

# **DISEÑO DEL PROCESO DE UNA ESTACIÓN DE TRATAMIENTO DE AGUA POTABLE CON BAJO CONSUMO ENERGÉTICO Y ESTUDIO COMPARATIVO CON UN PROCESO CONVENCIONAL**

**PROCESS DESIGN OF A DRINKING WATER  
TREATMENT PLANT WITH LOW ENERGY  
CONSUMPTION AND A COMPARATIVE STUDY  
WITH A CONVENTIONAL PROCESS**

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**Máster Universitario en  
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**TRABAJO FIN DE MÁSTER**

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# DISEÑO DEL PROCESO DE UNA ESTACIÓN DE TRATAMIENTO DE AGUA POTABLE CON BAJO CONSUMO ENERGÉTICO Y ESTUDIO COMPARATIVO CON UN PROCESO CONVENCIONAL

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## RESUMEN

En los últimos años, el consumo energético se ha incrementado en gran medida. En el panorama energético actual, con las recientes incertidumbres asociadas a los precios de la energía y las inestabilidades de algunos países exportadores de hidrocarburos, reducir el consumo energético es fundamental. Al mismo tiempo, el crecimiento poblacional demanda cada vez más potabilización de agua. El trasiego del agua implica importantes cantidades de energía, por lo que preocupa la mejora del rendimiento de los procesos de tratamiento. Conseguir la eficiencia de uso de ambos recursos, agua y energía, es un desafío clave para el planeta.

Como intento de aproximación a este reto, en el presente trabajo se plantea una comparativa de dos alternativas de diseño de proceso de potabilización de agua. Una opción de bajo consumo energético utilizando tecnologías existentes en el mercado desde hace ya varias décadas, y un proceso de tratamiento del tipo convencional, como el implementado en la mayoría de las Estaciones de Tratamiento de Agua Potable (ETAP) españolas.

**Palabras clave:** Consumo energético; Ahorro; Tratamiento del agua; Potabilización; CAPEX; OPEX; ETAP.

## INTRODUCCIÓN

La creciente demanda de potabilización del agua es un desafío clave para el futuro del planeta, sobre todo considerando el constante crecimiento demográfico y los cada vez más frecuentes fenómenos

climáticos extremos como las sequías y la desertificación. Por otro lado, el Objetivo Sostenible n.º 6 de la Organización de las Naciones Unidas (ONU) consiste en garantizar el derecho universal al acceso al agua de calidad a toda la población.

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El análisis del binomio “*potabilización del agua - energía*” resulta esencial si queremos abordar la problemática de manera social, económica y ambientalmente sostenible.

Optar por tecnologías simples, basadas en el aprovechamiento de la hidráulica y en la gravedad y reduciendo los equipos mecánicos en los procesos de tratamiento del agua, contribuyen al objetivo de conseguir un modelo que asegure el respeto al medio ambiente y garantice la seguridad del suministro energético y de agua potable.

## OBJETIVOS

El objetivo principal del presente trabajo consiste en realizar un estudio comparativo de consumo energético entre una ETAP con un proceso de tratamiento de bajo consumo y una de proceso convencional.

Para ello, se tomó como base el diseño de una ETAP de bajo consumo proyectada para Filipinas, la cual se redimensionó a un proceso de tratamiento convencional, a fin de poder realizar comparaciones.

## DISEÑO DEL PROCESO

Las dos alternativas de proceso se diseñaron para el caudal de la planta base, es decir, para una capacidad de tratamiento máxima de 300 millones de

litros al día (MLD), modulada en tres líneas de 100 MLD, de forma tal de poder funcionar con caudales de agua entrante desde 100 hasta 300 MLD. Como calidad de agua entrante se tomó también la correspondiente a la ETAP base filipina.

El tren de procesos considerado es el de tipo convencional: coagulación, floculación, sedimentación, filtración y desinfección. Sin embargo, para la alternativa de bajo consumo, se realizaron una serie de adaptaciones.

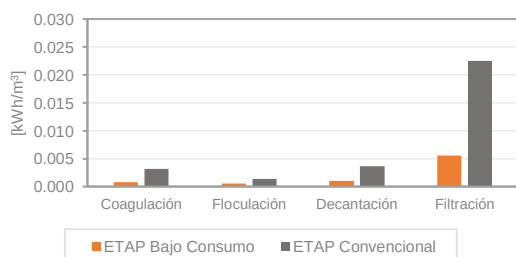
La tradicional cámara de mezcla rápida para la coagulación se reemplazó por mezcladores estáticos en línea que no requieren energía para su funcionamiento. La floculación convencional se sustituyó por un floculador hidráulico que tampoco requiere de energía para funcionar. En la decantación, se optó por una decantación lamelar sin recirculación de fangos, con lo que se obtiene un ahorro energético al reducir bombeos. Finalmente, los convencionales filtros de arena abiertos se proyectaron con el sistema de tasa declinante y lavado mutuo, con el que se reduce el gasto energético de operación ya que no requieren bombas ni un tanque de almacenamiento de agua para el lavado.

## CONSUMO ENERGÉTICO

Se realizó un inventario de todos los accionamientos eléctricos de ambas alternativas de proceso y se observó que las diferencias entre un proceso y otro se dan fundamentalmente en el incremento de equipos mecánicos que implica el proceso convencional en comparación con el de bajo consumo.

El consumo energético diario para la ETAP de bajo consumo es de 8.478.011,37 kWh/año y de 11.477.651,17 kWh/año para la ETAP convencional, lo que indica que, con el proceso de bajo consumo, se consigue una reducción del consumo energético en un 26%. El gasto energético específico por volumen de agua tratada resulta entonces de 0,082 kWh/m<sup>3</sup> y 0,104 kWh/m<sup>3</sup> respectivamente.

Se analizó, además, el consumo específico por proceso de tratamiento y se observó que, si bien se consigue una economía en todas las etapas, la filtración es aquella en la que se consigue un mayor ahorro, de un 77%.

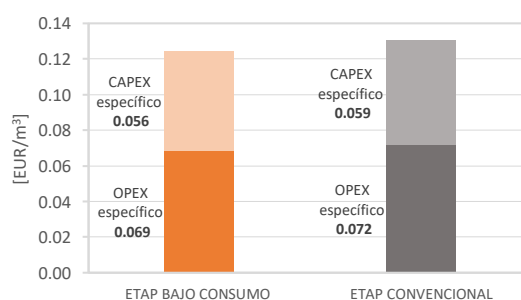


Consumo energético específico por proceso de tratamiento

## CAPEX Y OPEX

En cuanto a los costes de inversión (CAPEX) de las dos alternativas, a partir de los presupuestos realizados, se concluyó que los mismos son similares, obteniéndose solo un 4% de ahorro en la alternativa de bajo consumo.

Respecto a los costes operacionales (OPEX), se los calculó considerando una vida útil de la planta de 20 años. Para ello, se realizó una actualización de los valores calculados de OPEX para el año 1, estimando un Índice de Precios de Consumo (IPC) del 2% a 20 años y a continuación, se llevó dichos valores al valor actual neto (VAN) teniendo en cuenta una tasa de descuento del 8%. El ahorro en los costes operacionales conseguido con la ETAP de bajo consumo es del 6%.



CAPEX y VAN OPEX por volumen de agua tratada

## COMPARATIVA

Una vez calculados tanto los costes de inversión como de operación de las dos



alternativas, se procedió a realizar un análisis comparativo de los resultados.

El coste final de cada planta se obtuvo a partir de la suma del coste de inversión y el valor actual neto de los costes de operación. Para calcular tanto el CAPEX como el OPEX específico de la planta durante los veinte años de operación, se calculó un “VAN” del caudal máximo de agua a tratar en los veinte años de operación de la planta, a fin de obtener un caudal de tratamiento estimado que permitiese realizar comparaciones. Las tarifas finales de tratamiento resultaron de 0,124 EUR/m<sup>3</sup> y 0,131 EUR/m<sup>3</sup>, lo que implica un ahorro del 5,34% en la alternativa de bajo consumo.

Los costes de operación y mantenimiento constituyen el 45% del valor total de la planta en ambas alternativas. Dentro de éstos, en la ETAP convencional, el coste de la energía representa el 17% del OPEX, es decir, el coste energético compone el 8% del valor total de la planta en sus 20 años de vida útil.

Las modificaciones propuestas en la alternativa de bajo consumo permitirían reducir ese gasto energético pasando del 17% al 13% de los OPEX de la ETAP.

## CONCLUSIONES

De este análisis resulta que, solo con la aplicación de pequeñas adaptaciones al

sistema convencional, y únicamente en la línea de agua, se consigue reducir el consumo energético de la planta en un 26% y un ahorro en costes del 28%. Esta reducción representa un ahorro en emisiones de GEI correspondientes a electricidad, que ascienden a 749.910 kg CO<sub>2</sub>/año.

Debe considerarse que en el análisis se realizó una actualización futura de los costes de la energía con base en un IPC constante del 2%. Sin embargo, teniendo en cuenta la inestabilidad actual de los costes energéticos y la tendencia de los últimos años, éstos podrían verse incrementados en un porcentaje mayor, alcanzándose ahorros económicos finales superiores.

Con relación a los costes finales de inversión y operación se obtiene un ahorro del 4% y del 6% , respectivamente, respecto a la alternativa convencional. Esto resulta en una reducción final del 5,34% en la tarifa de tratamiento.

Debe tenerse en cuenta que se trata de un caso particular y que estas adecuaciones planteadas al proceso convencional de tratamiento se corresponderían únicamente para plantas de envergadura semejante y calidades de agua bruta afines.

