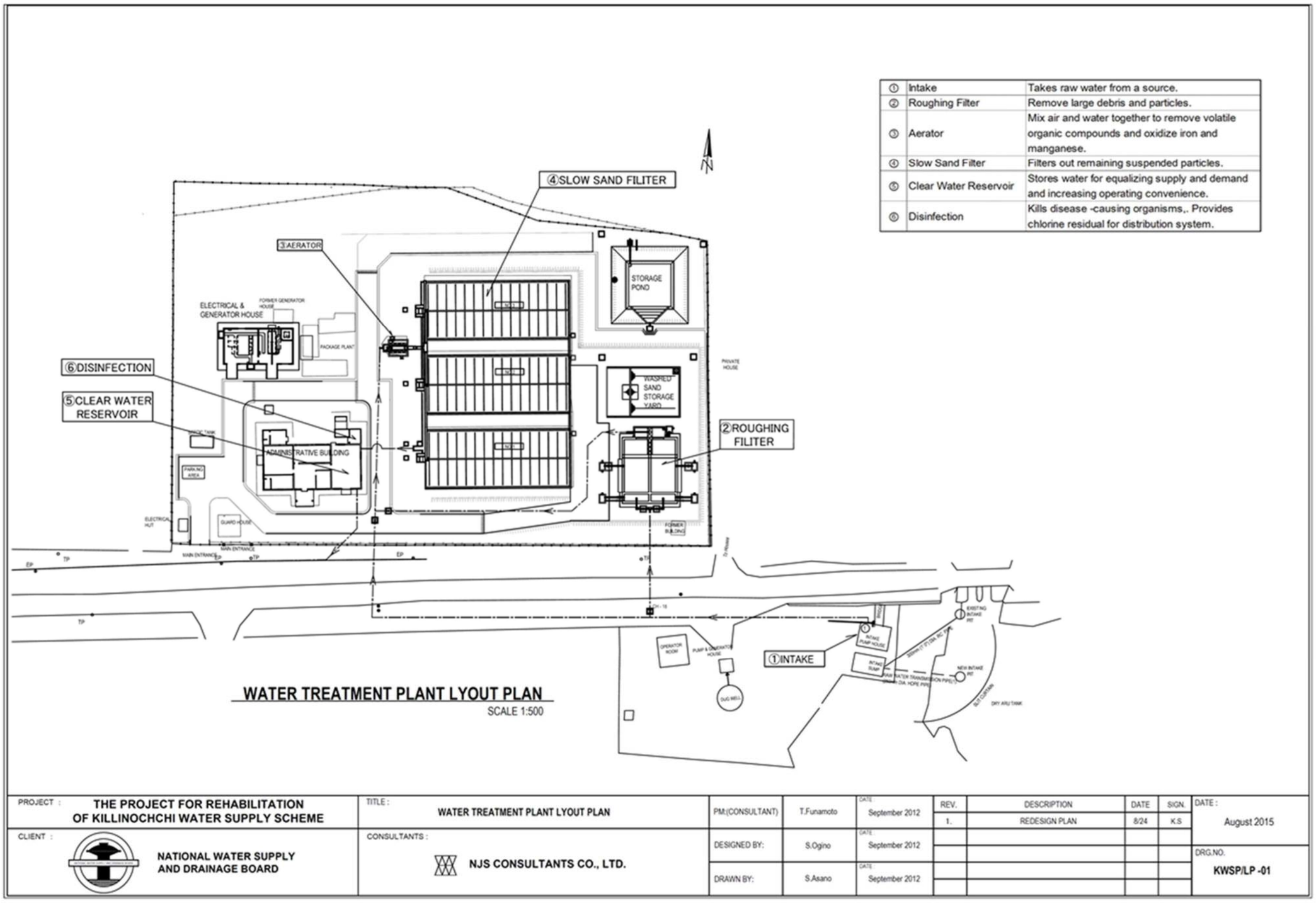


Figure 1-3 Layout Plan of Killinochchi Water Treatment Plant

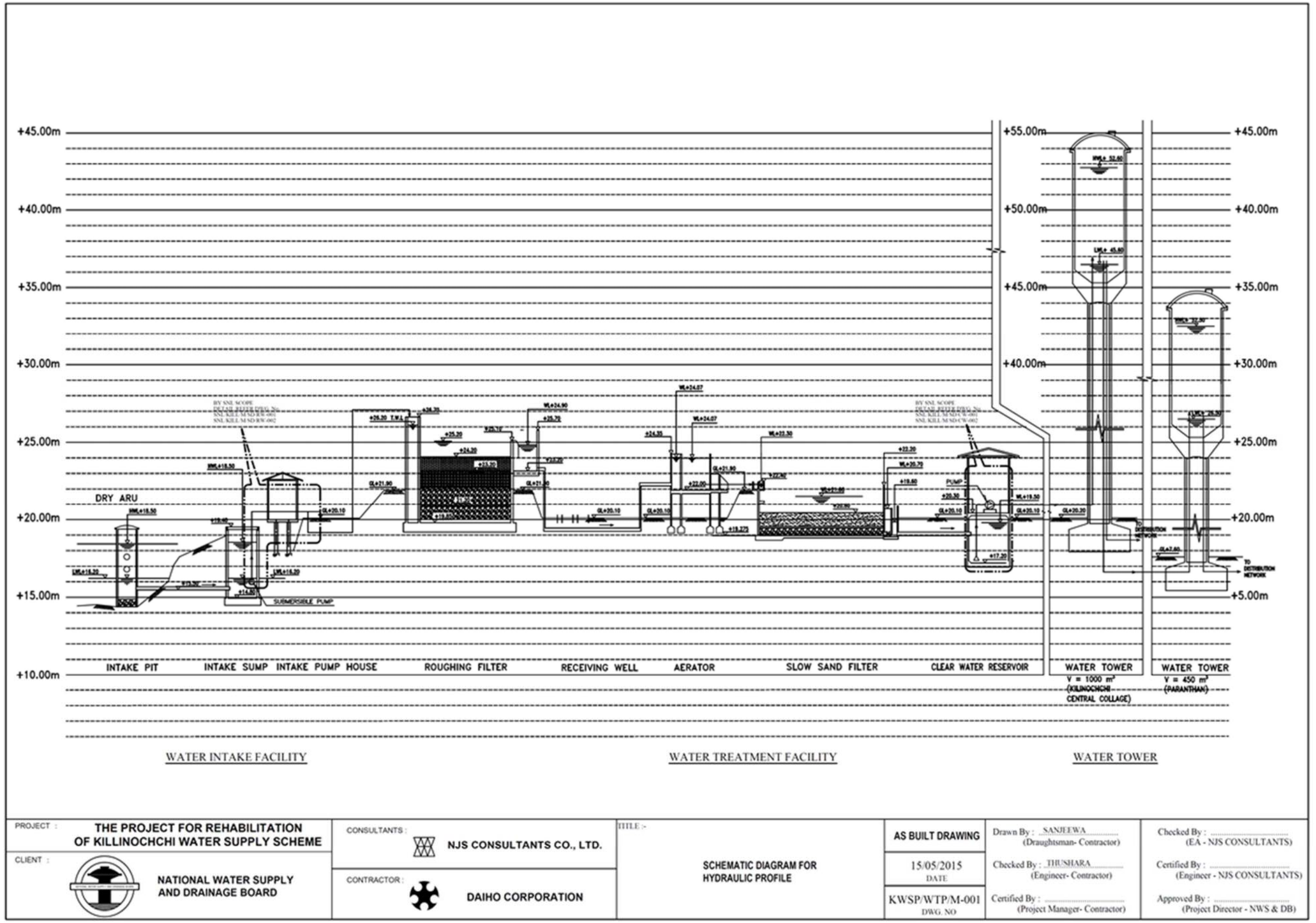


Figure 1-4 Hydraulic Profile

2. Operation and Maintenance Procedure

2.1 Start Up Procedure

(1) Confirm whether there is no abnormal condition such as chlorine gas leakage etc.

(2) Confirm that related valves (indicated "normally open") are open.

(3) Confirm electrical power resource condition as below;

- ✓ Select "A" for auto mode at KE-LV-1 in the Electrical Room.
- ✓ UPS battery in the Electrical Room is ON.
- ✓ Turn on the circuit breaker for UPS at KV-LV-3 in the Electrical Room.

Figure 2-1 VSD REMOTE DISPLAY UNIT

(4) Start the Intake Pump

- ✓ Select "R" for remote mode at KE-LP-1 in the Intake Pump House.
- ✓ Select "ALT" at KE-LP-1 in the Intake Pump House.
- ✓ Select "A" for Auto mode at KE-IS-1 and 2 in the Electrical Room .
- ✓ Adjust the flow rate to 158 m^3/hour by "VSD REMOTE DISPLAY UNIT" (approx. 47.0 Hz).
- ✓ The Intake Pump will start above LWL (+16.4 m) automatically.

(5) Adjust the filtration rate at each SSF

- ✓ Adjust the overflow depth to 163 mm at V-notch weir by the outlet valve in case that three SSF are running (191 mm in case that two SSF are running).

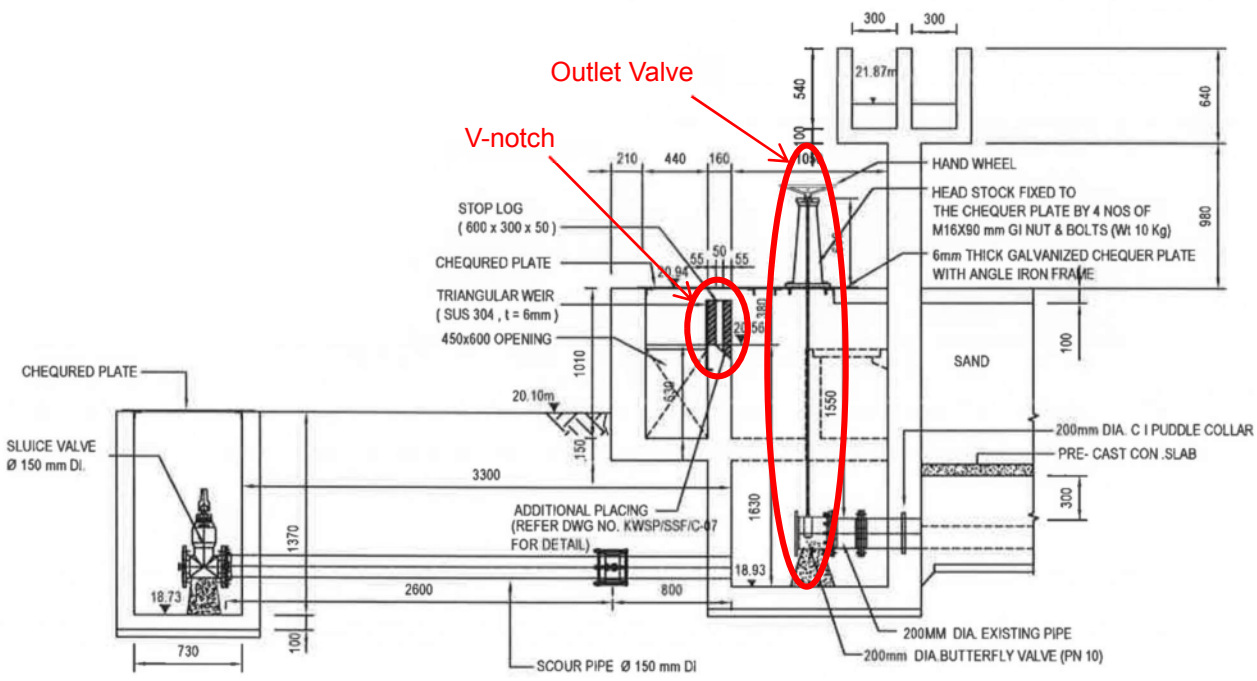


Figure 2-2 Location of the Flow Control Valve and V-notch in SSF

(6) Start the Transmission Pump

- ✓ Select "R" for remote mode at KE-LP-2 in the Transmission Pump Room.
- ✓ Select "ALT" at KE-LP-2 in the Transmission Pump Room.

