Feasibility Study for water recycling technologies

1. Overview

Namibia is among the most arid countries in southern Africa. Though it receives an average of 360mm of rainfall each year, 83 percent of this water evaporates immediately after rainfall. Another 14 percent goes towards vegetation, and one percent supplies the ground water in the region, thus leaving merely two percent for surface use. Despite these staggering statistics, Windhoek, Namibia's capital, endures the most severe environmental conditions of the nation. the nearest reliably running river (the Okavango River) is approximately 700 km away.

Limited water resources are still an issue in Namibia, due to its ever-growing population. An increase in demand and the misuse of water exacerbates this water scarcity issue. To mitigate this issue, the Country's most feasible option is to augment the percentage of reclaimed water.

2. Introduction

Direct reclamation became a reality in 1968 In Winddhoek, Namibia when severe water shortages were experienced before the extension of the state water supply scheme could be completed. The first reclamation plant started to operate in 1968 with a capacity of 4,800 m3/d. Since then the reclamation process has undergone various changes of improvement (Haarhoff and van der Merwe, 1995). Investigations conducted during 1991 recommended that with minor changes to the plant, the capacity could be extended and the final water quality improved (Haarhoff, 1991). During a drought in 1992, where state supplies could not deliver the required quantity, the then existing plant was upgraded and extended to an interim capacity of 14,000 m3/d with the intention of ultimately reclaiming 21,000 m3/d. During another severe drought in 1997 it was however decided to build a new reclamation plant at an adjacent site to the Old Goreangab Reclamation Plant. During the period 1992 to 1998, all the components of the reclamation system were reviewed and re-analyzed and incorporated into the design of a new reclamation plant. In September 2002 the New Goreangab Reclamation Plant (NGRP) was commissioned. The old plant is now treating effluents for irrigation of parks and sports fields.

3. Feasibility Study

3.1 Otjiwarongo

Otjiwarongo is situated in central-north Namibia on the TransNamib railway. It is the biggest business center for Otjozondjupa Region. It is located on the B1 road and its links between Windhoek, the Golden Triangle of Otavi, Tsumeb and Grootfontein, and Etosha National Park. It is one of Namibia's fast-growing towns, with a neat and peaceful quality environment, and many excellent facilities including supermarkets, banks, lodges and hotels. Some of Namibia's best-known private game farms and nature reserves are located in and around the town.

In many of Otjiwarongo's townships residents live in shacks. In 2020 the city had a total of 6,251 of these informal housing structures, accommodating more than 50,000 inhabitants, more than the most recent (2011) census reported as total population figure.

In this project, we are likely to focus on the informal settlement area for water supply if any other conditions for the construction of water infra structure is affordable. Because in many developing countries, the accessibility for water related infra structure is worse than the one of formal settlement area.

Otjiwarongo has a semi-arid climate with hot summers and mild winters. The average annual precipitation is 457 mm.

Table 1. Climate data for Otjiwarongo

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Ave (C)	32	30	29	29	27	24	24	27	31	32	33	34	29
Daily(C) Mean	24.5	23.5	22.5	21	18	15	15	17.5	22	23	24.5	25	21.0
Average Low	17	17	16	13	9	6	6	8	13	14	16	16	13