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## MASTER'S FINAL PROJECT

Master's Degree in Engineering and Environmental Management

# PROCESS DESIGN OF A DRINKING WATER TREATMENT PLANT WITH LOW ENERGY CONSUMPTION AND A COMPARATIVE STUDY WITH A CONVENTIONAL PROCESS

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## SUMMARY

In recent years, energy consumption has increased greatly. In the current energy context, with the recent uncertainties associated with energy prices and the instabilities of some hydrocarbon exporting countries, reducing energy consumption is essential. At the same time, population growth demands more and more water purification. The transfer of water involves significant amounts of energy, which is why there is concern about improving the performance of treatment processes. Achieving efficient use of both resources, water and energy, is a key challenge for the planet.

As an attempt to approach this challenge, this report presents a comparison between two design alternatives for water purification processes. A low energy consumption option using existing technologies on the market for several decades, and a conventional type treatment process, such as the one implemented in most of the Spanish Drinking Water Treatment Plants (DWTP).

**Keywords:** Energy consumption; Saving; Water treatment; Potabilization; CAPEX; OPEX; DWTP.

## INTRODUCTION

The growing demand for water purification is a key challenge for the future of the planet, especially considering the constant population growth and the increasingly

frequent extreme weather events such as droughts and desertification. On the other hand, Sustainable Goal No. 6 of the United Nations (UN) consists of guaranteeing the universal right of access to quality water for the entire population.

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The analysis of the binomial "purification of water - energy" is essential if we want to address the problem in a socially, economically and environmentally sustainable manner.

Opting for simple technologies, based on the use of hydraulics and gravity and reducing mechanical equipment in water treatment processes, contribute to the goal of achieving a model that ensures respect for the environment and guarantees security of energy supply and drinking water.

## OBJECTIVES

The main objective of this work is to carry out a comparative study of energy consumption between a DWTP with a low energy consumption treatment process and one with a conventional process.

For that purpose, the design of a low-consumption DWTP projected for the Philippines was taken as a baseline, which was then re-dimensioned into a conventional treatment process, in order to be able to make comparisons.

## PROCESS DESIGN

The two process alternatives were designed for the flow of the base plant, that is, for a maximum treatment capacity of 300 million liters per day (MLD),

modulated in three lines of 100 MLD, in such a way as to be able to work with incoming water flows from 100 to 300 MLD. As for the quality of water to be treated, that of the Philippine plant was considered.

The train of processes considered is the conventional type: coagulation, flocculation, sedimentation, filtration and disinfection. However, for the low consumption alternative, a series of adaptations were made.

The traditional rapid mixing chamber for coagulation was replaced by in-line static mixers that do not require energy to operate. Conventional flocculation was replaced by a hydraulic flocculator that also does not require energy to operate. For the settling, a lamellar decanter without sludge recirculation was chosen, in order to achieve energy savings by reducing the number of pumps. Finally, the conventional open sand filters were designed with the declining rate and mutual washing system, whereby energy use is reduced since they do not require either pumps or a water storage tank for filter washing.

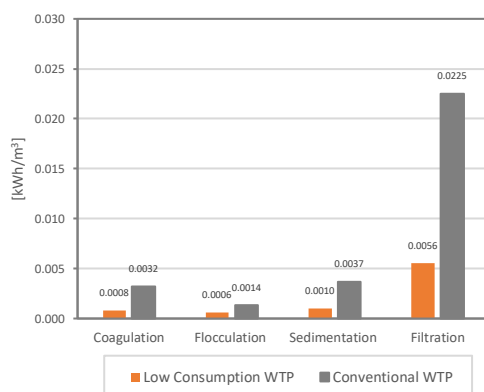
## ENERGY CONSUMPTION

An inventory of all the electrical drives of both process alternatives was carried out and it was observed that the differences

between one process and the other are fundamentally due to the increase in mechanical equipment that the conventional process implies compared to the low consumption one.

The daily energy consumption for the energy-saving DWTP is 8,478,011.37 kWh/year and 11,477,651.17 kWh/year for the conventional one, which suggests that, the low consumption process is a 26% more energy efficient than the conventional one. The specific power use per volume of treated water is then 0.082 kWh/m<sup>3</sup> and 0.104 kWh/m<sup>3</sup>, respectively.

Furthermore, it was analyzed the specific consumption per treatment process and it was observed that, although there is an economy in all stages, filtration is the one in which the greatest savings are achieved, reaching a 77%.

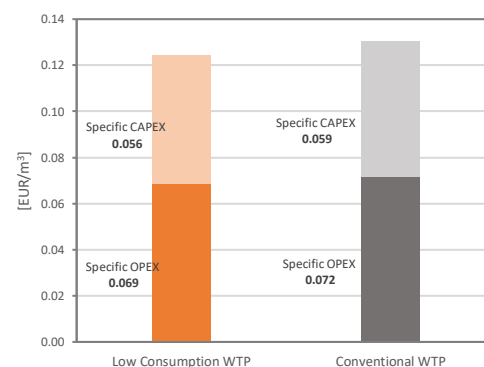


Specific energy consumption per treatment process

## CAPEX AND OPEX

Regarding the investment costs (CAPEX) of the two alternatives, based on the budgets made, it is concluded that they are very similar, obtaining only 4% of savings in the low consumption alternative.

Concerning the operational costs (OPEX), they were calculated considering a lifespan of the plant of 20 years. To this effect, an update of the calculated values of OPEX for year 1 was carried out, estimating a future Consumer Price Index (CPI) of 2% for 20 years and then, said values were taken to the net present value (NPV) using a discount rate of 8%. It was noted that the operational costs in the low consumption DWTP are lowered by 6%.



CAPEX and NPV OPEX by volume of treated water

## COMPARISON

Once both the investment and operating costs of the two alternatives had been

calculated, a comparative analysis of the results was carried out.

The final cost of each process was obtained from the sum of the investment costs and the net present value of the operating ones. To calculate both the specific CAPEX and OPEX of the plants during the twenty years of operation, an “NPV” of the maximum flow of water to be treated in the twenty years of operation of the plant was calculated in order to obtain an estimated lifespan treatment flow to compare. The final treatment rates obtained were 0.124 EUR/m<sup>3</sup> and 0.131 EUR/m<sup>3</sup>, which implies a saving of 5.34% in the energy-saving alternative.

The operation and maintenance costs constitute 45% of the total value of the plant in both process alternatives. Within these, in the conventional DWTP, the cost of energy represents 17% of OPEX, that is, the energy cost makes up 8% of the total value of the plant in its 20-year lifetime.

The modifications proposed in the low consumption alternative would allow this energy expenditure to be reduced from 17% to 13% of the process OPEX.

conventional treatment process, and only in the water line, it is possible to reduce the energy consumption of the plant by 26% and have a cost saving of 28%. This reduction represents a saving in greenhouse gases emissions corresponding to electricity of 749,910 kg CO<sub>2</sub>/year.

It must be considered that in the analysis a future update of energy costs was made based on a constant CPI of 2%. However, taking into account the current instability of energy costs and the trend of recent years, these could be increased by a higher percentage, achieving higher final economic savings.

In regard to the final investment and operation costs, savings of 4% and 6%, respectively, are obtained compared to the conventional alternative. This results in a final reduction of 5.34% in the treatment fee.

It must be taken into account that this is a particular case and that these adjustments proposed to the conventional treatment process would correspond only to plants of similar size and similar raw water qualities.

## CONCLUSIONS

From this analysis it turns out that, with the application of small modifications to the

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# PARTE 1

# MEMORIA

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## ABREVIATURAS

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A/C: Aire acondicionado (*Air Conditioning*)

Bq: Bequerelio (*Becquerel*)

CAPEX: Costes de Inversión (*Capital Expenditures*)

CFU: Unidad formadora de colonias (*colony-forming unit*)

CNMC: Comisión Nacional de los Mercados y la Competencia

EIONET: Red Europea de Información y Observación del Medio Ambiente

ETAP: Estación de Tratamiento de Agua Potable

GdO: Garantías de Origen

GEI: Gases de Efecto Invernadero

HPC: Recuento de placas heterótrofas (*Heterotrophic Plate Count*)

IPC: Índice de precios de consumo

MEICA: *Mechanical, Electrical, Instrumentation, Control and Automation*

MLD: Millones de litros al día

MPN: Número más probable (*Most Probable Number*)

MS: Materia Seca

NTU: Unidades nefelométricas de turbidez (*Nephelometric Turbidity Unit*)

OC: Obra Civil

ONU: Organización de las Naciones Unidas

OPEX: Costes de operación (*Operational Expenditures*)

PNIEC: Plan Nacional Integrado de Energía y Clima

PP: Polipropileno

SDT: Sólidos Disueltos Totales

SS: Sólidos en suspensión

SST: Sólidos en suspensión totales

TCU: Unidades de color verdadero (*True Color Units*)

TRH: Tiempo de retención hidráulico

UE: Unión Europea

UPS: Sistema de alimentación ininterrumpida (*Uninterruptable Power Supply*)

VAN: Valor Actual Neto

# 1. INTRODUCCIÓN

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En el presente informe se expone el Trabajo de Fin de Máster (TFM) realizado por la alumna María José San Román, estudiante del Máster Universitario en Ingeniería y Gestión Ambiental, dictado a través de un programa interuniversitario entre la Universidad de Cantabria y la Universidad de País Vasco. Los profesores Ana Lorena Esteban García y Alejandro Zarzuela López han actuado como co-directores de este.