- ✓ Select "A" for auto mode at KE-TS-1 and 2 in the Electrical Room.
- ✓ The Transmission Pump will start above HWL (+2.35 m) at CWR and below MWL (+5.6 m) at KWT automatically.
- ✓ The Transmission Pump will stop below LWL (+0.87 m) at CWR or above HWL (+6.6 m) at KWT automatically.

(7) Dose Chlorine Gas

- ✓ Turn on the main power switch of related panels.
- ✓ Open the Isolation Valve Assembly (No.6, **Figure 2-17**) of both chlorine gas cylinders.
- ✓ Select "R" for remote mode at KE-LP-2 in the Transmission Pump Room.
- ✓ Confirm whether the Chlorine Booster Pump is running.
- ✓ Adjust the flow rate to 160 g/hour as 1.0 ppm by the Wall Panel Mounted Control Valve (No.3, **Figure 2-17**).

2.2 Stop Procedure

(1) Stop the Intake Pump

- ✓ Select "M" for manual mode at KE-IS-1 and 2 in the Electrical Room.
- ✓ Push "STOP" button.

(2) Close the flow control valve of all SSFs.

(3) Stop the Transmission Pump.

- ✓ Select "M" for manual mode at KE-TS-1 and 2 in the Electrical Room.
- ✓ Push "STOP" button.

(4) Stop Chlorine Gas

- ✓ In case it will be need to stop for long period, turn off the main power switch of related panels and close the Isolation Valve Assembly of both chlorine gas cylinders (No.6, **Figure 2-17**).

2.3 Detail Operation Procedure of Each Facility

2.3.1 Intake Pump

The Intake Pump runs 24 hours a day alternately every 1 to 3 day(s) by timer setting in automatic operation.

(1) Normal Operation

- ✓ Confirm whether the water level is above LWL or more (+16.4 m).
- ✓ Open the discharge valve of Intake Pump and maintenance valves.
- ✓ Start the Intake Pump (See **Table 2-1**).
- ✓ Adjust the intake flow rate to 158 m^3/hr. (3,800 m^3/day) by "VSD REMOTE DISPLAY UNIT". The intake flow rate per one pump can be set from 83 m^3/hr. (approx. 38 Hz) to 158 m^3/hr. (approx. 47 Hz) in accordance with **Figure 2-4**.
- ✓ Check / measure the required data and water quality and record it on “WTP Daily Operation Record Sheet” and “Daily Maintenance Record Sheet” as shown in Appendix-1.

(2) Maintenance and Inspection of Intake Pump

- ✓ Stop the selected Intake Pump by manual operation (See **Table 2-1**).
- ✓ Close the discharge valve of selected Intake Pump.
- ✓ Turn off the MCCB of selected Intake Pump.
- ✓ Pull up the Intake Pump by using the manual chain hoist.
- ✓ Necessary maintenance and inspection shall be performed in accordance with the instruction manual.

(3) Cleaning of Intake Pump Sump (At least once a year, before Rainy Season)

- ✓ Stop all Intake Pump by manual operation (See **Table 2-1**).
- ✓ Confirm the bottom condition of Intake Pump Sump.
- ✓ If sediments such as sand/mud are found at the bottom, remove it by using another submersible pump.

Note) This procedure was added since a difference between turbidity value before Intake Pump and that of after Intake Pump was found during the Follow Up Survey conducted in 2019.