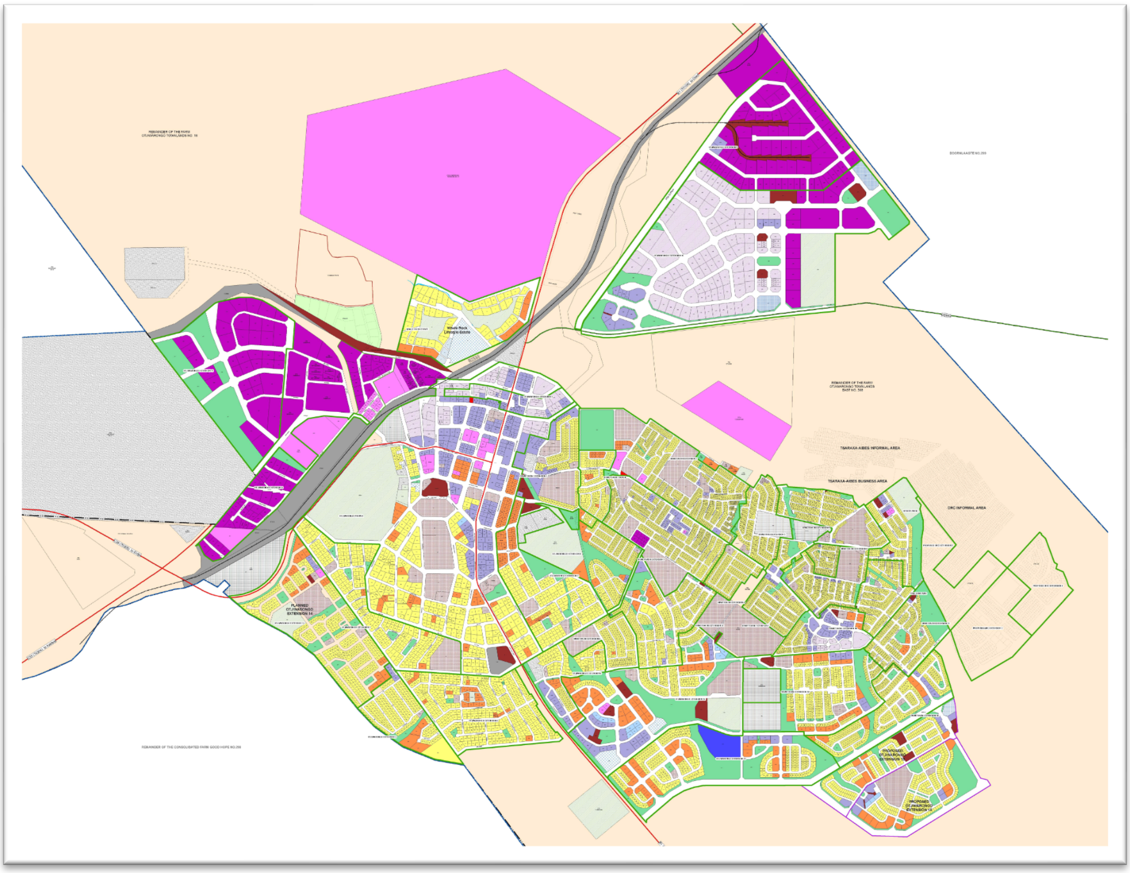


Figure 1. Map Otjiwarongo

Table 2. Water demand in Otjiwarongo (20 years) unit : ton

FY	January	February	March	April	May	June	July	August	September	October	November	December	Year	Ave/month	Ave/day
1999	94,612	106,887	127,095	147,709	123,979	122,202	112,119	121,761	131,647	140,466	157,158	95,121	**1,480,756**	**123,396**	**4,046**
2000	157,322	96,896	128,983	88,682	107,641	106,717	108,717	126,330	116,041	129,635	125,718	172,124	**1,464,806**	**122,067**	**4,002**
2001	168,728	136,700	86,627	95,471	102,900	102,900	98,953	105,412	129,506	110,727	149,568	82,309	**1,369,801**	**114,150**	**3,743**
2002	155,854	127,901	123,627	116,162	114,958	108,663	103,115	133,923	120,657	108,931	169,962	95,618	**1,479,371**	**123,281**	**4,042**
2003	170,924	111,613	102,730	126,794	119,501	131,518	109,270	156,969	104,133	161,684	144,745	94,151	**1,534,032**	**127,836**	**4,191**
2004	151,246	109,040	105,523	121,993	106,284	117,367	128,329	126,957	100,987	136,431	160,260	98,326	**1,462,743**	**121,895**	**3,997**
2005	146,111	87,125	90,292	118,805	105,160	139,464	109,027	122,121	156,036	115,884	117,413	129,689	**1,437,127**	**119,761**	**3,927**
2006	105,057	104,973	120,248	107,321	94,623	96,590	118,157	108,603	122,137	135,607	127,723	121,294	**1,362,333**	**113,528**	**3,722**
2007	177,673	94,652	88,165	112,861	112,137	115,987	119,852	136,802	106,151	135,873	110,412	139,087	**1,449,652**	**120,804**	**3,961**
2008	127,834	83,206	72,252	90,082	107,423	126,822	126,614	89,633	123,445	123,034	117,930	108,037	**1,296,312**	**108,026**	**3,542**
2009	104,241	107,640	118,230	99,752	110,059	120,488	85,217	120,433	121,004	121,004	128,014	109,257	**1,345,338**	**112,112**	**3,676**