El trabajo se desarrolla en el marco de las prácticas curriculares y extracurriculares de Máster, en las cuales la alumna participó en un proyecto de licitación para el diseño y la construcción de una estación de tratamiento de agua potable (ETAP) en la provincia de Rizal, Filipinas. Dicho proyecto, considerado de muy bajo consumo energético, se toma como punto de partida para la realización de un estudio comparativo del consumo con un proceso de tratamiento convencional como los implementados en las estaciones de tratamiento de agua españolas. Para ello, se realizará el redimensionamiento del proyecto base a un proceso de tratamiento convencional y se realizarán los análisis pertinentes.

## 1.1. MOTIVACIÓN

El incremento de la conciencia social en materia de medio ambiente nos exige un esfuerzo constante para conseguir la mitigación del calentamiento global. Ésta es una de las prioridades principales de las políticas energéticas y medioambientales de la Unión Europea (UE).

Como parte del Pacto Verde Europeo, la Comisión propuso en 2020, aumentar el objetivo de reducción de gases de efecto invernadero para 2030, incluidas las emisiones y absorciones, al menos en un 55% en comparación con 1990. Para ello, examinó las acciones requeridas en todos los sectores, y estableció los objetivos de reducir en un 40% las emisiones de gases efecto invernadero (GEI), lograr un 32% de participación de las energías renovables, conseguir un 32,5% de mejora en la eficiencia energética y demandó a los estados miembro la elaboración de un plan integrado de energía y clima (Comisión Europea 2020). En cumplimiento con ello, España traspuso esto en su Plan Nacional Integrado de Energía y Clima 2021-2030 (PNIEC). Éste tiene como objetivo avanzar en la descarbonización, sentando unas bases firmes para consolidar una

trayectoria de neutralidad climática de la economía y la sociedad en el horizonte 2050 (Ministerio para la transición ecológica y reto demográfico 2020).

El desafío que marca la Unión Europea de optimizar la eficiencia energética de las instalaciones industriales está directamente ligado a la revisión de los consumos energéticos de las tecnologías utilizadas actualmente y a la posibilidad de su mejora. Siendo el acceso al agua potable para toda la población mundial un reto marcado por los Objetivos de Desarrollo Sostenible (ODS), y que el consumo energético de la gestión integral de ésta es elevado, la eficiencia energética de las estaciones de potabilización de agua es muy importante.

Según datos reportados por la Red Europea de Información y Observación del Medio Ambiente (EIONET), el consumo energético en España correspondiente al transporte, potabilización y tratamiento del agua corresponde al 2-3% del consumo energético total nacional, y si a éste le incluimos la gestión hidrológica y la demanda agraria llega a alcanzar el 5,8% (EIONET 2017). Con base en estas consideraciones, puede decirse que el sector del agua es un gran consumidor de energía.

En la gestión del agua, las plantas de potabilización de aguas constituyen una parte esencial, ya que brindan a toda la población el acceso a un agua de consumo segura. Si bien el consumo energético dependerá de la envergadura, de las características y de la calidad de agua influente de cada planta, el objetivo principal para obtener una disminución significativa del consumo energético se relaciona con la implementación de técnicas energéticamente más eficientes, lo que no implica que sean necesariamente novedosas o de avanzada.

Otra de las principales razones de este objetivo de reducción del consumo energético es meramente económica, debido al desmesurado incremento de las tarifas energéticas de estos últimos años. Los precios crecientes de los combustibles fósiles y sus repentinas fluctuaciones hacen impredecible el coste energético, sobre todo en las instalaciones industriales.

Si bien la eficiencia energética ha aumentado en la industria europea en las últimas décadas, existe todavía un gran potencial por explotar en lo que respecta a la reducción de la demanda de energía, que podría materializarse mediante la combinación inteligente de soluciones y tecnologías existentes. La mejora en términos energéticos no solo genera beneficios ambientales evidentes, sino que también resulta en un ahorro desde el punto de vista económico.

## 2. OBJETIVOS

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### 2.1. OBJETIVO GENERAL

El presente trabajo tiene por objetivo realizar un estudio comparativo del consumo energético de un proceso de tratamiento de agua para consumo humano de bajo coste energético y un proceso convencional utilizando como base el dimensionamiento de una Estación de Tratamiento de Agua Potable (ETAP) desarrollado en el marco de las prácticas profesionales del Máster.

### 2.2. OBJETIVOS ESPECÍFICOS

Para alcanzar el objetivo general, se plantearon una serie de objetivos específicos:

- Se realizará el redimensionamiento de la ETAP base, teniendo en cuenta un proceso de tratamiento convencional, a fin de poder realizar comparaciones.
- Se estudiará el diseño de ambos procesos para la calidad de agua y el caudal de la planta base.
- Se hará un inventario de los puntos de consumo de todos los accionamientos eléctricos en los dos procesos, con el objetivo de valorar los ahorros energéticos que se alcanzarían al diseñar plantas con tecnologías existentes de mejor eficiencia energética que las utilizadas habitualmente en un proceso convencional.
- Se estimará un presupuesto de inversión y de explotación para ambas alternativas y se analizarán los ahorros en materia económica que podrían obtenerse.



## 3. CASO DE ESTUDIO

### 3.1. UBICACIÓN

La Estación de Tratamiento de Agua Potable (ETAP) cuyo diseño se tomará como base del presente trabajo, se proyectó para ser instalada en la provincia de Rizal, ubicada al este de Metro Manila, específicamente en el municipio de Teresa (Figura 1), en Filipinas.

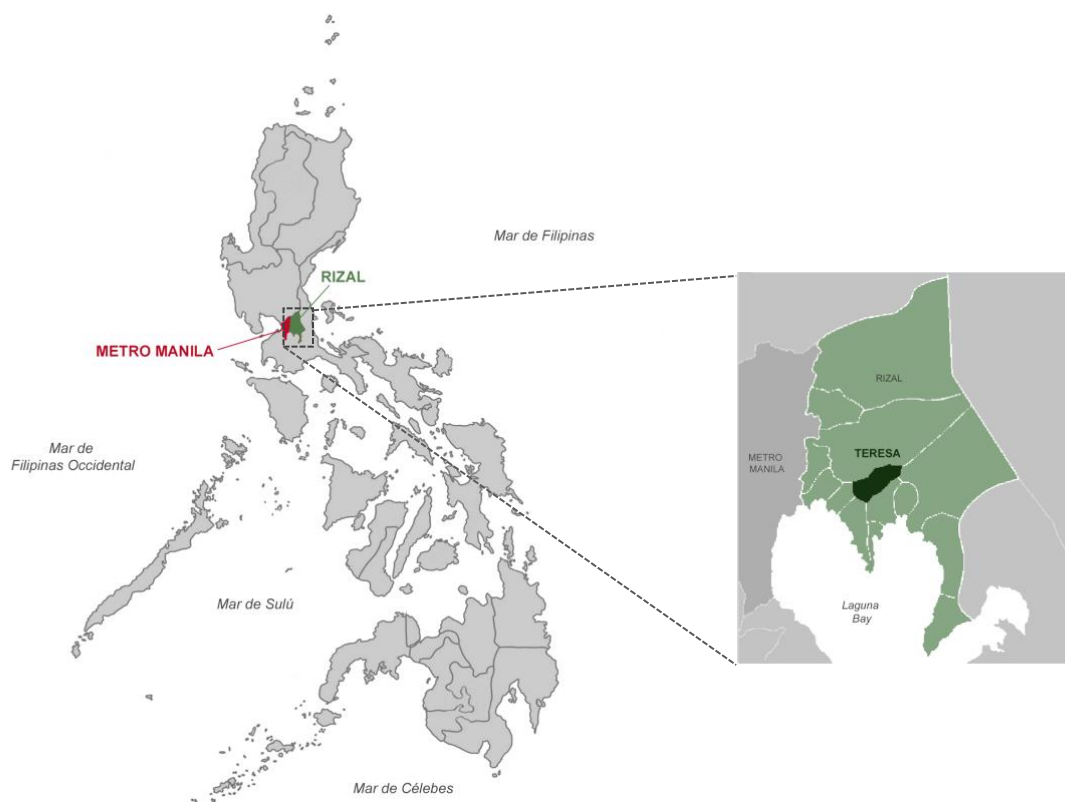


Figura 1. Ubicación Municipio de Teresa. (Fuente: Elaboración propia).

El diseño de la planta se enmarca en un proyecto de gran envergadura que prevé la construcción de una presa, *Kaliwa Low Dam*, su conducción y dos plantas potabilizadoras que tienen como objetivo abastecer a los municipios de Antipolo, San Mateo, Cainta, Taytay, Angono y Teresa. En la Figura 2 puede verse un esquema del sistema de abastecimiento y su área de influencia.

La ETAP se proyecta en un predio ubicado en las afueras del casco urbano, en un punto intermedio entre la presa y la zona a abastecer (Figura 2). La parcela de implantación de la planta tiene una superficie de aproximadamente 5,7 ha.