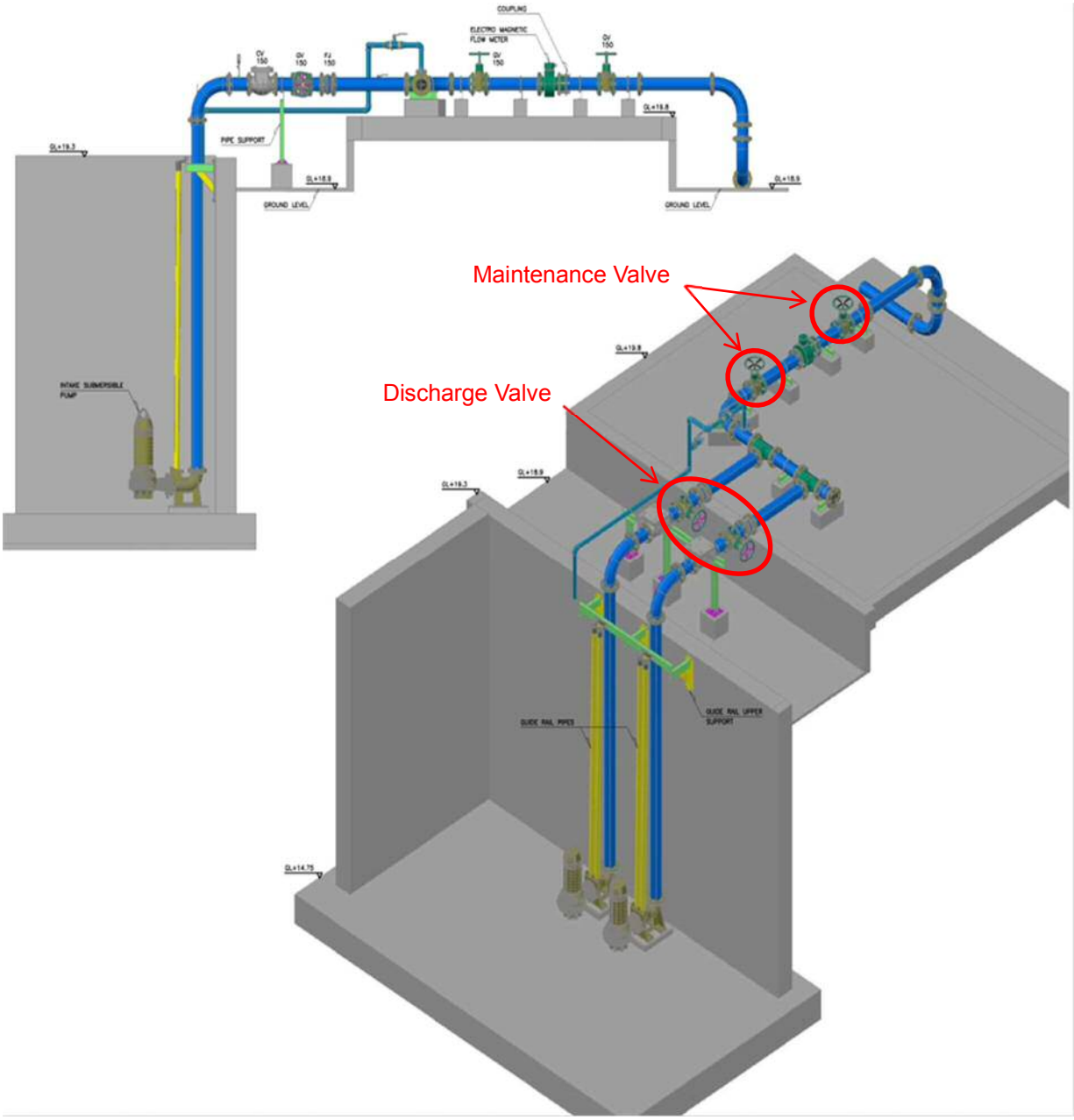


Figure 2-3 Layout of Intake Pump

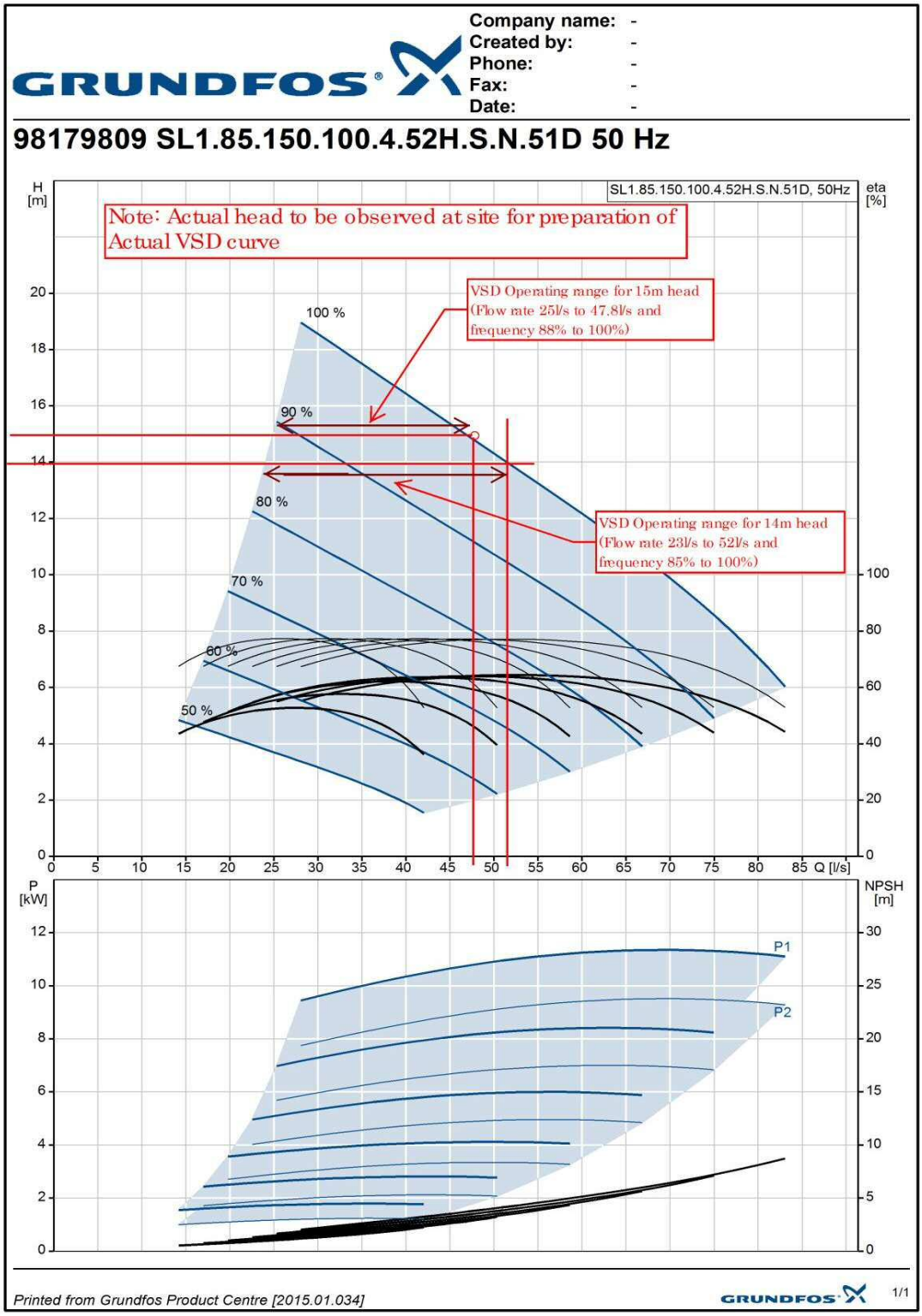


Figure 2-4 Q-H Curve of Intake Pump

Table 2-1 Detail Operation Procedure of Intake Pump

Contents	KE-IS-1&2 (Starter Panel)	KE-LP-1 (Local Control Panel)
Photo		
Auto Operation	Auto Operation 1. Select “A” for auto mode at KE-IS-1&2 and select “R” for remote mode at KE-LP-1 2. Select the pump to be operated by “P1/ALT/P2” switch at KE-LP-1 2. The selected pump will operate continuously 3. You can adjust the pump operation speed manually at both KE-IS-1&2 or KE-LP-1 4. The pump will automatically stop in case of water level L @Intake sump. < Setting for alternative operation > 1. Select “A”, for auto mode at both KE-IS-1 & 2 2. Select “ALT” for alternation mode at KE-LP-01	
Manual Operation	Pump ON 1. Select “M” for manual mode 2. Push “START” button 3. Pump operating speed can be adjusted by setting value on the VSD display (Note1) Pump OFF 1. Push “STOP” button in manual mode 2. Change the mode from “A” to “M”	Pump ON 1. Select “L” for local mode 2. Push “START” button 3. Pump operating speed can be adjusted using speed controller (Note1) Pump OFF 1. Push “STOP” button in Local mode 2. Change the mode from “R” to “L”
Interlock Condition	1. “L” (Local mode) selected at KE-LP-1 2. LL detects @ Intake sump (Dry run protection) 3. Electrical faults (Over Load, Earth Fault, Inverter Fault) 4. PLC Communication Failure (Note2)	Same as left except for No.1
Remark	Note1: In case of Inverter Fault, “STAR DELTA” mode can be selected and utilized as backup instead of “VSD” mode at KE-IS-1&2 although it does not have speed control function. Note2: Even in case of PLC Failure, the intake pump can be operated by KE-IS-1&2 only in manual mode. However, the dry run protection cannot function so please visually check the water level of intake pit in advance.	

2.3.2 Roughing Filter (RF)

Basically, **RF shall be operated continuously** in accordance with the following procedures.

(1) Preparation

- ✓ Clean the inside of RF before filling the water and remove rubbish if it exists.
- ✓ Check that the surface of filter media is even and there is no abnormality.
- ✓ Close the drain valve-1.
- ✓ Open the inlet valve.
- ✓ Start the Intake Pump (See **clause 2.3.1**).
- ✓ Fill the RF with raw water up to above the filter media.

(2) Normal Operation

- ✓ Start the Intake Pump (See **clause 2.3.1**)
- ✓ Check the water level, the condition of filter media and appearance of treated water*1.

  *1) Design filtration rate is 36 m / day (1.5m / hour).
- ✓ Measure the turbidity of treated water and record it on "WTP Daily Operation Record Sheet (as shown in Appendix-1)".
- ✓ If the treated water turbidity of either RF exceed 30 NTU, the inlet valve of RF shall be closed.
- ✓ If the treated water turbidity of both RF exceed 30 NTU, the procedure as shown in **clause 2.4 (3) 1)** shall be performed.

(3) Procedure of Washing

In case that the turbidity of RF continues to increase and/or the filtration resistance (the water level of inlet chamber) is high, RF shall be washed by the following procedure. However, RF shall be washed at least once a month.

- ✓ Confirm the condition of the Storage Pond (SP); the inlet valve is fully opened, water level is low enough, the drain valve is closed.
- ✓ Reduce the intake flow up to 1.4 m^3/min (half of design flow rate: 2.77 m^3/min)
- ✓ Close the inlet valve of the selected RF.
- ✓ Open the drain valve-1 of the selected RF as quickly as possible and wash out the inside water completely. Calculated water amount of RF is shown in **Table 2-2**.
- ✓ Check the water level of SP.
- ✓ When the wash waste water of RF is stopped flowing, close the drain valve-1 of selected RF.

  (Discharge flow rate: approx. 8.2 m^3/min with full open of drain valve of RF, Effective volume of SP: approx. 172 m^3)
- ✓ After suspended solid is settled enough in SP, open the drain valve of SP and discharge the supernatant.
- ✓ Open the inlet valve of the selected RF and increase the intake flow rate up to 2.77 m^3/min.

Figure 2-5 Appearance of Wash Waste Water of RF in SP

- ✓ Fill the selected RF with raw water up to the surface of filter media.
- ✓ Repeat the above procedures until the appearance of wash waste water of both RFs will be clean.
- ✓ In case that the appearance of wash waste water is not clean enough at the end of washing, keep open the drain valve-1 and open the inlet valve of selected RF for washing out the sediments/mud remained at the bottom part. After the appearance of wash waste water is clean enough, close the drain valve-1.
- ✓ After finishing the RF washing, start operation in accordance with the procedure as shown in above (1). It is recommended to open the drain valve-2 until the treated water turbidity will be clean enough.

Table 2-2 Calculated Water Amount of RF

Item	Dimension (m)	Area (m^2)	Above the Surface of Filter Media		Below the Surface of Filter Media		Water Amount (m^3)
			Depth (m)	Volume (m^3)	Depth (m)	Volume (m^3)	
Inlet Chamber	W5.1 x L1.5	7.65	2.0	15.3	4.35	33.3	48.6
RF	W5.1 x L11.0	56.1	1.0	56.1	4.35	244	300.1
Total	-	63.75	-	71.4	-	277.3	348.6

(4) Maintenance and Inspection

- ✓ Confirm the inlet valve of SP is fully opened and close the drain valve of SP.
- ✓ Close the inlet valve of the selected RF.
- ✓ Open the drain valve-1 of the selected RF and wash out the inside water completely.
- ✓ Perform the maintenance or inspection work.

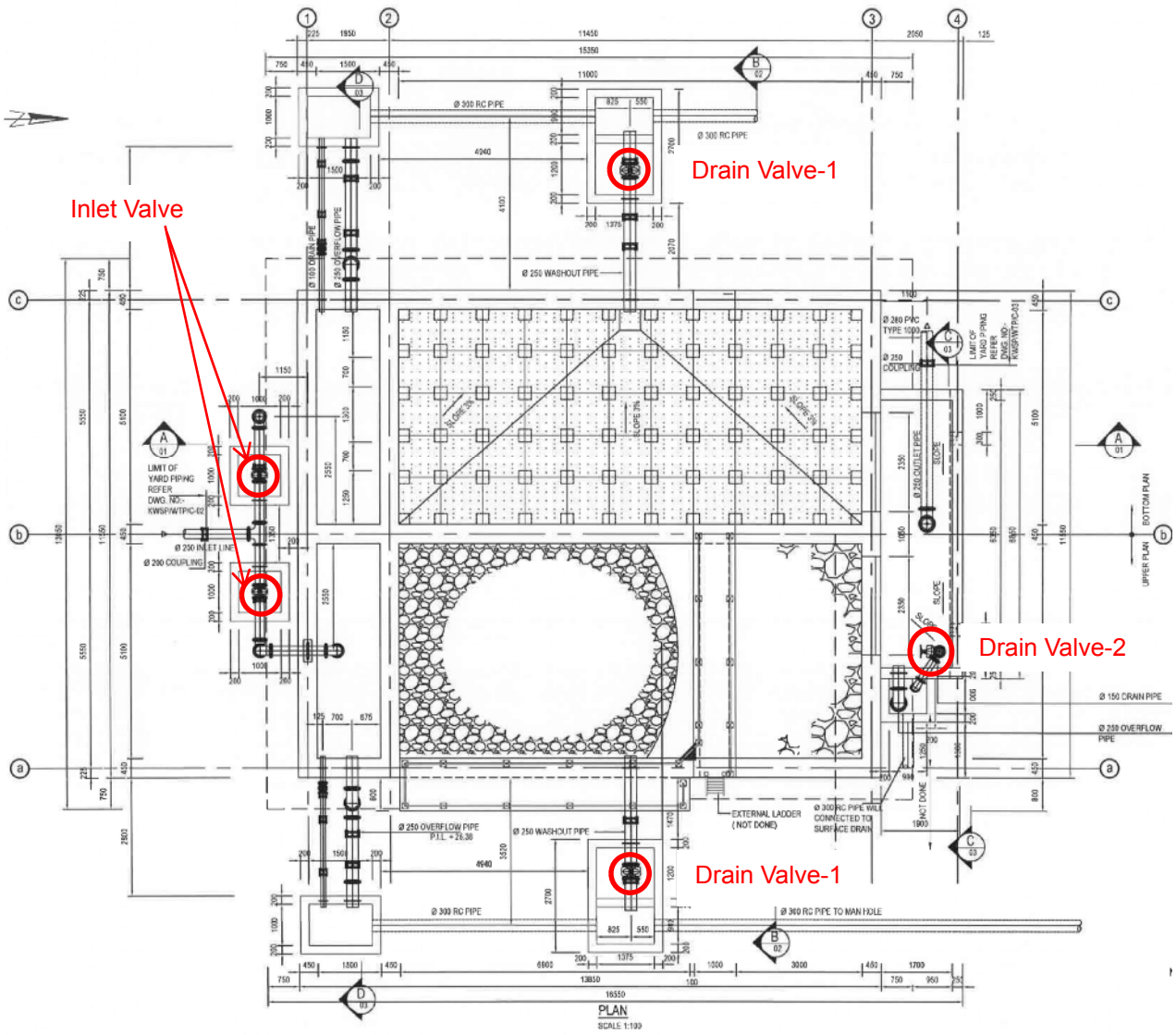


Figure 2-6 Layout of Roughing Filter

2.3.3 Receiving Well / Aerator

(1) Normal Operation

- ✓ Confirm that the drain valves of Receiving Well and Aerator are closed.
- ✓ Open the Inlet valve of Receiving Well.

(2) In Case of Maintenance and Inspection

- ✓ Close the Inlet valve of Receiving Well.
- ✓ Open the drain valves of Receiving Well and Aerator.
- ✓ Perform the maintenance or inspection work. Cleaning shall be done at least once a month.