2010	117,290	90,413	91,632	109,988	89,540	101,075	88,658	141,064	120,090	91,515	156,770	101,911	**1,299,946**	**108,329**	**3,552**
2011	87,114	81,538	85,229	99,051	74,063	99,897	87,727	101,421	104,816	101,352	110,513	106,413	**1,139,134**	**94,928**	**3,112**
2012	94,984	110,048	115,902	88,463	101,503	86,145	104,658	102,195	101,295	109,730	125,299	103,785	**1,244,007**	**103,667**	**3,399**
2013	117,719	85,419	88,245	102,255	103,486	107,684	103,673	119,535	89,915	129,164	127,491	103,623	**1,278,210**	**106,517**	**3,492**
2014	141,208	100,721	124,257	83,088	97,645	100,949	106,851	114,966	106,730	119,904	128,337	92,389	**1,317,045**	**109,754**	**3,598**
2015	101,771	115,660	122,897	102,075	104,131	131,166	122,670	150,948	114,705	150,706	145,675	116,235	**1,478,638**	**123,220**	**4,040**
2016	115,407	107,836	110,297	110,936	123,196	104,285	140,982	129,472	134,517	150,581	117,705	128,334	**1,473,548**	**122,796**	**4,026**
2017	127,206	114,396	116,889	101,931	130,301	120,224	113,993	113,993	124,516	124,817	131,561	123,618	**1,443,443**	**120,287**	**3,944**
2018	145,416	113,132	125,696	102,615	117,053	117,186	114,865	126,174	129,360	134,127	154,079	136,204	**1,515,906**	**126,326**	**4,142**
2019	127,594	107,752	115,746	121,228	125,951	107,682	121,616	127,709	131,953	148,622	137,570	123,672	**1,497,094**	**124,758**	**4,090**
2020				119,568	102,608	91,242	123,069	100,534					**537,020**	**107,404**	**3,521**
Ave	**129,727**	**103,237**	**105,679**	**106,749**	**105,457**	**112,218**	**109,699**	**122,697**	**116,878**	**126,235**	**134,483**	**110,984**	**1,384,044**		