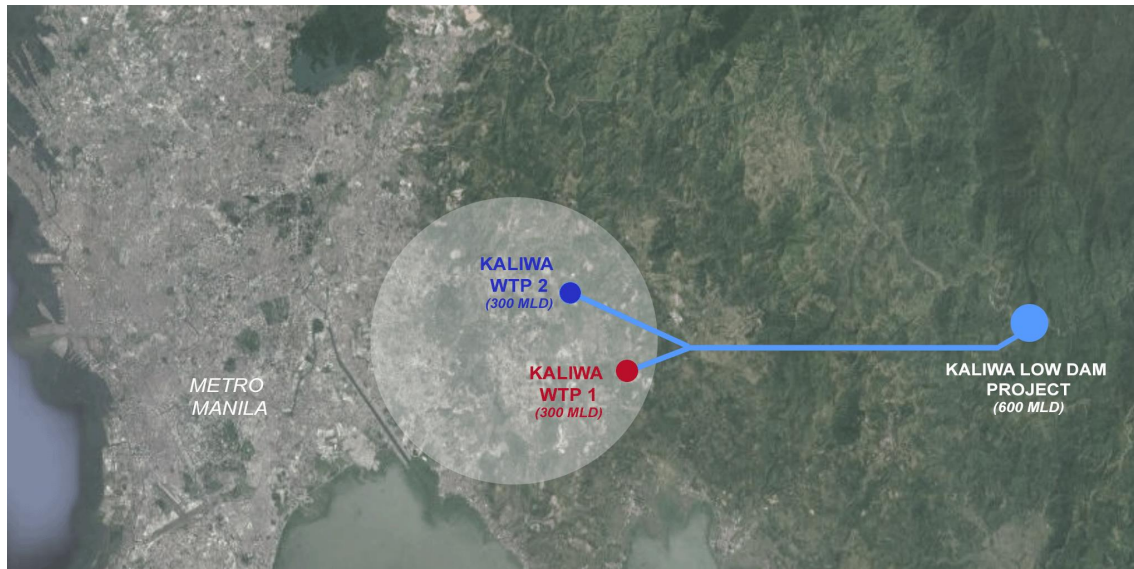


Figura 2. Sistema de Abastecimiento KALIWA. (Fuente: Elaboración propia).

### 3.2. CAPACIDAD DE LA INSTALACIÓN

La planta deberá tener una capacidad de tratamiento máxima de 300 MLD. Cabe señalar que el proceso ha sido diseñado en forma tal de poder funcionar con una amplia gama de caudales de agua entrante, desde 100 Millones de litros al día (MLD) hasta 300 MLD, debido a la variabilidad de agua entrante expresada en el pliego de licitación.

El consumo de agua per cápita en Filipinas es muy variado dependiendo de las diversas zonas del país. Si consideramos el consumo medio de agua en Metro Manila según la *National Economic and Development Authority (NEDA)*, de entre 120-230 L/Hab/día, la planta abastecería como máximo a 1,5 – 2,5 millones de habitantes (NEDA 2019).

### 3.3. CALIDAD DEL AGUA BRUTA Y DEL AGUA TRATADA

#### 3.3.1. CARACTERÍSTICAS DEL AGUA BRUTA

El agua bruta que se toma como base se corresponde con el agua que se tomará de la presa *Kaliwa Low Dam*. Para establecer la calidad del agua que deberá tratar la planta, se cuenta con un estudio desarrollado durante julio de 2018 y septiembre de 2019, realizado por *Manila Water Company INC*, en el cual se tomaron una gran cantidad de muestras en diversos puntos y se realizaron gran número de análisis de estas. La Tabla 1 resume los parámetros objetivo, incluyendo el rango de datos recopilados, que deberán ser tratados por la ETAP.

**Tabla 1. Parámetros de calidad del agua bruta. (Fuente: Pliego de licitación).**

| PARÁMETRO          | UNIDAD     | MEDIA  | MÁXIMO  |
|--------------------|------------|--------|---------|
| Color              | TCU        | 6,50   | 25,00   |
| Turbidez           | NTU        | 6,90   | 125,00  |
| SST                | mg/L       | 12,00  | 165,00  |
| pH                 | -          | 7,80   | 8,80    |
| Temperatura        | ° C        | 26,90  | 33,00   |
| Aluminio           | mg/L       | 0,17   | 4,40    |
| Hierro             | mg/L       | 0,16   | 4,10    |
| Manganeso          | mg/L       | 0,01   | 0,10    |
| Amoníaco           | mg/L       | 0,10   | 0,90    |
| Alcalinidad        | mg/L       | 135,00 | 228,00  |
| Dureza total       | mg/L       | 92,00  | 124,00  |
| SDT                | mg/L       | 166,00 | 237,00  |
| Cloruros           | mg/L       | 4,40   | 11,00   |
| Sulfatos           | mg/L       | 9,30   | 12,00   |
| Arsénico           | mg/L       | 0,008  | 0,008   |
| Cadmio             | mg/L       | 0,001  | 0,001   |
| Plomo              | mg/L       | 0,005  | 0,005   |
| Nitratos           | mg/L       | 1,00   | 1,00    |
| Coliformes Totales | MPN/100 mL | 11.810 | 160.000 |
| Coliformes Fecales | MPN/100 mL | 8.902  | 160.000 |
| HPC                | CFU/mL     | 16.037 | 270.000 |

Cabe mencionar la variabilidad en la calidad del agua entrante, y a la necesidad que habrá de realizar cambios en la operación de la planta para manejar dichas fluctuaciones. Puede notarse la gran diferencia entre las concentraciones de SST, Turbidez, Aluminio y Hierro presentes en el agua bruta en condiciones medias y máximas.

### 3.3.2. REQUISITOS DE CALIDAD DEL AGUA TRATADA

Atendiendo a la calidad final del agua tratada, se deberán cumplir los límites establecidos en la Orden Administrativa del Departamento de Salud de Filipinas, *Philippine National Standards for Drinking Water of 2017 (PNSDW 2017)*, por el que se establecen los criterios sanitarios de la calidad del agua de consumo humano.

Los parámetros físicos y las concentraciones máximas finales que el agua tratada deberá de presentar se muestran en la Tabla 2.

**Tabla 2. Requisitos de calidad del agua tratada. (Fuente: Department of Health Office of the Secretary 2017).**

| PARÁMETRO              | UNIDAD     | LÍMITE  |
|------------------------|------------|---------|
| <b>MICROBIOLÓGICOS</b> |            |         |
| Coliformes Totales     | MPN/100 mL | <1,10   |
| E. Coli                | MPN/100 mL | <1,00   |
| <b>INORGÁNICOS</b>     |            |         |
| Antimonio              | mg/L       | 0,02    |
| Arsénico               | mg/L       | 0,01    |
| Bario                  | mg/L       | 0,70    |
| Boron                  | mg/L       | 2,00    |
| Cadmio                 | mg/L       | 0,003   |
| Cromo Total            | mg/L       | 0,05    |
| Cianuro Total          | mg/L       | 0,50    |
| Fluoruro               | mg/L       | 1,50    |
| Plomo                  | mg/L       | 0,01    |
| Manganeso              | mg/L       | < 0,021 |
| Mercurio Total         | mg/L       | 0,001   |
| Níquel                 | mg/L       | 0,07    |
| Nitratos               | mg/L       | 50,00   |
| Nitritos               | mg/L       | 3,00    |
| Selenio                | mg/L       | 0,04    |

| PARÁMETRO                                  | UNIDAD | LÍMITE   |
|--------------------------------------------|--------|----------|
| <b>ORGÁNICOS</b>                           |        |          |
| Benceno                                    | mg/L   | 0,01     |
| Benzo(a)pireno                             | mg/L   | 0,0007   |
| Tetracloruro de carbono                    | mg/L   | 0,004    |
| 1,2-Diclorobenceno                         | mg/L   | 1,00     |
| 1,4- Diclorobenceno                        | mg/L   | 0,30     |
| 1,2- Dicloroetano                          | mg/L   | 0,03     |
| 1,2-Dicloroetano                           | mg/L   | 0,05     |
| Diclorometano                              | mg/L   | 0,02     |
| Di(2-etilhexil) ftalato                    | mg/L   | 0,008    |
| Etilbenceno                                | mg/L   | 0,30     |
| Estireno                                   | mg/L   | 0,02     |
| Tetracloroetano                            | mg/L   | 0,04     |
| Tolueno                                    | mg/L   | 0,70     |
| Cloruro de vinilo                          | mg/L   | 0,0003   |
| Xylenos Totales                            | mg/L   | 0,50     |
| Aldrín y Dieldrín                          | mg/L   | 0,00003  |
| Atrazina y su cloro-estriazina metabolitos | mg/L   | 0,10     |
| Carbofuranos                               | mg/L   | 0,007    |
| Clordano                                   | mg/L   | 0,0002   |
| DDT                                        | mg/L   | 0,001    |
| 1,2-dibromo-3-cloropropano (DBCP)          | mg/L   | 0,001    |
| 2,4-diclorofenoxiacético ácido (2,4-D)     | mg/L   | 30,00    |
| Endrín                                     | mg/L   | 0,0006   |
| 1,2-dirbromoetano (dibromuro de etileno)   | mg/L   | 0,0004   |
| Glifosato                                  | mg/L   | 1,00     |
| Lindano                                    | mg/L   | 0,002    |
| Pendimetalina                              | mg/L   | 0,02     |
| <b>FÍSICO-QUÍMICOS</b>                     |        |          |
| Color                                      | TCU    | < 5,00   |
| Turbidez                                   | NTU    | < 2,50   |
| Aluminio                                   | mg/L   | < 0,12   |
| Cloruros                                   | mg/L   | < 200,00 |
| Cobre                                      | mg/L   | 1,00     |
| Dureza Total                               | mg/L   | < 250,00 |
| Sulfuro de hidrógeno                       | mg/L   | 0,05     |
| Hierro                                     | mg/L   | < 0,40   |