Figure 2-7 Cleaning Work of Aerator

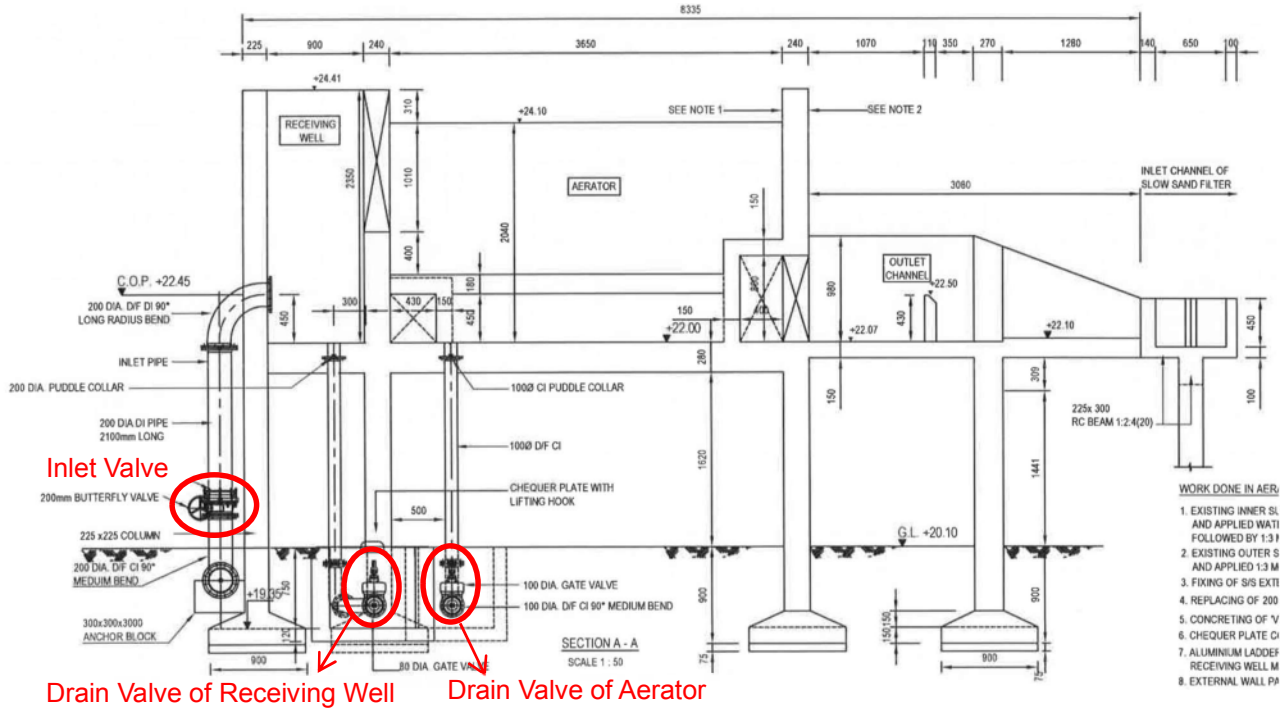


Figure 2-8 Layout of Receiving Well and Aerator

2.3.4 Slow Sand Filter (SSF)

Basically, **at least two SSFs shall be operated simultaneously and continuously** in accordance with the following procedures.

(1) Preparation

- ✓ Clean the inlet channel, inside of SSF and collecting chamber.
- ✓ Close the outlet valve and drain valve.
- ✓ Check that sand level is even and there are no visible crack on the surface or other abnormalities.
- ✓ Open the inlet valve slowly to avoid unevenness of the sand surface.
- ✓ Fill the SSF with water up to above the sand surface.

(2) Normal Operation

- ✓ Open the inlet valve.
- ✓ Check / Adjust the height of stop log in order to keep even inflow of each SSF.
- ✓ Check / Adjust the filtration rate*2 (discharge flow) of each SSF by the opening of outlet valve.

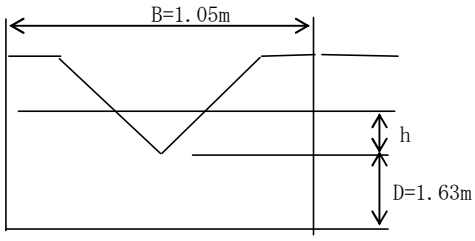
*2) Design filtration velocity is 3.5 m/day (three SSFs are in operation) and 5.3 m/day (two SSFs are in operation). Filtration rate/velocity shall be measured/checked by the overflow depth (h) at the V-notch as shown in **Figure 2-9**.

< Formula to calculate the filtration amount of SSF>

$$Q = Ch^{\frac{5}{2}}$$

$$C = 1.35 + \left(\frac{0.004}{h}\right) + \left(0.14 + \frac{0.2}{D^{1/2}}\right) \times \left(\frac{h}{B} - 0.09\right)^2$$

Filtration Rate: Q (m^3/s)
Overflow Depth: h (m)



Number of Operated SSF	Filtration Rate per one SSF (m^3/d)	Filtration Velocity per one SSF (m/d)	Overflow Depth: h (mm)
3	1,267	3.5	163
2	1,900	5.3	191
2	1,440	4.0	171
2	1,080	3.0	153
2	720	2.0	129
2	360	1.0	98

Figure 2-9 Filtration Rate, Filtration Velocity and Overflow Depth at the V-notch

- ✓ Check the water level*3, the condition of biological film*4/filter sand and appearance of treated water.

*3) Water depth above the sand surface shall be kept between 800 mm to 1,200 mm.

*4) An aerobic condition (recommended DO value: 6-7 mg/L) shall be required to keep proper condition of biological film. (See Appendix-3)

- ✓ Measure the required parameters of treated water quality such as turbidity of at the Collection Chamber and record it on “WTP Daily Operation Record Sheet (as shown in Appendix-1).

(3) Procedure of Sand Scraping

1) Timing of Sand Scraping

Sand scraping shall be carried out once in one to three months depending on the water level (filtration resistance) in SSF. It is recommended to carry out the scraping before start of rainy season. Basically, sand scraping shall be carried out when;

- ✓ Filtration resistance (water level above the sand) increase.
- ✓ Treated water quality become difficult to satisfy with NDWQS.
- ✓ Abnormal condition in SSF is observed.

2) Procedure of Sand Scraping

Sand scraping of SSF shall be carried out as follows;

- ✓ Put on gloves and cleaned boots before entering SSF.
- ✓ Close the inlet valve and remove all floating materials.
- ✓ Drain out water from the drain valve slowly and keep the water level approx.200 mm below the sand surface.
- ✓ Wash / clean the walls of filter.
- ✓ Remove algae and remaining scum on the surface sand.
- ✓ Start scraping approx. 10 mm of surface sand from one edge. Scraping must be finished within one day.

Figure 2-10 Sand Scraping Work by Using Wooden Scraper

- ✓ Carry the scraped sand to the Storage Yard.
- ✓ Check / measure the sand thickness. If it is less than 500 mm, re-sanding must be done.
- ✓ Level the sand bed.

(4) Restart of SSF

- ✓ Open the inlet valve slowly to avoid unevenness of the sand surface.
- ✓ Fill the SSF with water up to above the sand surface.
- ✓ Drain off treated water from the drain valve until the biological film on the sand surface will be formed[*5].

*5) Filtration rate shall be kept 1.0 m /day at the beginning and it shall be increased up to design value gradually. It will take at least 7 days (around 30 days in the worst case) until SSF will function normally, and this period depends on the weather condition and raw water quality.

- ✓ Collect sample of treated water and check the turbidity.
- ✓ After the turbidity of treated water is below 2 NTU, close the drain valve.

(5) Procedure of Washing Filter Sand

Washing filter sand shall be carried out by using the Sand Washer in accordance with the following procedure. The detail operation procedure is shown in Appendix-2.

1) Setup

- ✓ Set up the Sand Ejector Unit (1) on the sand surface.
- ✓ Set up the Sand Separator Tank (2) outside the SSF*6.

  *6) The vertical level difference between the Sand Ejector Unit (1) and the Sand Separator Tank (2) shall be within 4 m. Otherwise, water pressure has to be increase.
- ✓ Connect the Connecting Parts for Pressure Water (3) and related hoses as shown in **Figure 2-11** properly.
- ✓ Be sure to remove sands and/or dusts attached on screws and/or other metal parts, and insert the packing. Galling of the screw shall be carefully avoided.
- ✓ The bending angle of the rubber hose shall be as large as possible.

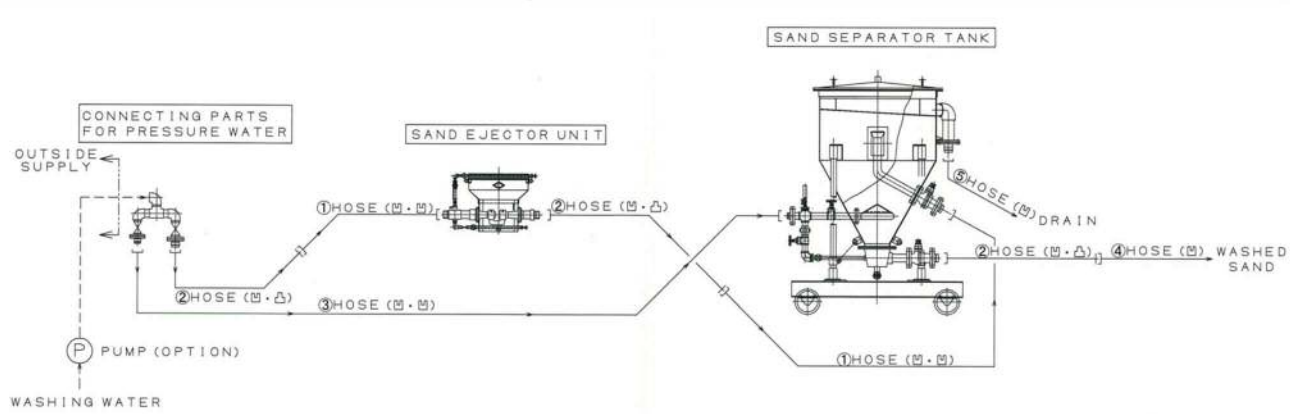


Figure 2-11 Setup of Sand Washer

2) Start Washing

- ✓ Close the all valves.
- ✓ Run the submersible pump installed at the outlet chamber of RF.
- ✓ Open fully the shut valve (4).
- ✓ Open the valves (5), (6) and (7) and send water to the tank (2).
- ✓ When the tank (2) is filled with water and start overflowing, open the valve (8).
- ✓ Check the pressure is more than 0.25 MPa.
- ✓ Throw the scraped sand to the ejector unit (1) and the sand will be sent to the tank (2) by a function of the ejector.
- ✓ The scraped sand is washed by the pressurized water by the function of Sprayer (9). The wash waste water overflows from the drain and the washed sand settles at the bottom of the tank.
- ✓ When the washed sand accumulates and comes up to the sight glass (10), open the valve (11) a little.