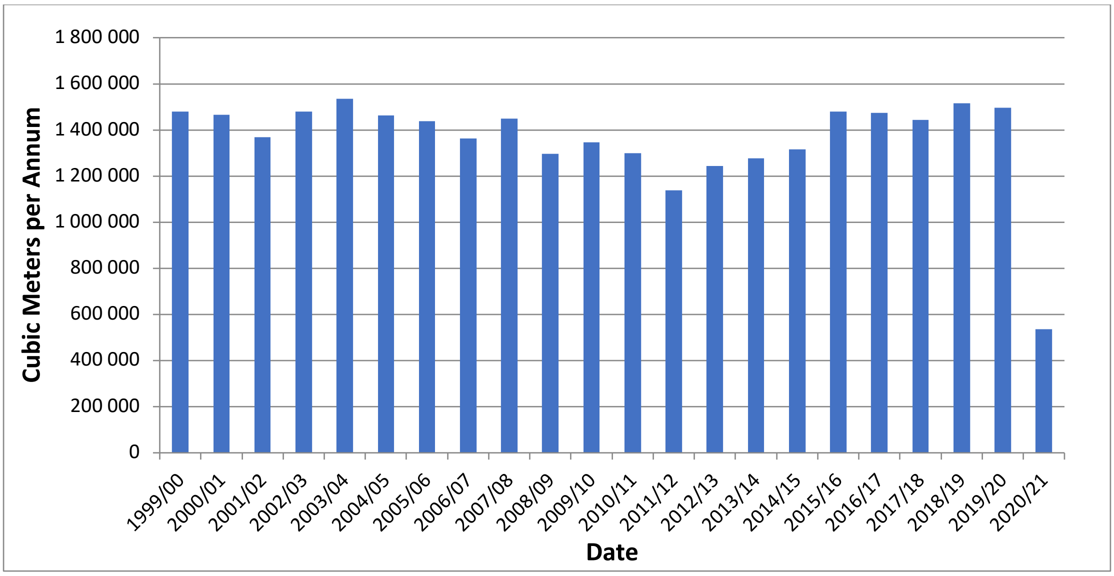


Figure 2. Otjiwarongo historical water demand

Now, Otjiwarongo receives the water supply from Nam Water, however, due to the lack of water resources, the water supply is not sustainable and stable. In the informal settlement area, the condition is worse.

The average water demand by month varies around from 3,500 m^3/d to 4,000 m^3/d.

3.2 Existing Oxidation Pond in Otjiwarongo

Oxidation ponds are large, shallow ponds designed to treat various wastewaters naturally through the interaction of sunlight, bacteria, and algae. They are designed to reduce organic content and remove pathogens from wastewater. They are man-made depressions confined by earthen structures. Wastewater enters on one side of the pond and exits on the other side, after spending several days in the pond, during which treatment processes take place. There are often several ponds with different functions to reduce organic content and remove pathogens. In most ponds both bacteria and algae are needed in order to maximize the decomposition of organic matter and the removal of other pollutants.

Oxidation ponds are especially well suited for warm climates, because the intensity of sunlight and temperature that are needed for the treatment process. They cost less to build than other treatment facilities and can be considered as one of the cheapest wastewater treatments options in terms of maintenance.

However, Oxidation ponds do require relatively large areas, they emit odours that may be incommoding to close-by residential areas, and there is a risk of ground water contamination or overflow, especially when the pond is operating above its rated capacity.