| PARÁMETRO                                                     | UNIDAD | LÍMITE      |
|---------------------------------------------------------------|--------|-------------|
| pH                                                            | -      | 6,50 - 8,00 |
| Sodio                                                         | mg/L   | 200,00      |
| Sulfatos                                                      | mg/L   | 200,00      |
| SDT                                                           | mg/L   | < 400,00    |
| Zinc                                                          | mg/L   | 5,00        |
| <b>CONTAMINANTES DE LOS PRODUCTOS QUÍMICOS DE TRATAMIENTO</b> |        |             |
| Acrilamida                                                    | mg/L   | 0,0005      |
| Epiclorhidrina                                                | mg/L   | 0,0004      |
| <b>QUÍMICOS DE DESINFECCIÓN</b>                               |        |             |
| Cloro residual                                                | mg/L   | 0,90 – 1,50 |
| Dióxido de cloro residual                                     | mg/L   | 0,20 – 0,40 |
| <b>SUBPRODUCTOS DE LA DESINFECCIÓN</b>                        |        |             |
| Bromato                                                       | mg/L   | 0,01        |
| Clorito                                                       | mg/L   | 0,70        |
| Clorato                                                       | mg/L   | 0,70        |
| Dibromoacetoniitrilo                                          | mg/L   | 0,07        |
| Dicloroacetato                                                | mg/L   | 0,05        |
| Dicloroacetoniitrilo                                          | mg/L   | 0,02        |
| Monocloroacetato                                              | mg/L   | 0,02        |
| Tricloroacetato                                               | mg/L   | 0,20        |
| 2,4,6-triclorofenol                                           | mg/L   | 0,20        |
| <b>TRIHALOMETANOS</b>                                         |        |             |
| Bromoformo                                                    | mg/L   | 0,10        |
| Bromodiclorometano (BDCM)                                     | mg/L   | 0,06        |
| Cloroformo                                                    | mg/L   | 0,30        |
| Dibromoclorometano (DBCM)                                     | mg/L   | 0,10        |
| Trihalometanos totales                                        | mg/L   | 1,00        |
| <b>COMPONENTES RADIOLÓGICOS</b>                               |        |             |
| Actividad alfa bruta (excluyendo radón)                       | Bq/L   | 0,50        |
| Beta bruta                                                    | Bq/L   | 1,00        |
| Radón                                                         | Bq/L   | 11,00       |

## 4. JUSTIFICACIÓN DE LAS TECNOLOGÍAS UTILIZADAS

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El tren de procesos seleccionado para la potabilización del agua objeto será el de tipo convencional: coagulación, floculación, sedimentación, filtración y desinfección. Para la alternativa de bajo consumo, se realizaron una serie de adaptaciones al mismo:

- COAGULACIÓN

Con el objetivo de reducir tanto el coste de inversión como de operación, se reemplaza la tradicional cámara de mezcla rápida para la coagulación por mezcladores estáticos en línea que no requieren energía para su funcionamiento.

- FLOCULACIÓN

La convencional cámara de contacto y maduración para la floculación se sustituye por un floculador hidráulico que tampoco requiere de energía para su funcionamiento. Si bien presenta un coste constructivo más elevado, su ahorro energético es significativo.

- DECANTACIÓN

En el proceso de decantación, se optó por una decantación lamelar sin recirculación de fangos, con lo que se obtiene un ahorro energético al reducir bombeos. Al igual que en los floculadores hidráulicos, esta alternativa supone un coste constructivo más elevado, ya que el volumen de tanque necesario será superior, pero trae consigo un ahorro energético significativo.

- FILTRACIÓN

Los habituales filtros de arena abiertos convencionales, se los proyectó con el sistema de tasa declinante y lavado mutuo, con el que se reduce el gasto energético de operación ya que no requieren bombas para su lavado como así tampoco de un tanque de almacenamiento de agua para el lavado. En este caso, no solo habrá una reducción de consumo desde el punto de vista energético, sino también un ahorro desde el punto de vista constructivo.

A continuación, se describe en detalle el proceso diseñado para la estación potabilizadora, así como las variantes que se introdujeron en el sistema de bajo coste en relación con el proceso de tratamiento convencional.

## 5. DISEÑO DEL PROCESO: LÍNEA DE AGUA

Los 300 MLD a tratar se modularán en tres líneas de 100 MLD de tratamiento unitario:

**Tabla 3. Caudales y líneas de la ETAP. (Fuente: Elaboración propia).**

| Descripción                | Cantidad |
|----------------------------|----------|
| Caudal por línea en MLD    | 100      |
| N.º de líneas en operación | 3        |
| Caudal total en MLD        | 300      |
| Caudal total en m³/h       | 12500    |
| Caudal total en m³/d       | 300.000  |

### 5.1. CAPTACIÓN Y LÍNEA DE CONDUCCIÓN DEL AGUA BRUTA

La toma de agua se realizará desde un portal de agua provisto por la presa *Kaliwa Low Dam*, desde el cual se conducirá el agua bruta a través de dos líneas de tubería de acero DN2600 que luego se reducirán a DN1400, garantizando una velocidad mínima de 0,6 m/s, diámetro con el cual llegarán hasta el pozo de bombeo de entrada a planta, previa medición del caudal de entrada con caudalímetros electromagnéticos en línea.

### 5.2. BOMBEO DE ENTRADA A LA ETAP

La cámara de entrada a la ETAP estará conformada por una arqueta de llegada del agua de 11,00 x 2,64 m con una altura útil de 4,20 m y un pozo de bombeo rectangular de 14,00 x 8,00 m y altura útil de 8,40 m, resultando en un volumen útil de 940 m³.

Para impedir el paso del agua dentro del pozo en caso de emergencia, se colocará en cada tubería de llegada, una válvula de mariposa de diámetro nominal DN1400.

El bombeo se diseñó de forma tal de que pueda trabajar en los diferentes escenarios de caudal entrante e incluso con una unidad fuera de funcionamiento por mantenimiento. Para ello, se ha previsto que las bombas puedan alcanzar un caudal máximo de bombeo del 10% por encima del caudal máximo de diseño. Se proyectaron 4 bombas (3+1) centrífugas sumergibles situadas en una cámara seca adyacente al pozo, de 4.167 m³/h, 210 kW de potencia, a 8 m.c.a. de altura manométrica.



Las bombas dispondrán de variadores de frecuencia, de forma que se pueda adaptar el caudal de bombeo al de llegada de agua bruta, evitando de esta manera, los aumentos bruscos del mismo al ponerse en marcha uno de los equipos. Éstos permitirán, además, conseguir caudales intermedios a los descritos anteriormente y dotar al sistema de una amplia variabilidad de trabajo, optimizando al máximo el consumo energético y minimizando el coste del ciclo de vida. Estará previsto un sistema que permita una rotación automática de las unidades de igual capacidad, a fin de conseguir que funcionen un tiempo semejante. Las unidades de elevación entrarán en servicio, se regularán, y se pararán de forma automática en función de la tendencia del nivel de agua en el pozo. En la Tabla 4 se detalla el esquema de funcionamiento del conjunto de bombas.

**Tabla 4. Funcionamiento del bombeo de entrada. (Fuente: Elaboración propia).**

| PARÁMETRO              | 100 MLD | 200 MLD | 300 MLD | UNIDAD            |
|------------------------|---------|---------|---------|-------------------|
| Caudal total requerido | 100.000 | 200.000 | 300.000 | m <sup>3</sup> /d |
|                        | 4.167   | 8.333   | 12.500  | m <sup>3</sup> /h |
| Bombas activas         | 1,00    | 2,00    | 3,00    | Uds.              |
| Bombas en reserva      | 3,00    | 2,00    | 1,00    | Uds.              |
| Caudal unitario        | 4.167   | 4.167   | 4.167   | m <sup>3</sup> /h |
| Altura manométrica     | 8       | 8       | 8       | m.c.a.            |
| Variador de frecuencia | Si      | Si      | Si      |                   |

Para la extracción de las bombas para su reparación o mantenimiento se instalará un puente grúa eléctrico con capacidad de hasta 10.000 Kg. Las bombas irán dotadas de sistema de extracción y montaje adecuados, tubos guía y zócalo de acoplamiento automático, así como válvula de retención individual, para evitar que la carga hidráulica pueda hacerlas girar en sentido contrario. Contarán además, con válvulas de compuerta que permitirán aislar cada uno de los equipos para mantenimiento o en caso de emergencia. Las tuberías individuales de cada equipo se dimensionarán de tal forma que no se superen velocidades superiores a 2 m/s, cuidando adecuadamente los codos y las uniones a fin de evitar vibraciones. Se instalará un medidor de caudal en la tubería de impulsión del agua, y la cámara de bombas contará con el espacio necesario para el acceso del personal en caso de reparaciones y mantenimiento. Véase Figura 3.

Las cuatro tuberías del bombeo, de DN800, se reúnen en un colector DN1600 que deriva el flujo de agua en tres (2+1) líneas de diámetro DN1400 hacia el pre-tratamiento.

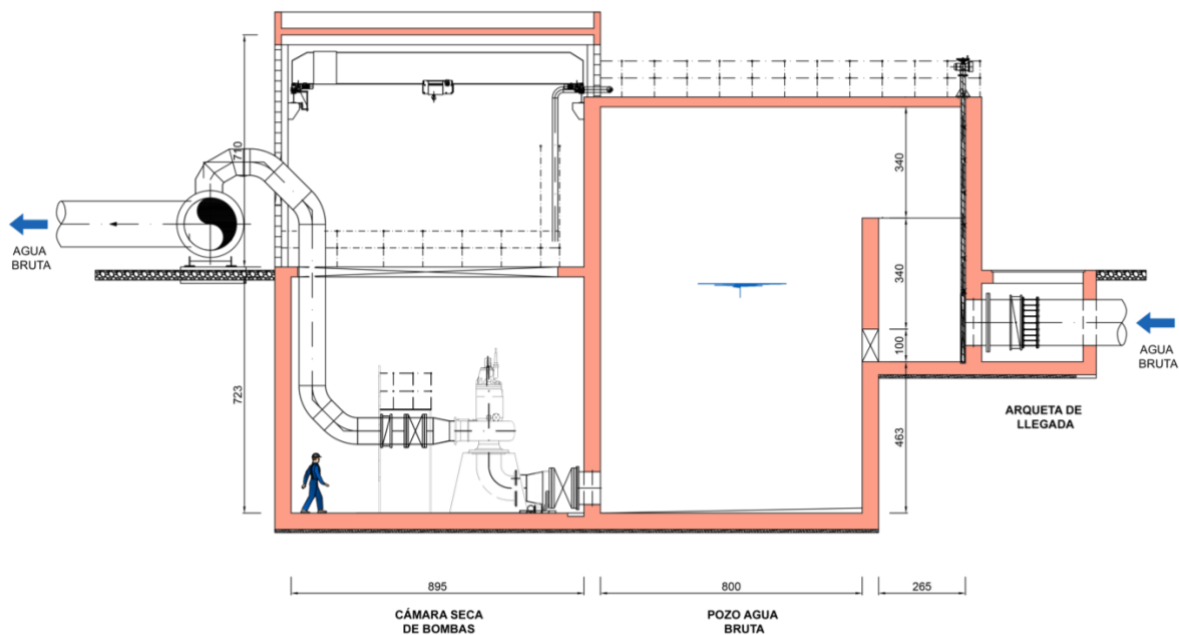


Figura 3. Sección pozo de bombeo de agua bruta. (Fuente: Elaboración propia).