✓ Open the shut valve (12) little by little and discharge the washed sand.

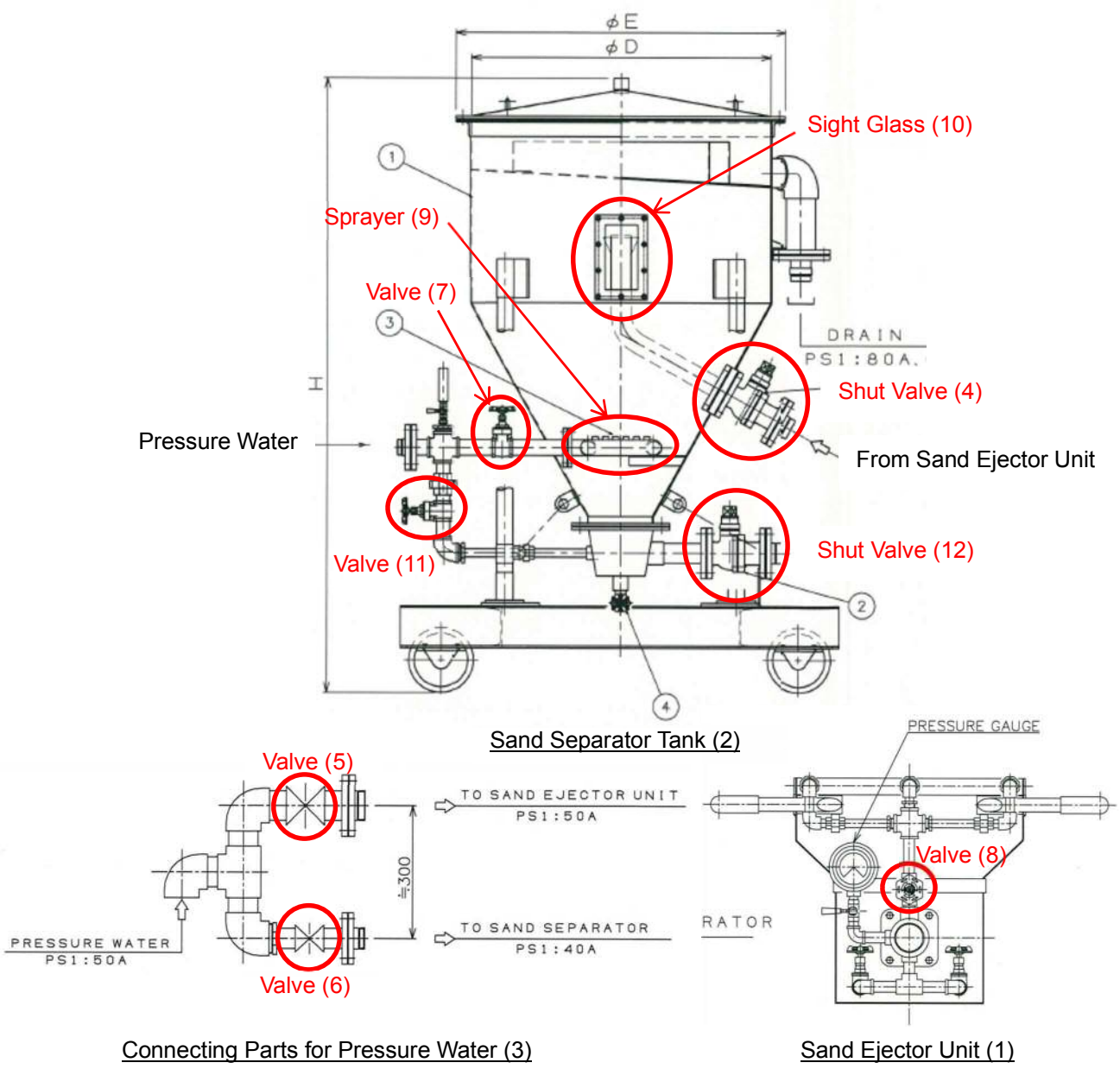


Figure 2-12 Details of Sand Ejector Unit, Sand Separator Tank and Connecting Parts for Pressure Water

[Notes]

a) The shut valve (12) has to be fully opened during washing filter sand. Then, adjust the opening of the valve (11) to balance the scraping sand and the washed sand. It is recommended to keep the washed sand level at the bottom of the sight glass (10) by adjusting the valve opening. The effect of the washing can be observed by the appearance of the washed sand and effluent water.

b) Adjust the opening of the valve (8) for the screen shower of the feeder properly.

3) Stop washing

✓ Stop feeding the scraped sand to the ejector unit (1).

✓ When the appearance of the wash waste water becomes clear and the scraped sand is sent to the tank (2) completely, close the valves (5), (8) and the shut valve (4).

- ✓ After all the washed sand has been discharged from the tank (2), close the valves (6), (7) and (11).
- ✓ Close the shut valve (12) completely.

[General Notes]

a) After washing works has been finished, open the shut valves (4)/(12), the valves (7)/(11) and the drain cocks of the ejector unit (1) and the tank (2), then drain out the inside water from the ejector unit (1), the tank (2), hoses and the pressurized pipe completely.

b) Detach the hoses carefully not to damage its screw, and store them in a dry and cool place with good ventilation.

c) Use a screen attached to the ejector unit (1) when the scraping sand contains gravel or other materials.

d) When the pressure reaches 0.25 MPa at the ejector unit (1), the unit can send the sand 4 m above it. In case that the sand is sent to the place higher than 4 m above it, the pressure shall be set/adjusted more than 0.25 MPa.

e) Generally, the spraying nozzles of sprayer (9) tends to wear away. The spraying condition of nozzles shall be checked from the sight glass (10) of the tank (2), and the nozzle shall be replaced timely in case that the spraying condition is changed.

f) The spraying nozzles can be checked by opening the valve (6) and supply water to the nozzles before open the valve (5). Use a special spanner in case of replacing the nozzles.

g) The ejector part of the Sand Ejector Unit (1) shall be replaced in case that the ability of ejector is decreased by wearing away. A clogging at the throat part of the ejector will cause a sudden drop of the suction force of the ejector. In this case, the clogging shall be removed.

h) The shut valves (4) and (12) shall be fully opened during an operation. In case that these valves are not opened fully, the Sand Separator Tank (2) will be damaged due to wearing away by sand.

Figure 2-13 Setup of Sand Separator Tank (Left) and Connection Point of Pressure Water (Right)

Figure 2-14 Pressure Gauge of Sand Ejector Unit (Left) and Throwing of Scraped Sand (Right)

(6) Procedure of Re-sanding

Re-sanding shall be carried out when the remaining sand depth reach up to 500 mm.

- ✓ Measure the sand depth after scrapping the sand.
- ✓ In case that the remaining sand depth is almost 500 mm, re-sanding is required.
- ✓ Remove the sand from one edge and place above the sand in other side.
- ✓ Place washed sand (or new sand) in emptied edge.
- ✓ Level the sand with 500 mm.
- ✓ Remove old sand next to new sand and place over new sand.
- ✓ Carry on similar activities till next edge.
- ✓ Remove all old sand and place over newly installed new and old sand.
- ✓ Fill the vacant place with new sand.
- ✓ Place the removed old sand over new sand.
- ✓ Level the sand with 1,000 mm (design value).

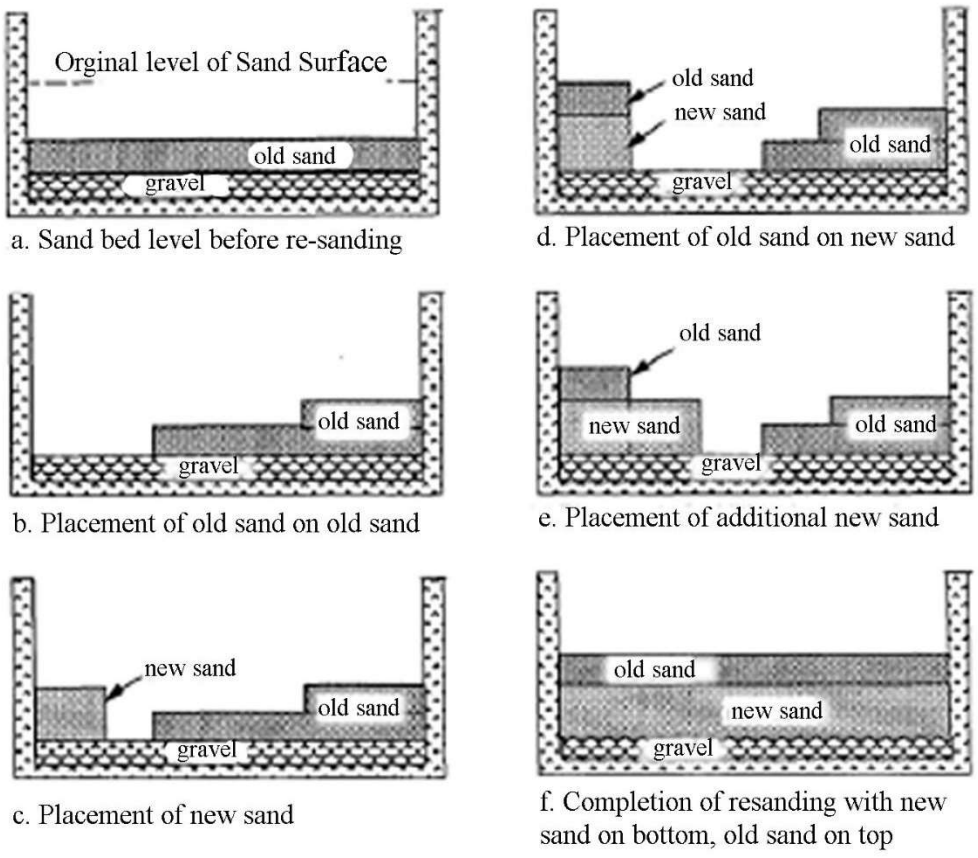


Figure 2-15 Procedure of Re-sanding (AWWA, 1991)

(7) Maintenance and Inspection

- ✓ Confirm the inlet valve is fully opened and close the drain valve of SP.
- ✓ Close the inlet valve of the selected SSF.
- ✓ Open the drain valve of the selected SSF and wash out the inside water.
- ✓ Perform the maintenance or inspection work.

2.3.5 Clear Water Reservoir (CWR)

The Transmission Pump runs to keep the HWL at Killinochchi Water Tower (KWT) in automatic operation. While the pump are stopping, the CWR water level keeps overflowing at HHWL.

(1) Normal Operation

- ✓ Confirm whether the CWR water level is above LWL and the KWT water level is 1.0 m below the HWL.
- ✓ Open the Suction Valve, Discharge Valve and related valves of Transmission Pump.
- ✓ Start the Transmission Pump (See **Table 2-3**).
- ✓ Check / Measure the required data including water quality and record it on “WTP Daily Operation Record Sheet” and “Daily Maintenance Record Sheet” as shown in Appendix-1.