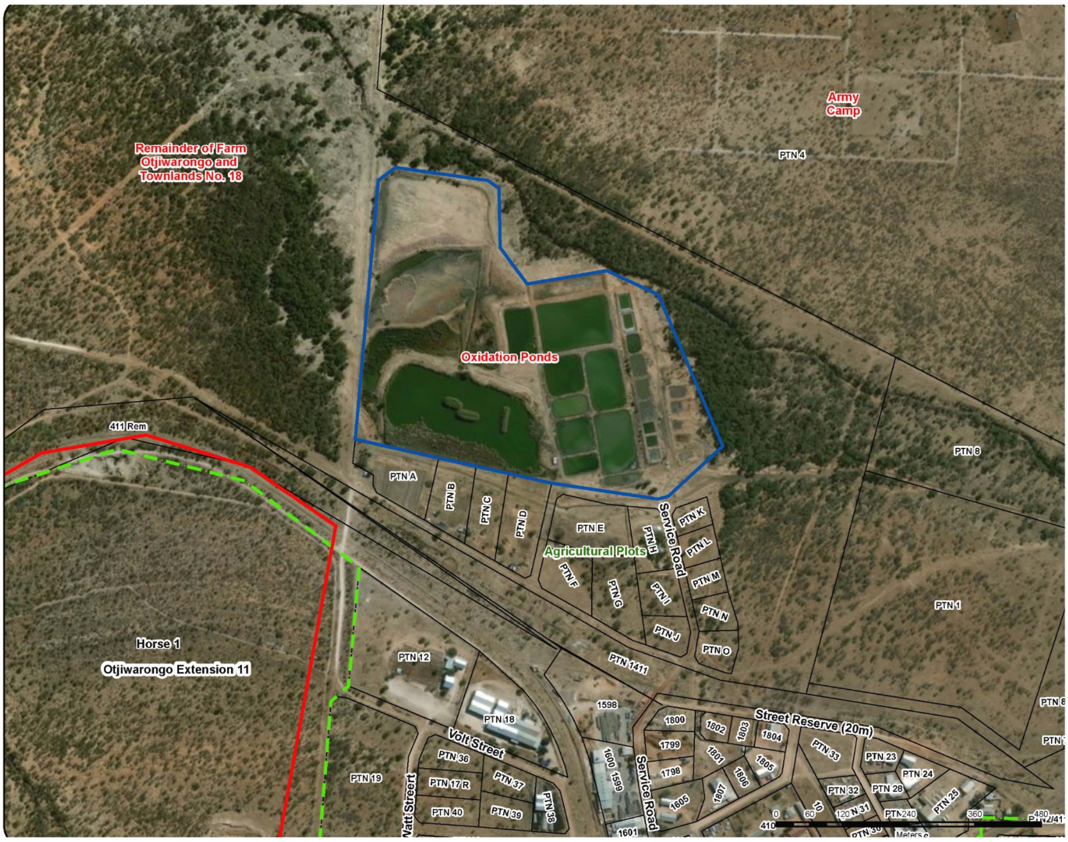


Figure 3. Existing Oxidation Pond in Otjiwarongo

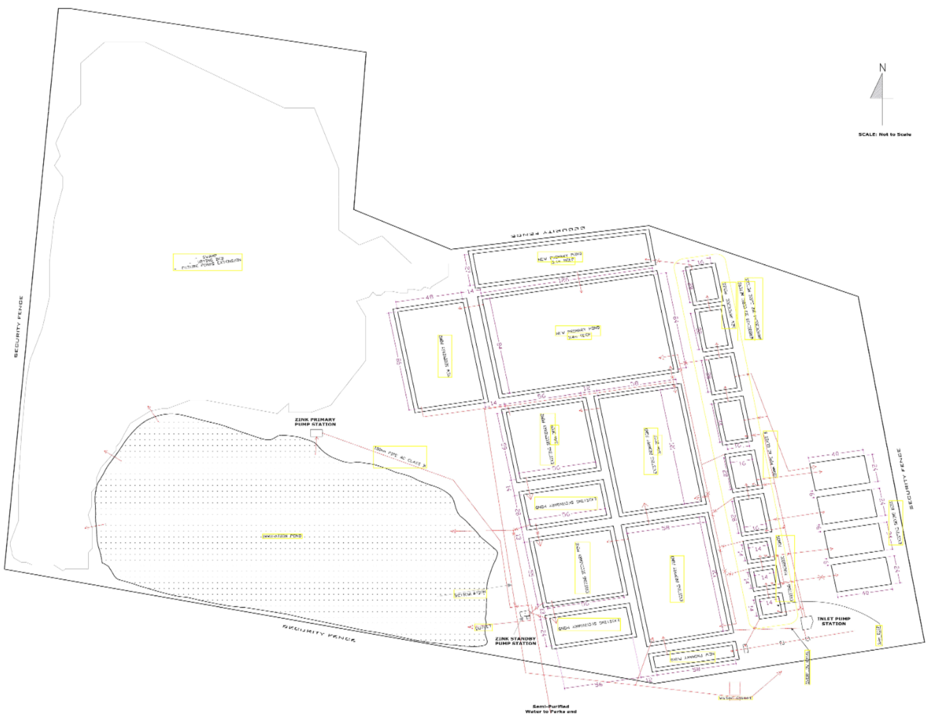


Figure 4. Lay out of Existing Oxidation Pond in Otjiwarongo

The existing oxidation pond in Otjiwarongo is located at North-western side of city, and the Figure 3 and 4 shows the current status and pipe line network in oxidation pond. As it is shown, there is enough unused space in the pond. Now in this Feasibility study, we are going to make locate the water recycling plant in the available area in the existing plant area.

Table 3. Result of water quality test

	Value	Unit	Remarks
pH	8.0	Ms/m	
Conductivity	151.3	mg/l	
TDS	1014	mg/l	
Sodium as Na	140	mg/l	
Nitrate as N	0.5	mg/l	
Nitrite as N	0.1	mg/l	
Temperature (C)	21.3		
COD	105	mg/l	
Oxygen Absorbed	11.2	mg/l	
BOD	22	mg/l	
P	2.2	mg/l	
Total Nitrogen as N	43.0	mg/l	
Ammonia as N	2.6	mg/l	
TSS	17.0	mg/l	
Fat, Oil & Grease as FOG	<0.10	g/l	

▶ **Date sample taken: 2018/4/17**

Otjiwarongo has almost 100 % sewerage network coverage. All of wastewater occurred in the city are gather in the existing oxidation pond, and the effluent water quality is shown in the above table. Even though the values of some categories are over the common standard such as BOD, the overall status of effluent quality is not so bad to use as an influent of water recycling plant which is being planned in the feasibility study.