### 5.3. COAGULACIÓN

Esta etapa tiene una relevancia importante en los procesos de tratamiento de agua, ya que se lleva a cabo la agrupación de la fracción coloidal de los sólidos presentes en el agua que no puede eliminarse por sedimentación. El objetivo es eliminar las propiedades que hacen que la fracción coloidal de los sólidos se mantenga en suspensión. Para ello, se utilizan reactivos químicos que anulan las cargas eléctricas entre las partículas, desestabilizándolas. Estos reactivos requieren de un tiempo muy bajo para producir la coagulación, por lo que es necesario que su mezcla con el agua se realice de forma rápida y violenta. Una buena mezcla se consigue en un tiempo de entre 30 segundos y 3 minutos aproximadamente (Tejero, I. et al. 2004).

Lo convencional para lograr la coagulación es la construcción de cámaras de agitación formadas por depósitos con un sistema de agitación, normalmente vertical. La velocidad de mezcla en estas cámaras suele oscilar entre 3 y 5 m/s, con potencias de entre 20 y 50 kW/m<sup>3</sup>/s, por lo que su consumo energético es considerable.

Los reactivos a incorporar en esta etapa fueron determinados por el pliego de licitación del proyecto, y serán los mismos en ambas alternativas de diseño:

## COAGULANTES

- *Policloruro de aluminio al 10%*
- *Sulfato de alúmina al 8%*

## AJUSTE DE pH

- *Ácido sulfúrico al 98%*
- *Hidróxido de sodio al 50%*

## OXIDACIÓN

- *Cloro gas*

Puede consultarse su dosificación en el apartado 5.9.

### 5.3.1. MEZCLA CONVENCIONAL

En la alternativa de tratamiento convencional, según el cálculo realizado, para un caudal de 300 MLD y tres líneas de tratamiento, considerando un tiempo de retención hidráulica (TRH) de 1 minuto, se requiere un volumen de 72 m<sup>3</sup> por cámara. Si se adopta una altura de tanque de 4,50 m, cada lado de la cámara cuadrada deberá ser de 4,00 m. Para conseguir una mezcla completa, cada cámara necesitará tener un agitador vertical de 11 kW. Pueden consultarse más datos sobre el dimensionamiento en la Tabla 25 de los Anexos.

### 5.3.2. MEZCLA DE BAJO CONSUMO

En lugar de la construcción de cámaras de mezcla, en la alternativa de bajo consumo, se optó por la instalación de mezcladores estáticos en línea. Éstos son elementos mecánicos que generan una turbulencia repentina para lograr una mezcla homogénea de líquidos en un proceso continuo. Se los conoce también como “mezcladores en línea sin movimiento”, ya que no presentan piezas móviles ni requieren de corriente eléctrica adicional, lo que deriva en un muy bajo mantenimiento. Además, la pérdida de carga provocada por estos elementos es mínima por lo que su consumo indirecto es muy bajo, ya que las bombas de impulsión de cada una de las corrientes de soluciones químicas que ingresan al mismo no requerirán de gran potencia.

El principio de funcionamiento de estos elementos se basa en la perturbación del flujo a través de una serie de elementos colocados en el interior de éste de tal manera que la

mezcla resultante sea homogénea. La mezcla que se produce en el interior de estos mezcladores es de tipo turbulenta y se da en una sección corta a velocidades de flujo altas, lográndose mediante la rotación interna y el corte de las capas dentro del líquido. El trenzado de los elementos mezcladores genera un giro axial al patrón de flujo, y cada elemento sucesivo va alternando un giro a la izquierda y a la derecha. Además, cada elemento subsiguiente se coloca con una rotación de 90° en comparación con su predecesor.

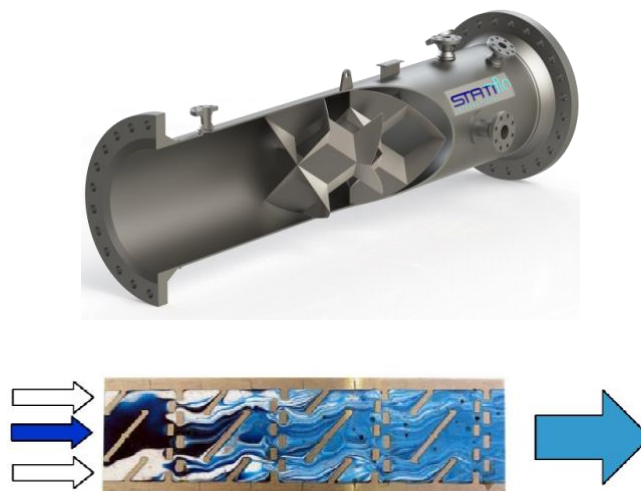


Figura 4. Esquema de funcionamiento de un mezclador estático. (Fuente: [www.statiflo.com](http://www.statiflo.com)).

Se instalará un mezclador estático en cada una de las tres líneas de agua bruta bombeada, de diámetro DN1400 que tendrán las conexiones para incorporar las cinco soluciones de reactivos que serán adicionados según los requerimientos de cada momento en base a la calidad del agua bruta entrante y de su caudal.

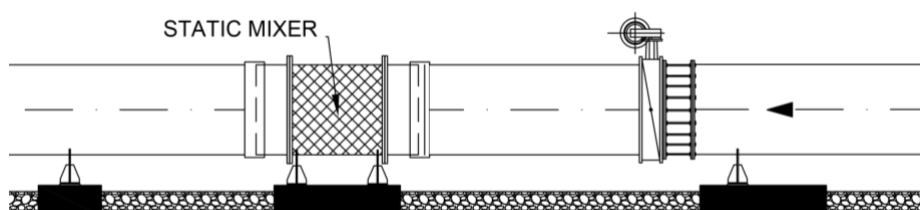


Figura 5. Mezclador estático. (Fuente: Elaboración propia).

## 5.4. FLOCULACIÓN

La floculación tiene por objetivo agregar las partículas coloidales desestabilizadas por la coagulación. El proceso de formación de enlaces entre éstas es lento y requiere de una mezcla lenta con tiempos de retención hidráulica de entre 10 y 30 minutos, lo que aumenta los volúmenes de los depósitos. Es necesario producir la mezcla del floculante con el agua, pero con una energía que no rompa los flóculos ya formados. El objetivo de esta etapa del proceso es proporcionar a la masa de agua coagulada una agitación lenta aplicando velocidades decrecientes para promover el crecimiento de los flóculos y su conservación hasta que la suspensión de agua y flóculos salga de la unidad. La energía que produce la agitación del agua puede ser de origen mecánico o hidráulico (CPIS/OPS 2004).

Las instalaciones convencionales de floculación consisten en cámaras de mezcla lenta con un sistema de agitación mecánico con paletas de mayor superficie que las de mezcla rápida, con velocidades periféricas de 0,15 a 0,60 m/s y que no suelen superar los 3 a 4 kW/m<sup>3</sup>/s. Se diseñan con una zona de mezcla y una zona de maduración, donde la energía a aplicar debe ser menor, ya que en ella se busca mantener en suspensión los flóculos ya formados (Tejero, I. et al. 2004).

### 5.4.1. FLOCULACIÓN CONVENCIONAL

A partir del cálculo realizado, el cual puede consultarse en la Tabla 26 de los Anexos, en la alternativa de diseño convencional, para un caudal de 300 MLD y tres líneas de tratamiento, las dimensiones de una cámara de floculación para un TRH de 10 minutos, y una profundidad de 5,80 m serán de 11,50 x 11,50 m de lado para la zona de contacto y de 2,00 x 21,50 m para la zona de maduración, en consonancia con las dimensiones de los decantadores, ya que se diseñan en conjunto. En total, son 767 m<sup>3</sup> por cámara de contacto y 249 m<sup>3</sup> por cámara de maduración. Se instalará un agitador por cámara de 5,20 kWh cada uno.

### 5.4.2. FLOCULACIÓN DE BAJO CONSUMO

Por otro lado, en línea con el objetivo de diseñar una planta con muy bajo consumo energético, la floculación en la ETAP de bajo consumo se plantea mediante el uso de floculadores hidráulicos, donde la energía requerida para la mezcla se logra a través de la gravedad, utilizando la altura de agua disponible en lugar de utilizarse equipos

mecánicos de agitación. Son otro sistema de mezclado lento que, en lugar de utilizar agitadores, utiliza canales laberínticos en depósitos de gran tamaño.