(2) Maintenance and Inspection of Transmission Pump

- ✓ Stop the selected Transmission Pump by manual operation (See **Table 2-3**).
- ✓ Close the Suction and Discharge Valve of the selected Transmission Pump.
- ✓ Turn off the MCCB of the selected Transmission Pump.
- ✓ Necessary maintenance and inspection shall be performed in accordance with the instruction manual.

(3) Maintenance of CWR

- ✓ Stop the Intake Pump (See **Table 2-1**).
- ✓ Close the Outlet Valves and the Drain Valves of all SSFs.
- ✓ Run the Transmission Pump in manual operation until LLWL (See **Table 2-3**)
- ✓ Perform the maintenance or inspection work after check/measure the oxygen concentration of inside CWR.

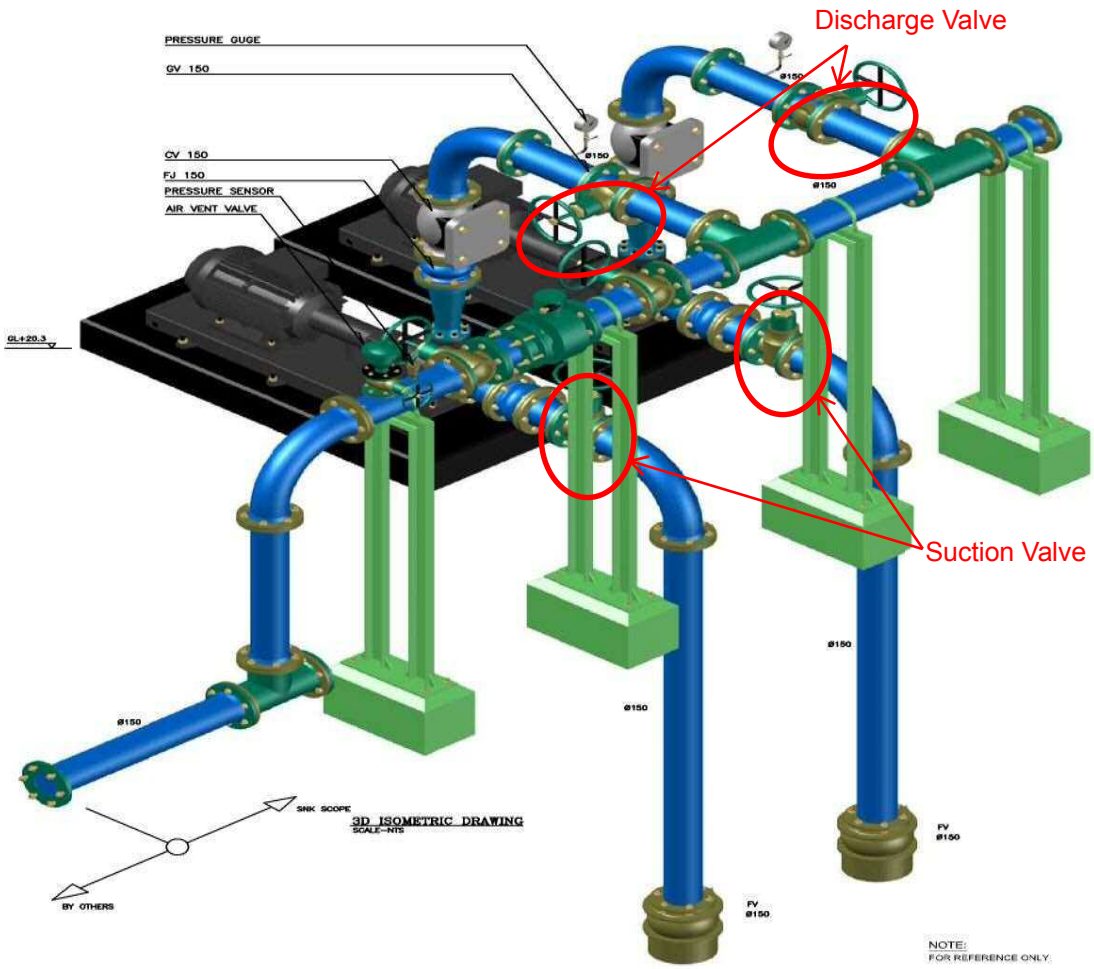


Figure 2-16 Layout of Transmission Pump

Table 2-3 Detail Operation Procedure of Transmission Pump

Contents	KE-TS-1&2 (Starter Panel)	KE-LP-2 (Local Control Panel)
Photo		
Auto Operation	Auto Operation 1. Select “A” for auto mode at KE-TS-1&2 and select “R” for remote mode at KE-LP-2 2. Select the pump to be operated by “P1/ALT/P2” switch at KE-LP-2 3. The selected pump will automatically operate according to water level of CWR and KWT as shown below. ● Start Condition "≥ H@CWR" and "≤ @KWT" ● Stop Condition "< L @CWR" or "≥ H@KWT" < Setting for alternative operation > 1. Select “A”, for auto mode at both KE-TS-1 & 2 2. Select “ALT” for alternation mode at KE-LP-02	
Manual Operation	Pump ON 1. Select “M” for manual mode 2. Push “START” button Pump OFF 1. Push “STOP” button in manual l mode 2. Change the mode from “A” to “M”	Pump ON 1. Select “L” for local mode 2. Push “START” button Pump OFF 1. Push “STOP” button in local mode 2. Change the mode from “R” to “L”
Interlock Condition	1. “L” (Local mode) is selected at KE-LP-2 2. LL detects @ CWR (Dry run protection) 3. ≥ H detects @ KWT 4. Electrical faults (Over Load, Earth Fault, Inverter Fault) 5. "Killinochchi Tower Power" Fails 6. “PLC Communication Failure” (Note1) 7. “GSM Communication Failure” 8. "High Pressure" and "Low Flow" detect together (Note2) 9. "Low Low Flow" detects (Note2)	Same as left except for No.1
Remarks	Note1: Even in case of PLC Failure, the intake pump can be operated by KE-IS-1&2 only in Manual mode. However, the dry run protection cannot function so please visually check the water level of CWR in advance. Note2: See attached 【Setting Values】 in detail.	

2.3.6 Chlorination Facility

The Chlorine Booster Pump runs alternately (sequential running with the Transmission Pump) in automatic operation.

(1) Preparation

- ✓ Start the ventilating fan.
- ✓ Check the leakage of chlorine gas at fittings, valves and related instruments etc.
- ✓ Open the Isolation Valve Assembly (No.6) and check the main pressure of the cylinders (No.8).
- ✓ Open the Suction Valve (No.13), Discharge Valve (No.14) and related valves of Chlorine Booster Pump.

(2) Normal Operation

- ✓ Confirm whether the CWR water level is above LWL.
- ✓ Confirm whether the related valves are opened.
- ✓ Turn on the main power switch of related panels.
- ✓ Select "R" for remote mode at KE-LP-2 in the Transmission Pump Room.
- ✓ Check that the Chlorine Booster Pump is running*7.

  *7) The Chlorine Booster Pump will run automatically while the Transmission Pump is running.
- ✓ Adjust the flow rate to 160 g/hour as 1.0 ppm by the Wall Panel Mounted Control Valve (No.3).
- ✓ Check / Measure the required data including residual chlorine and record it on “WTP Daily Operation Record Sheet” and “Daily Maintenance Record Sheet” as shown in Appendix-1.