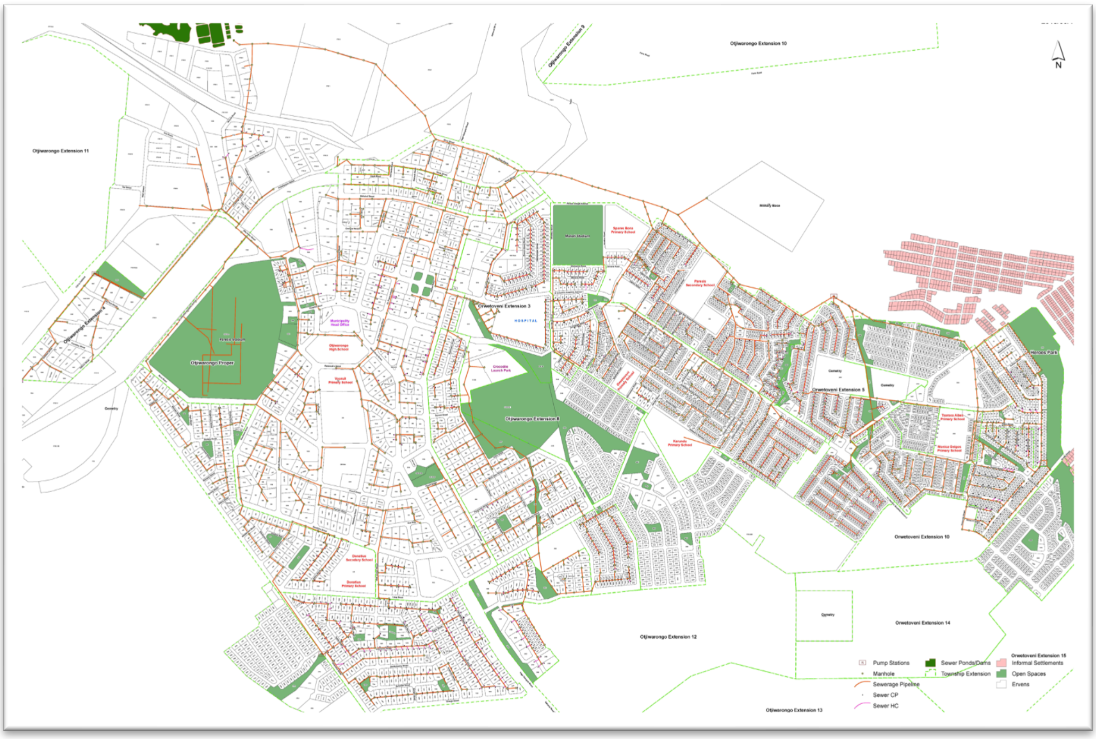


Figure 5. Sewerage Network in Otjiwarongo

3.3 Water recycling plant (Component 1)

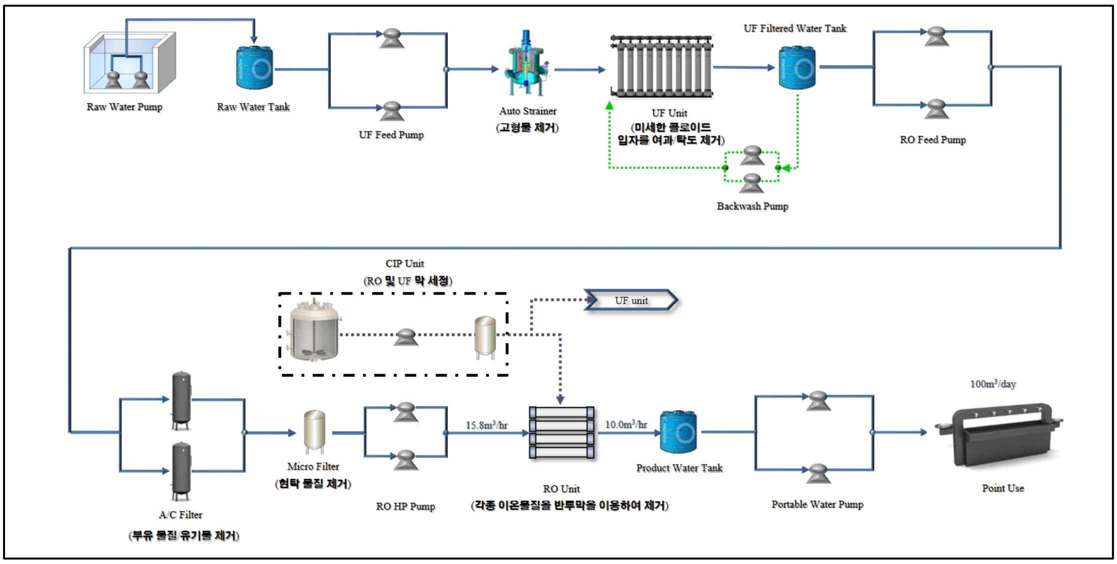


Figure 6. water treatment process for component 1

After the communication with local authorities, the location of component 1 was planned at the next to existing oxidation pond. This location has advantage to receive the treated wastewater as influent of component 1.

The main process of plant consists of UF and RO with the capacity of 100 m^3/day. The beneficiaries of this plant shall be from 500 to 1,000 people as per the unit water demand. In case of 100 LPCD, it will be 1000 people of beneficiaries. Considering the unstable power supply, Photovoltaics is applied as power sources together with ESS. The plant will be operated 10 hrs a day. We have applied 2 places of kiosk for the distribution of treated tap water and 5 km of pipe line. However, due to the covid-19, the field survey was not implemented. This kiosk items and the length of pipe line can be changed during the implementation stage based on the field survey within the available budget.
The total estimated construction cost is 5,359,131 USD including transportation cost and commissioning cost as shown below;

Table 4. Estimated construction cost for component 1

	Specification	amount	(USD)
Civil + Architect	W8m x L15m	1	86,957
Process	UF + RO =100m^3/day=10m^3/hr (10hr Operation)	1	521,379
Photovoltaics	PV (25kw) + ESS	1	69,565
Transportation	Packing + transportation (Duty free)	1	52,174
Installation	Process *0.3	1	156,522
commissioning	3 Month x 2 people	6	58,261
Kiosk	Kiosk	2	13,913
Distribution	5 km		4,440,000
Total			**5,359,131**