En un floculador hidráulico, el gradiente de velocidad debe variar de forma uniformemente decreciente desde que la masa de agua ingresa a la unidad hasta que sale. Pueden operar indefinidamente sin riesgos de interrupción ya que solo dependen de la energía hidráulica, rasgo que los hace muy confiables. Por su bajo coste de operación y mantenimiento, se los considera como una tecnología muy apropiada para países en desarrollo. Para crear el recorrido del agua dentro de la unidad, pueden utilizarse pantallas removibles de materiales que no constituyan un riesgo de contaminación para el agua que se está tratando.

El gradiente de velocidad es una función de la pérdida de carga y la pérdida de carga se produce a lo largo de los canales, principalmente en los giros. Para un mejor funcionamiento, en el fondo de la unidad se debe considerar una pendiente igual a la pérdida de carga obtenida en el cálculo de tal forma que la altura de agua permanezca constante al igual que el gradiente de velocidad. Además, las pantallas deberán cruzarse por lo menos en un tercio de su longitud (CPIS/OPS 2004b).

Se proyectaron tres tanques de 29,50 m de longitud con tres líneas de floculación en cada uno de ellos, de 7,40 m de ancho y 6,20 m de altura útil. Este diseño garantiza el funcionamiento a plena capacidad incluso cuando una de las líneas se encuentre en fase de mantenimiento, siendo las restantes las encargadas de acomodar la capacidad total de agua a tratar. La entrada y la salida del agua a los tanques se diseñó con el objetivo de evitar la destrucción de los flóculos, asegurando una velocidad de entrada y de salida no menor a 0,15 m/s y no superior a 0,45 m/s, con un tiempo de retención hidráulico de 30 minutos.

La floculación se llevará a cabo en tres etapas con diferentes velocidades de mezcla, las cuales se conseguirán con la disposición de las pantallas deflectoras. La primera etapa será la de mayor intensidad, alcanzando un gradiente de velocidad de casi  $80 \text{ s}^{-1}$  y la tercera será la de intensidad más baja, no superando los  $40 \text{ s}^{-1}$ . Al estar hidráulicamente conectados a los decantadores, la fase de maduración se dará ya dentro del decantador. Puede consultarse más información sobre el cálculo en la Tabla 27 de los Anexos.

El diseño de nueve floculadores divididos en tres grupos de tres (2+1), se debe al hecho de dotar de versatilidad al sistema y poder trabajar con el resto de las líneas en caso de

parada de una línea de decantación. Como puede verse en la Figura 6, si se encuentran trabajando las tres líneas de decantación, para mantener un correcto TRH y una intensidad de mezcla adecuada, se trabaja con seis de los nueve floculadores. En cambio, en caso de necesitar llevarse a cabo tareas de mantenimiento en alguna línea, se trabaja con dos líneas de decantación y con los seis floculadores asociados a las líneas principales. En la figura se identifican las líneas en funcionamiento en color azul y las líneas en reserva o mantenimiento en color rosa.

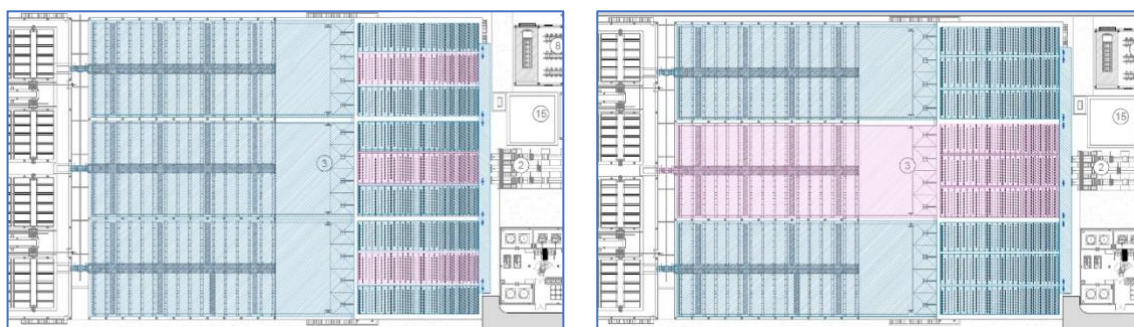


Figura 6. Versatilidad de funcionamiento de las líneas de floculadores y decantadores. (Fuente: Elaboración propia).

Tanto en la alternativa de diseño de bajo consumo como en la convencional, el agua coagulada previo a su ingreso a los floculadores, deberá contar con la adición de los reactivos floculantes y oxidantes: polielectrolito catiónico (PolyDADMAC) y permanganato potásico en las dosis que se detallan en el apartado 5.9.

## 5.5. DECANTACIÓN LAMELAR

Los decantadores se diseñan en general integrando en una sola unidad de proceso las etapas de coagulación-floculación y decantación, a fin de optimizar espacio, costes de inversión y de explotación. Es habitual que se los diseñe anexando depósitos de planta rectangular o cuadrada en el lado de la entrada del influente, como se observa en la Figura 7.

La decantación es un proceso básico en cualquier proceso de tratamiento del agua, puesto que sirve para eliminar los sólidos sedimentables presentes en ésta. Constituyen una parte fundamental en el proceso global de tratamiento ya que sus errores de diseño



trasladan el problema a las etapas posteriores. El papel del decantador es el de separar los elementos semipesados y pesados en suspensión en el agua.

Una alternativa muy utilizada para mejorar los rendimientos de eliminación de sólidos es la de emplear decantadores con recirculación de fangos. De esta forma, se alcanzan concentraciones de entrada superiores a los 300-500 mg/L, permitiendo que los mismos funcionen con sedimentación zonal.

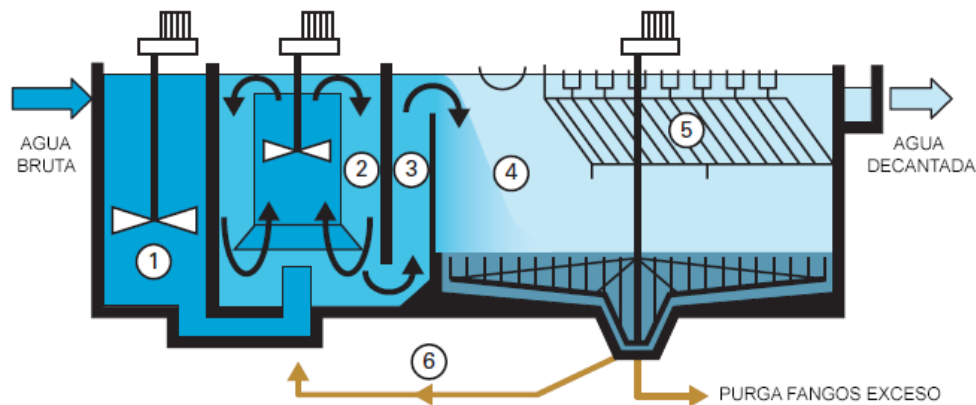


Figura 7. Decantador físico-químico con recirculación de fangos. (Fuente: Degrémont 1979).

Para alcanzar rendimientos aceptables, habrá que elegir una velocidad ascensional en función de la partícula más desfavorable a eliminar. En el presente proyecto, deberá ser inferior a  $13 \text{ m}^3/\text{h} \cdot \text{m}^2$

Otra estrategia muy utilizada para aumentar el rendimiento es aumentar la superficie de sedimentación mediante la utilización de lamelas. De esta forma, la superficie horizontal efectiva, es la proyección horizontal de cada placa por el número de placas, siendo este valor de superficie el que interviene en el cálculo de la velocidad ascensional. Otra ventaja de los decantadores lamelares es que el paquete de lamelas permite que la distancia que deban recorrer las partículas hasta sedimentar sea mucho menor, y, por ende, se pueda aumentar la capacidad de clarificación. Esto, además, reduce las dimensiones del decantador y, en consecuencia, los costes de inversión y explotación. En el diseño de sedimentadores con módulos de sedimentación de alta tasa, como son los lamelares, se utiliza el concepto de velocidad de Hazen en lugar de la carga superficial, definida como el cociente entre el caudal y el área proyectada efectiva. De igual forma que con la carga superficial, a menor velocidad de Hazen, mayor eficiencia en la remoción de sólidos, pero requiere de más volumen de módulos para el mismo flujo, incrementando los costes constructivos.



### 5.5.1. DECANTADOR CON RECIRCULACIÓN DE FANGOS

Para el diseño de la alternativa convencional de decantación, se optó por un decantador físico-químico con recirculación externa de fangos como se observa en la Figura 7. Consiste en un sistema compacto que agrupa las etapas de coagulación-floculación y clarificación en un único elemento integrado. Además, al contar con la recirculación de fangos, se podrá aumentar la velocidad de Hazen incluso hasta 3 m/h.

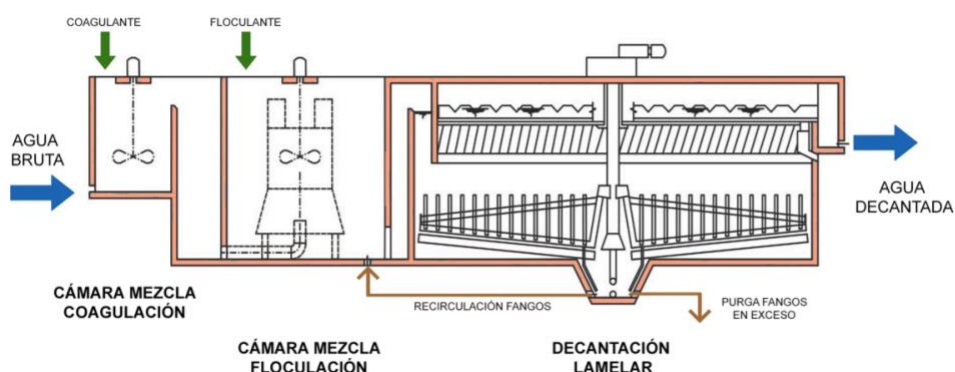


Figura 8. Decantador lamelar con recirculación de fangos y cámaras de floculación y coagulación anexas. (Fuente: Elaboración propia).