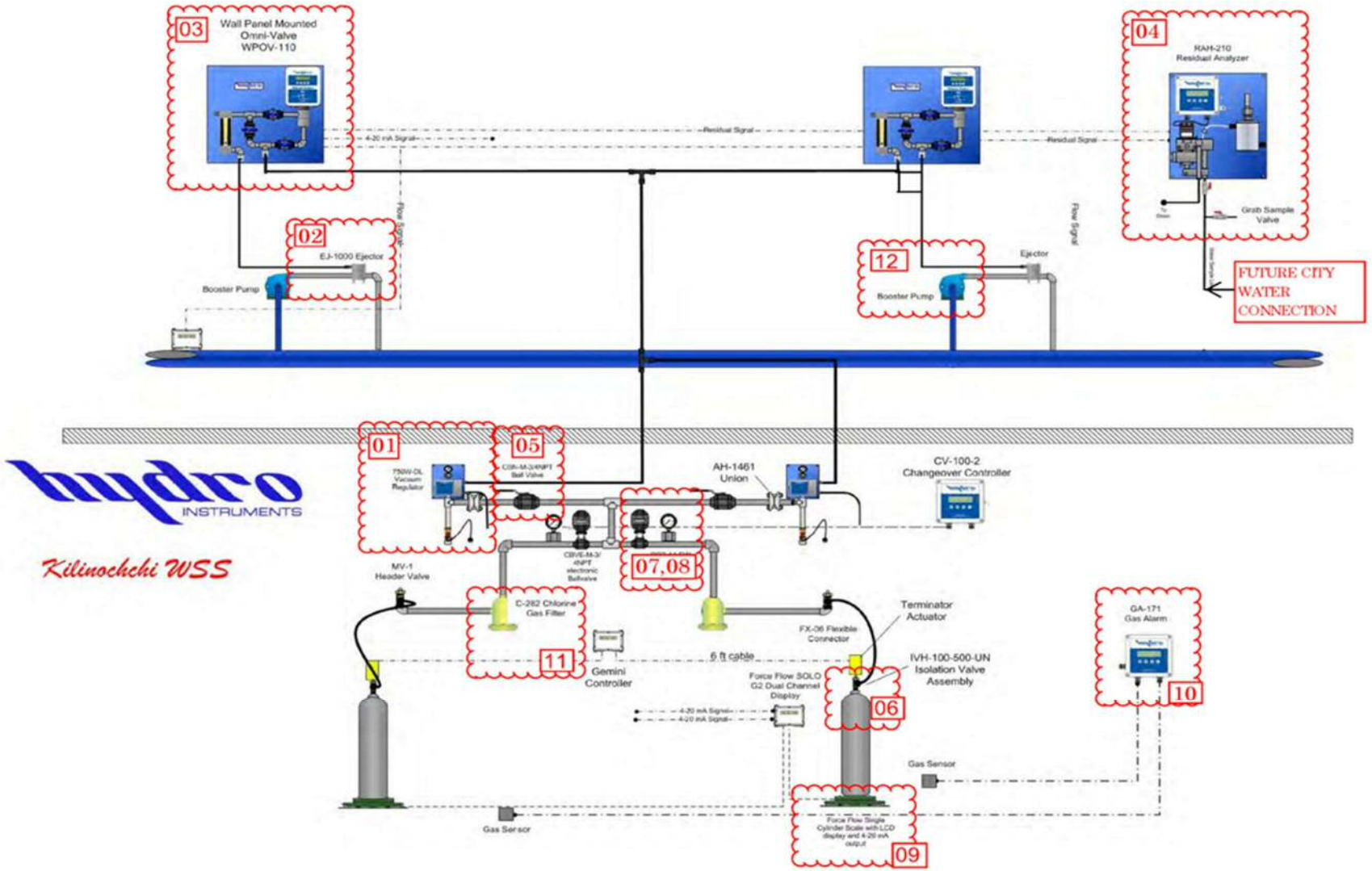


Figure 2-17 Flow Diagram of Chlorination Facility

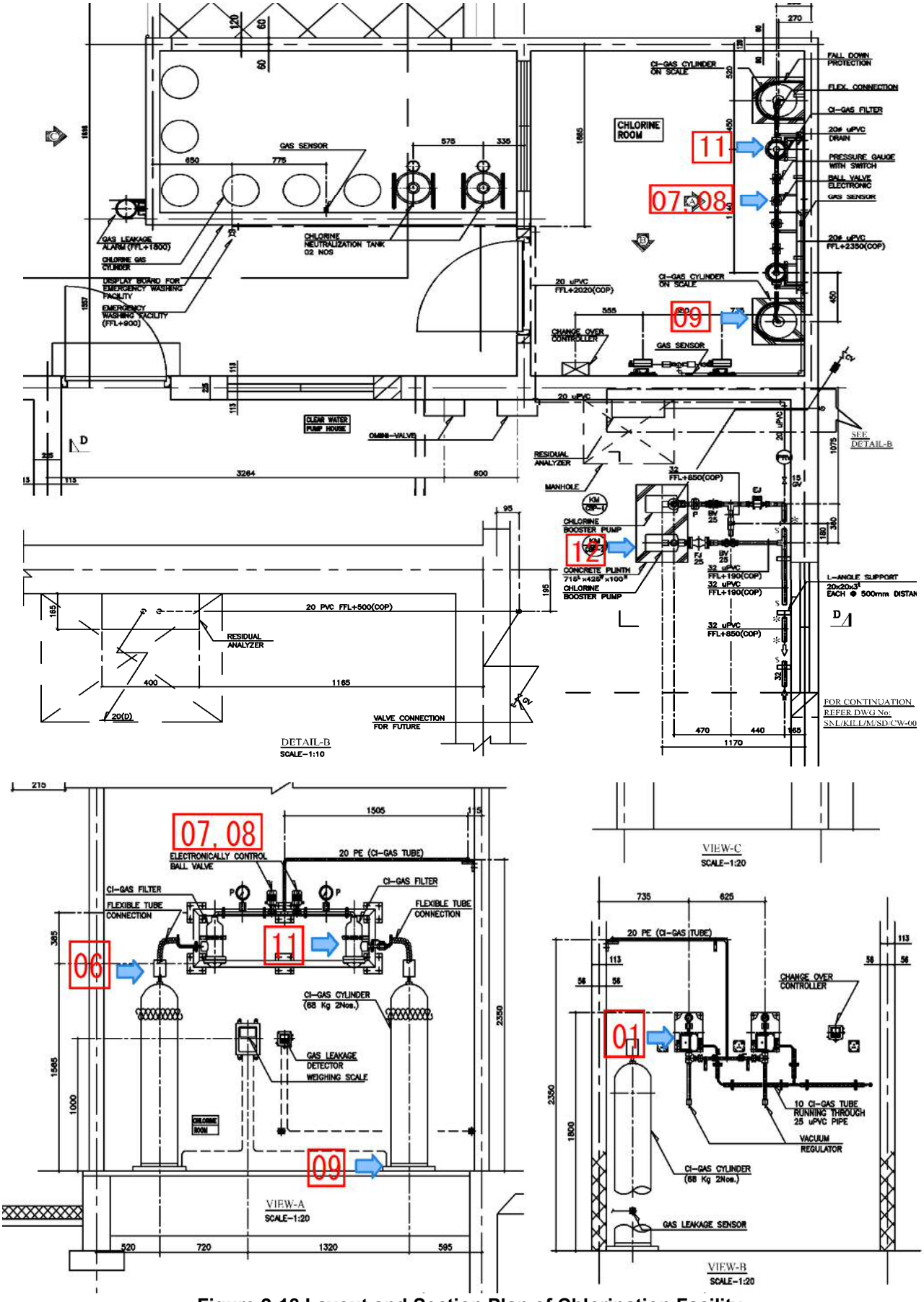


Figure 2-18 Layout and Section Plan of Chlorination Facility

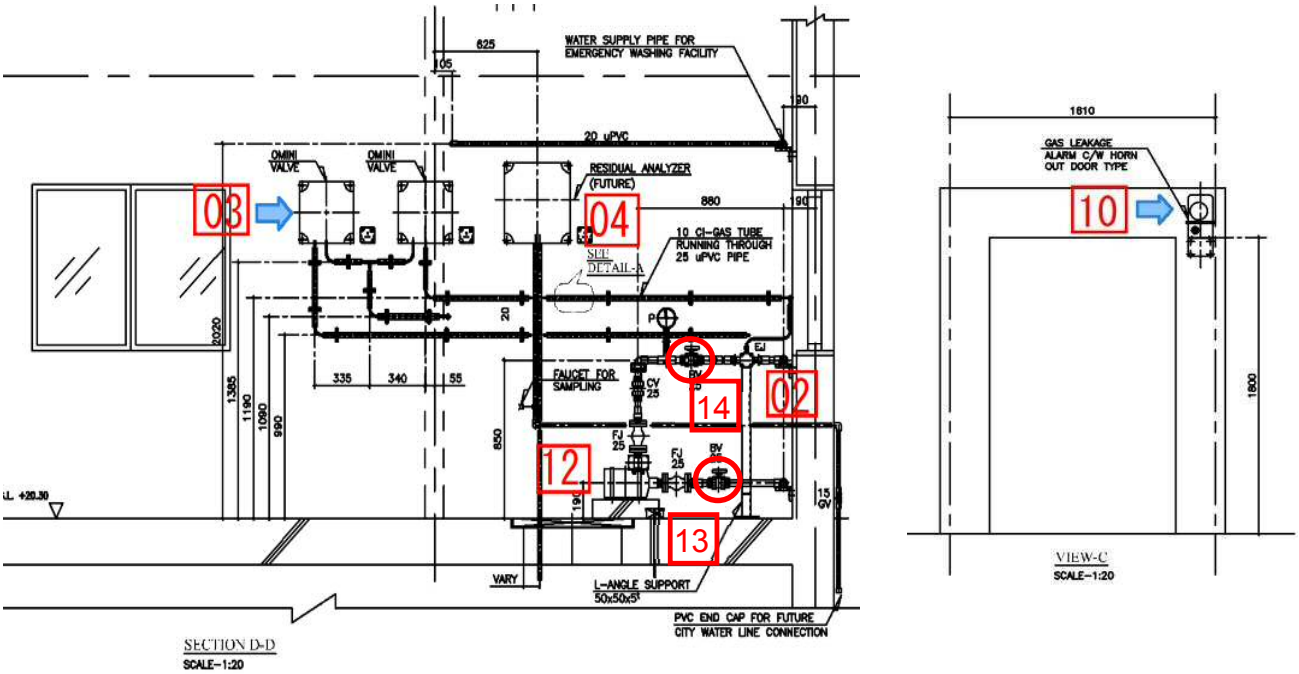


Figure 2-19 Section Plan of Chlorination Facility

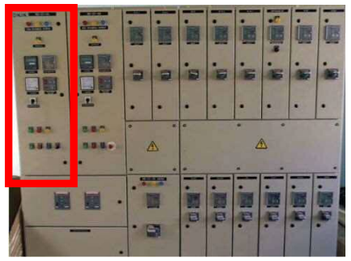
Table 2-4 Equipment List of Chlorination Facility

No.	Equipment Name
01	Vacuum Regulator
02	Ejector
03	Wall Panel Mounted Control Valve
04	Residual Analyzer
05	Chlorine Gas Filter
06	Isolation Valve Assembly
07	Electronically Actuated Chlorine Ball Valve
08	Pressure Gauge Adjustable Switch
09	Electronic Cylinder Scale
10	Chlorine Gas Leak Detector
11	Gas Filter
12	Chlorine Booster Pump
13	Suction Valve
14	Discharge Valve

2.3.7 Electrical Facility

The detail operation procedure of power source equipment is shown in **Table 2-5**, and the outline of automatic control system is shown in **Figure 2-20**.

Table 2-5 Detail Operation Procedure of Power Source Equipment

Contents		CEB (Electrical Company)	Standby Generator	UPS for Control Source
Photo		From CEB Transformer		
Panel related				
Operation	Auto	Auto Operation 1. Confirm the main breaker of the Standby Generator itself (not KV-LV-2) is ON. 2. Select “A” for auto mode at KE-LV-1. < In case of CEB power failure > 1. The main circuit breaker for CEB will be automatically turned off. 2. The generator will automatically start. 3. After the voltage of the generator has become stable, a main circuit breaker for the generator will be automatically turned on.	< In case of CEB power recovery > 1. When the recovery of CEB power is detected, the main breaker for CEB is turned on as soon as the main breaker for the generator is turned off automatically. 2. After some idling operation, the generator will stop automatically.	Auto Operation 1. Confirm whether the UPS battery is ON. 2. Turn on the circuit breaker for UPS at KE-LV-3 As long as the UPS battery itself and the circuit breaker for UPS at KE-LV-3 are turned on, they automatically function in case of power failure. On the other hand, if the circuit breaker at KE-LV-3 is turned off, even though the UPS power is on, it will not be able to provide back up control power to the PLCs and instruments during the power failure.
	Manual	CEB ON 1. Select “M” for manual mode at KE-LV-1. 2. Confirm the main breaker for Generator is OFF at KE-LV-2 (Note1). 3. Push “START” button at KE-LV-1. Note1: There is an interlock function between two main breakers to prevent from human error. Therefore, even if you push START before turning off the other operating breaker, it will not be operated together. CEB OFF 1. Push “STOP” button at KE-LV-1. Note that there will be no automatic power back-up.	Generator ON 1. Select “M” for manual mode at KE-LV-1. 2. Confirm the main breaker for CEB is OFF at KE-LV-1(Note2) 3. Push “START” button at KE-LV-2. Note2: In case of a maintenance operation of the generator, you can manually operate it by the control panel equipped on itself even though the main breaker of KE-LV-2 is OFF. Generator OFF 1. Push “STOP” button at KE-LV-2. 2. After some idling operation, the generator will stop automatically Note that there will be no automatic power back-up.	No need to be operated manually.
Procedure of Daily Operation/Inspection		Check Voltage, Ampere, Power Factor, and kWh by the devices as shown below on KE-LV-1. ・Digital Power Analyzer ・Voltmeter ・kWh meter	Check Voltage, Ampere, Power Factor, and kWh by the devices as shown below on KE-LV-2. ・Digital Power Analyzer ・Voltmeter ・kWh meter	・Cleaning