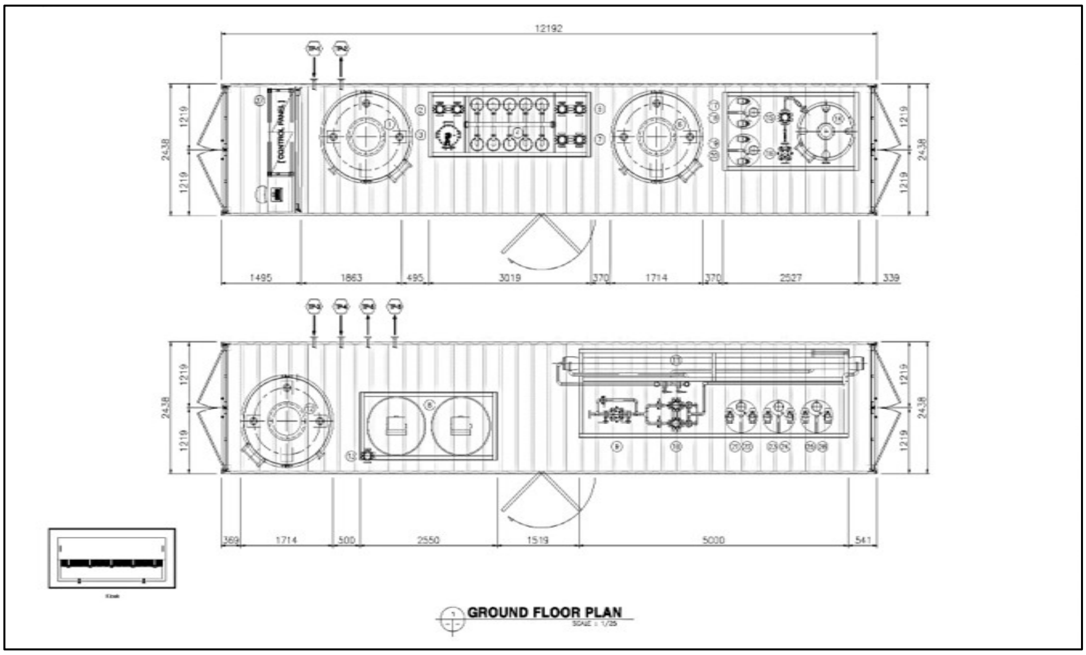
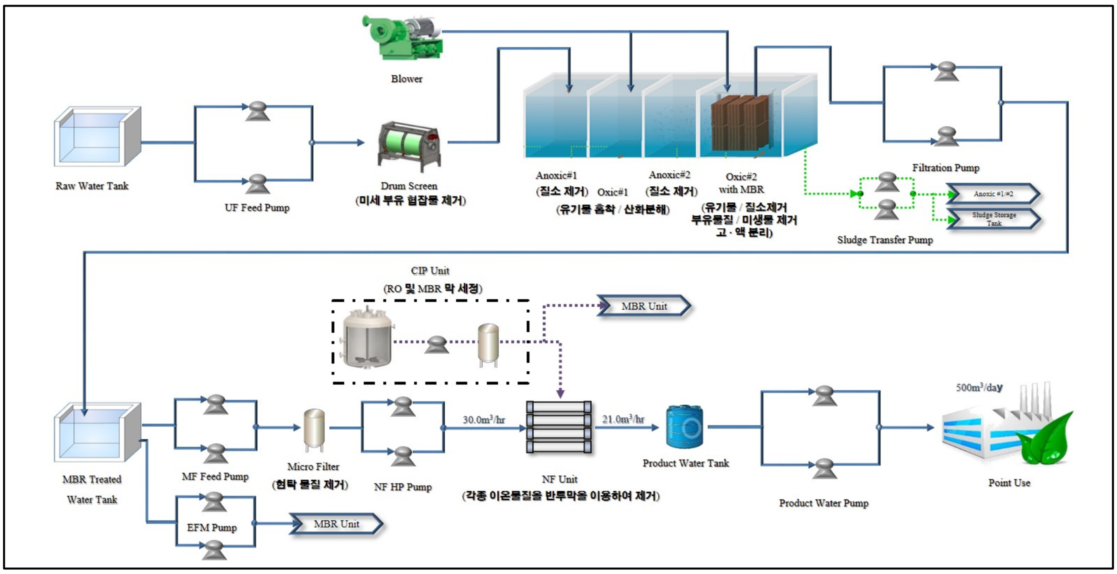


Figure 7. Plane drawing of component 1

3.4 Grey water recycling (Component 2)



Greywater recycling plant named as component 2 shall be located at near the primary school. It will receive the used water from the school and hospital (if possible) and supply to the school again for toilet water after treatment. The MBR (Membrane Bio Reactor) and NF is the main process of this plant. The photovoltaics is also applied in component 2 considering unstable power supply condition.

The capacity of greywater recycling plant is 500 m^3/day with the condition of 24hrs operation. The number of students in the school is not surveyed due to the covid-19, but generally speaking, it is assumed the 500 CMD is enough to supply water to one primary school. After field survey during the implementation stage, it will be decided to supply water to the hospital near school or not considering the capacity of the plant and available budget.