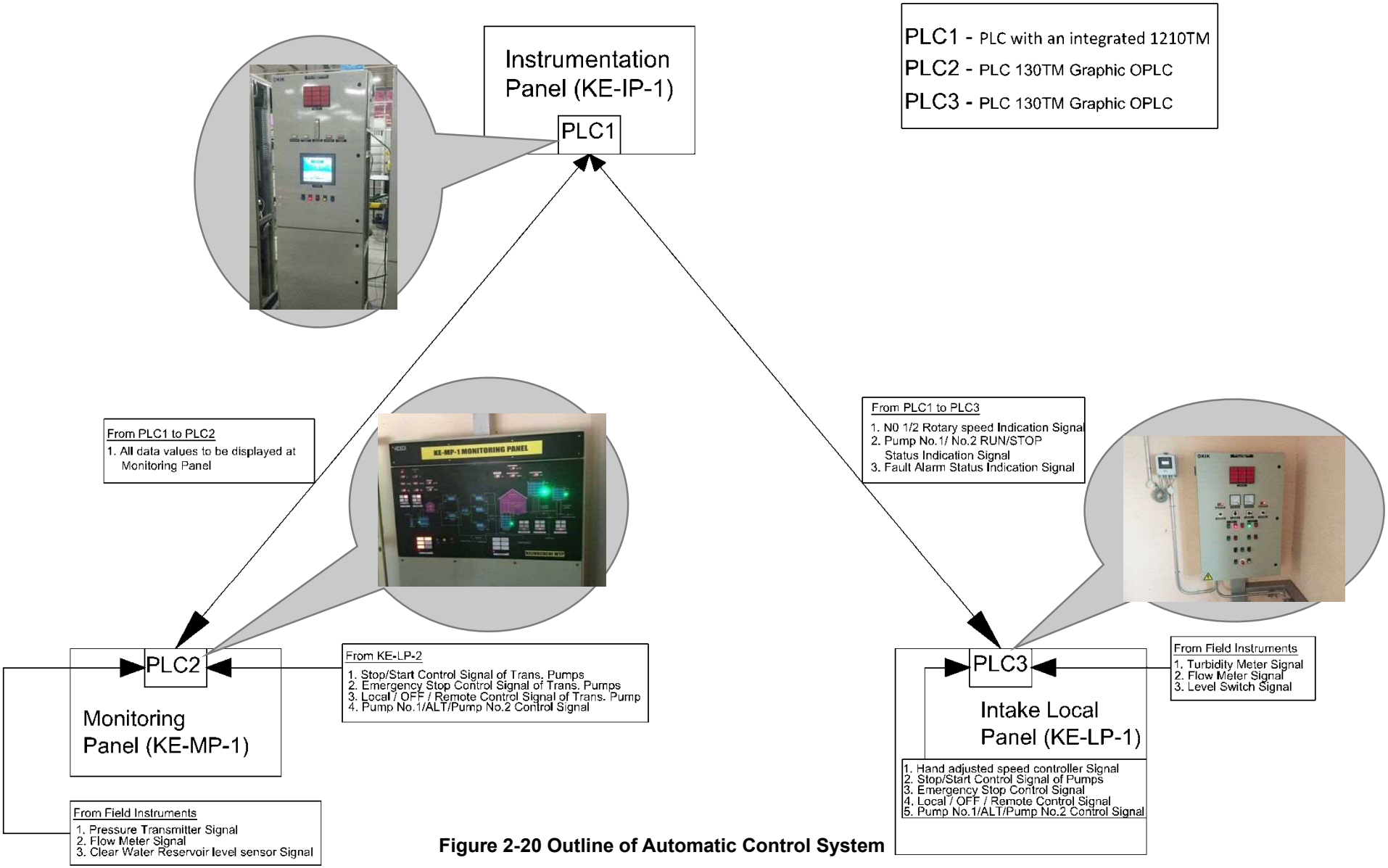


Figure 2-20 Outline of Automatic Control System

2.4 Trouble shooting

(1) Mechanical and Electrical Equipment

See Appendix-2 and the instruction manual of each equipment.

(2) Chemical

In case of chlorine gas leakage, the neutralization equipment “Chloless” shall be used properly and immediately in order to neutralize the leaked chlorine gas.

1) Operation Procedure

- ✓ Stand the cylinder vertically and extend the hose.
- ✓ Open the yellow valve (for nitrogen gas) and green valve (chemical powder) fully.
- ✓ Grasp the lever and spray the chemical powder.

2) Characteristics of Chloless.

- ✓ The Chloless is a sprayer which sprays chlorine-absorbing powder. The powder is moisture proof and has high fluidity.
- ✓ The chemical powder reacts with the leaked chlorine gas immediately.
- ✓ Easy handling like an extinguisher.
- ✓ The chemical powder is safe and good for prolonged storage.
- ✓ Loaded chemical weight is 25kg.
- ✓ Spraying duration is approx. 300 sec.
- ✓ Average spray rate is approx. 5.0 kg/min.
- ✓ The chemical reaction formula is shown as below.

$2Ca(OH)_2 + 2Cl_2 \rightarrow Ca(ClO)_2 + CaCl_2 + 2H2O$

Figure 2-21 Appearance of Chloless

(3) Water Quality

In case of water quality trouble, the following measures shall be taken in order to minimize the influence of it.

- ➢ To investigate the source
- ➢ To identify the causative substance
- ➢ To remove the causative substance

  (If impossible, it is necessary to stop water intake and distribution)
- ➢ To inform stakeholders

Furthermore, the following advance preparations are necessary in order to take appropriate measures quickly.

- ➢ To confirm the source of water pollutant around the intake point.

  (It is necessary to confirm the place of sources, distance from sources to intake point and reaching time.)

- To monitor raw water quality and abnormalities around intake point every day.
- To establish the reporting and contact system.
- To prepare a manual on water quality trouble.

1) High Turbidity of Raw Water / RF Treated Water (especially during Rainy Season)

The following actions and measures shall be taken in case that the turbidity of raw water and/or RF treated water exceeds the allowable limit of turbidity. The allowable limit of raw water is 80 NTU and that of RF treated water is 30 NTU based on the operation record from 2016 to 2018. According to the result of Follow Up Survey conducted in 2019, it is recommended that at least two SSFs are operated to decrease the filtration rate during rainy season.

- ✓ Measure / Monitor the water quality of raw water and RF treated water at appropriate frequency.
- ✓ In case that engineer / operator get an information of heavy rain (more than 50 mm/hour, it can be measured by rainfall meter installed at DE office.) or observed the high turbidity of raw water, the intake flow rate shall be decreased/adjusted until the turbidity will decrease up to 30 NTU (the minimum flow rate of Intake Pump is 83 m^3/hr.).
- ✓ In case that the turbidity of SSF treated water is less than 2 NTU, it can be sent to CWR.
- ✓ If the turbidity of SSF treated water exceeds 2 NTU, it shall be drained and the opening of SSF outlet valve shall be closed/adjusted in order to reduce the filtration rate of SSF.
- ✓ Check the turbidity of SSF drained water in case that the raw water turbidity continues to decrease and/or the turbidity of RF treated water is less than 30 NTU.
- ✓ In case that the turbidity of SSF treated water is less than 2 NTU, it can be sent to CWR.
- ✓ If the turbidity of SSF drained water still exceeds 2 NTU, the opening of SSF outlet valve shall be closed/adjusted more and checked/monitored it again.
- ✓ The above procedure shall be repeated until the turbidity of SSF treated water measures below 2 NTU. If not, the Intake Pump shall be stopped until the raw water turbidity is decreased up to 80 NTU, it is called as “Peak Cut”.
- ✓ The water level of KWT and PWT shall be monitored carefully, and also the distribution flow rate from each water tower shall be controlled accordingly.
- ✓ In case that the distribution flow from each reservoir will be reduced or stopped, necessary information shall be provided to consumers.

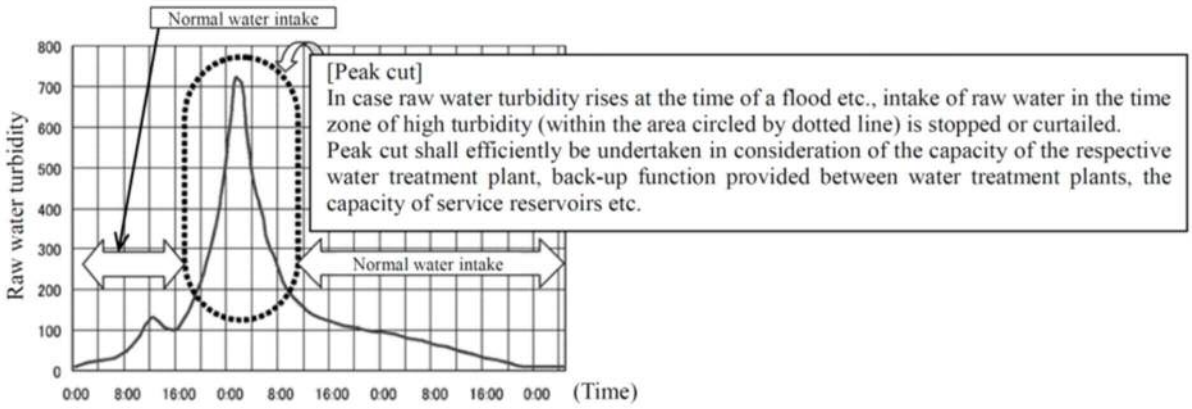


Figure 2-22 Outline of Peak Cut

Reference: “Water Supply Facilities Maintenance Manual 2006” (Japan Water Works Association)

2) Color and Odor due to Algae Bloom during Dry Season

According to the result of Follow Up Survey conducted in 2019, it is recommended to operate SSF with 4.8 m/day (design upper limit of filtration rate) in order to shorten the retention time and prevent algae growth in the SSF during dry season.

3) Oil Contamination

The following actions and measures shall be taken.

- ✓ Remove the oil by using an oil fence, oil mat (adsorbent) or suction vehicle.
- ✓ Stop water intake according to the situation.
- ✓ Inform consumer not to drink.

4) Contamination by Toxic Substances

The following actions and measures shall be taken.

- ✓ Stop water intake immediately. It is better to stop water distribution at the same time.
- ✓ Identify the toxic substance by the reaction of fish[*8] or physicochemical method.

  *8) Reactions such as floating on a water surface or rolling.
- ✓ Inform consumer not to drink.

5) Odor Due to Industrial or Domestic Wastewater

The following actions and measures shall be taken.

- ✓ Stop water intake according to the situation.
- ✓ Inform consumer.
- ✓ In case of low odor intensity, consumer can use (drink) tap water after boiling.

6) Excessive Chlorine Dosing

The following actions and measures shall be taken.

- ✓ Stop water distribution and the dosing of chlorine gas.
- ✓ Drain the treated water from CWR, KWT, PWT and/or distribution main according to the situation. In case that the R-Cl value of drain water is too high, it is necessary to dechlorinate it[*9].

  *9) High R-Cl value may cause environmental damage such as the mass death of fishes.
- ✓ Inform consumer not to drink.

7) Lack of Chlorine Dosing

The following actions and measures shall be taken.

- ✓ Stop water distribution.
- ✓ Increase the dosing rate of chlorine gas.
- ✓ Inform consumer not to drink without boiling.