Table 5. Estimated construction cost for component 2

	Specification	amount	USD
Civil Architect	W27m x L15m	1	869,565
Process	MBR + NF =500m3/day=21m3/hr (24hr operation)	1	1,304,348
Photovoltaics	PV (90kw) + ESS	1	1,800,000
Transportation	Packing + transportation Duty free condition	1	173,913
Installation	Process *0.3	1	391,304
commissioning	3 Month x 3 people	9	87,391
Total			**4,626,521**

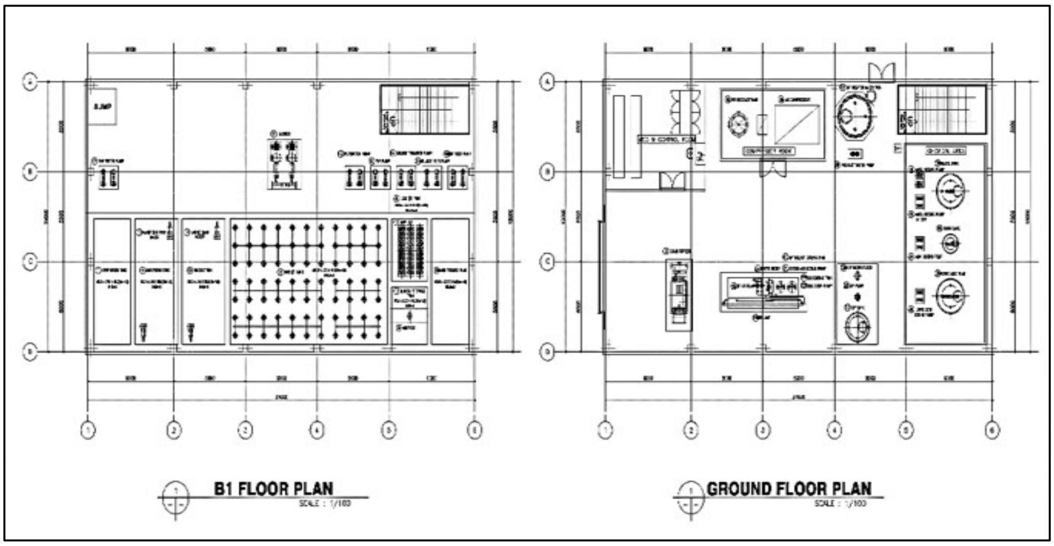


Figure 7. Plane drawing of component 2

The total construction cost is shown below;

Category	Total	Component 1	Component 2
Construction cost(USD)	**9,985,652**	**5,359,131**	**4,626,521**

3.5 Financial Analysis (Component 1)

A. Basic Assumptions for Economic Feasibility Study

Table 6. Basic assumptions

Category		Description
Project Duration	Reference date	Jan 1, 2020
	Construction period	6 months (Jan. ~ Jun. 2023)
	Operating period	20 years (Jul. 2023 ~ Jun. 2043)
	Operation Days in a Year	Water Supply : 365 days
Total Investment Costs	Total Project Costs	5,678,614 USD
	Total Investment Costs	6,091,633 USD
Financing Structure	Funding ratio	Public Sector : 100.0 %
		Private Sector : -
Revenues and Expenses	Operating Revenues	Water supply: 0.69 USD/ ton
	Operating Expenses	Labor cost, electric power cost, general expense, maintenance cost
Others	Corporate Tax	32.0%(single tax rate)
	Inflation Rate	3.0% assumed
	Exchange Rate	KRW/USD = 1,085.30 assumed

B. B/C Ratio Analysis

The unit price of water supply at the level that can cover the operating expenses of this project was calculated at 0.69 USD/Tone, and the B/C Ratio at that price level was calculated at 1.00 on both before-tax and after-tax basis.

Table 7. B/C Ratio

Category	Before Tax	After Tax
B/C Ratio	1.00	1.00

In this feasibility study, we show the result of financial analysis, and the detailed analysis result is described in the financial mechanism analysis report.

3.6 Financial Analysis (Component 2)

A. Basic assumptions for economic feasibility analysis

- Basic assumptions for economic feasibility analysis are as follows

Table 8. Basic Assumption

Category		Description
Project Duration	Reference date	Jan 1, 2020
	Construction period	6 months (Jan. ~ Jun. 2023)
	Operating period	20 years (Jul. 2023 ~ Jun. 2043)
	Operation Days in a Year	Water supply : 365 days
Total Investment Costs	Total Project Costs	4,902,331 USD
	Total Investment Costs	5,258,889 USD
Financing	Funding Ratio	Public sector : 100.0 %
		Private sector : -
Revenue and cost	Revenues	Water supply: 0.41 USD/ ton
	Operating Expenses	Labor cost, electric power cost, general expense, maintenance cost
Other assumptions	Corporate Tax	32.0%(single tax rate)
	Inflation Rate	3.0% assumed
	Exchange Rate	KRW/USD = 1,085.30 assumed

B. Analysis of B/C ratio

The unit price of water supply at the level that can cover the operating expenses of this project was calculated at 0.41 USD/m3, and the B/C Ratio at that price level was calculated at 1.00 on both before-tax and after-tax basis.

Table 9. B/C Ratio

Category	Before Tax	After Tax
B/C Ratio	1.00	1.00

In this feasibility study, we show the result of financial analysis, and the detailed analysis result is described in the financial mechanism analysis report.