Según cálculo, para un caudal de 300 MLD, tres líneas de tratamiento, una concentración máxima de SS en el agua de 165 mg/L, y una velocidad ascensional inferior a  $13 \text{ m}^3/\text{h} \cdot \text{m}^2$ , se necesita una superficie mínima de decantación-espesamiento de  $353 \text{ m}^2$ , por lo que se adopta un diámetro unitario de 21,50 m. La altura total del tanque se diseñó en 5,80 m. La recirculación de fangos estará entre el 5% y el 8%, por lo que se adoptan cuatro (3+1) bombas de recirculación de  $200 \text{ m}^3/\text{h}$ . Las dimensiones finales de una línea de tratamiento del conjunto se detallan en la Figura 9, siendo “J” la zona de contacto de la floculación, y “G” y “F” las zonas de maduración.

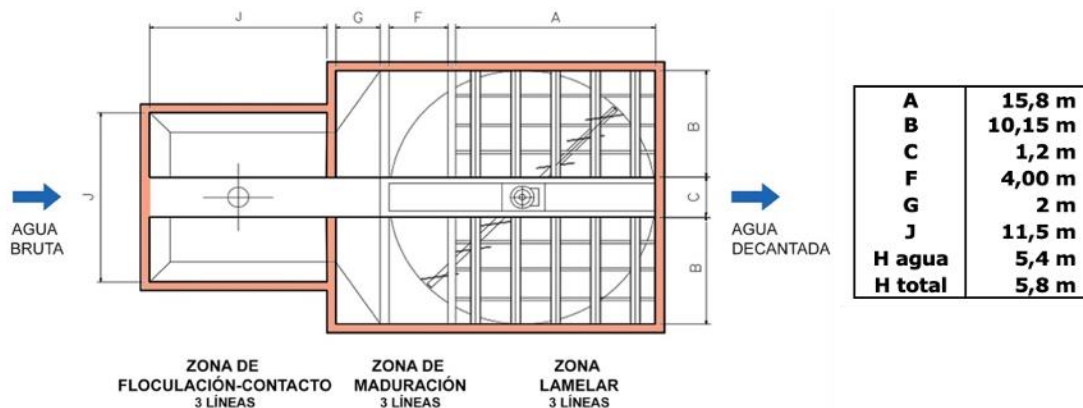


Figura 9. Dimensiones floculador-decantador convencional. (Fuente: Elaboración propia).

Pueden consultarse más datos del dimensionamiento en la Tabla 26 de los Anexos.

Una vez completada la sedimentación, se realizará una cloración intermedia que llevará a cabo en un canal de distribución previo al ingreso a los filtros.

### 5.5.2. DECANTADOR SIN RECIRCULACIÓN DE FANGOS

En el diseño de bajo consumo, se optó por decantadores rectangulares lamelares con barrido mecánico de fangos, pero sin recirculación de éstos. De esta forma, se consigue un ahorro en equipos mecánicos, en consumo energético y por ende en costes de operación. Para un buen funcionamiento del diseño seleccionado, al no contar con recirculación de fangos, se deberá conseguir una velocidad de Hazen inferior a 1 m/h.

Los tanques de decantación estarán hidráulicamente conectados a la floculación, para permitir un flujo continuo y directo, como se observa en la Figura 10. Para un caudal de 300 MLD y una concentración máxima de SS en el agua de 165 mg/L, se diseñaron tres tanques de 46,10 m de longitud y 23,20 m de ancho que serán capaces de absorber el máximo flujo de agua de entrada incluso teniendo una línea en reserva. De estos 46,10 m, 44,20 m serán de zona lamelar y 1,90 m de zona de floculación-maduración, como se observa en la Figura 11.

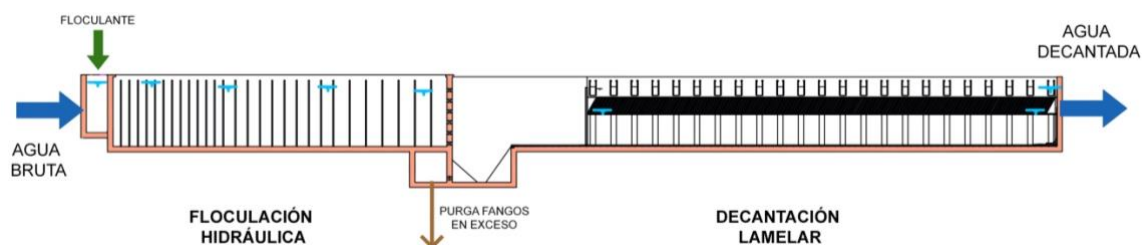


Figura 10. Floculador hidráulico y decantador sin recirculación de fangos. (Fuente: Elaboración propia).

Cada uno de estos tanques tendrá con un sistema de limpieza autónomo, sin necesidad de acceso de personal a los mismos. Contarán, además, con un sistema de vaciado y eliminación de fangos en un tiempo no superior a ocho horas. El sistema lamelar será de tipo hexagonal, de polipropileno (PP) y con inclinación de 60°. Además, estarán equipados con rascadores de fondo para recoger los fangos sedimentados y conducirlos a un canal de recolección, desde donde serán bombeados para su tratamiento. Para controlar la purga, se colocarán sensores de nivel de fangos. La turbidez del agua una vez decantada será inferior a 7,00 NTU. Puede consultarse más información sobre el dimensionamiento en la Tabla 28 de los Anexos.

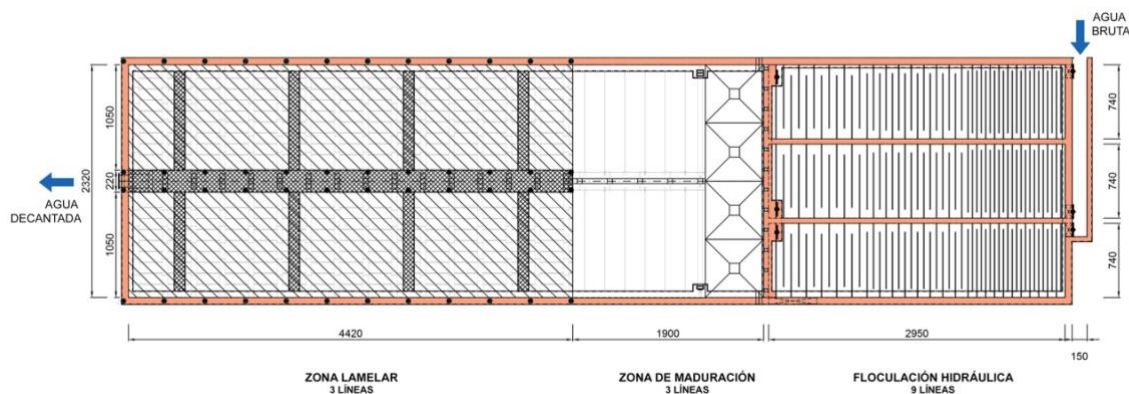


Figura 11. Dimensiones sistema floculación-decantación bajo consumo. (Fuente: elaboración propia).

En ambas alternativas, se proyectaron cuatro (2+1) bombas helicoidales de 150 m<sup>3</sup>/h a 8 m.c.a. para la purga de fangos y dos (1+1) bombas centrífugas de 500 m<sup>3</sup>/h a 10 m.c.a. para el vaciado de las líneas de floculación y decantación.

## 5.6. FILTRACIÓN

La filtración es el proceso más complejo de una planta de tratamiento de agua. Su correcto diseño depende de la relación entre las características del agua a tratar y del medio filtrante para que se den los mecanismos de filtración adecuados con la máxima eficiencia posible. El objetivo fundamental consiste en eliminar los sólidos en suspensión (SS) de un agua, haciéndola pasar a través de un material filtrante. Mejora la calidad del agua coagulada, floculada y decantada, al retener posibles flóculos y partículas que hayan escapado a la decantación, disminuyendo la turbidez del efluente.

A medida que el lecho se carga de materia retenida, el filtro se va atascando. Cuando ese atascamiento alcanza un valor excesivo, o la calidad del filtrado no es aceptable, debe procederse al lavado del lecho filtrante. Con ese lavado es indispensable devolver al lecho sus cualidades iniciales, sin las cuales perdería su eficacia y el material filtrante debería retirarse por completo para su limpieza o reemplazo.

El buen funcionamiento de un filtro dependerá del perfecto reparto a través de la masa filtrante, del agua a filtrar, y del agua y del aire de lavado. Por lo tanto, es muy importante la forma de recogida del agua filtrada, el reparto del agua de lavado y el sistema de soporte del lecho filtrante.

La eficacia de un filtro depende fundamentalmente del sistema de regulación de su caudal, evitando golpes bruscos tanto en los períodos de cambio de caudal como en las fases de lavado, ya que, en caso contrario, las materias retenidas por el lecho atraviesan rápidamente el filtro que es traspasado prematuramente por la materia en suspensión del agua. Para asegurar una buena filtración, un filtro debe reunir numerosas condiciones, no existe un filtro universal, sino filtros adaptados a cada uno de los problemas planteados (Degremont 1979).

En el presente proyecto, el pliego de licitación especifica una velocidad de filtración máxima de 12 m/h, con un lecho bicapa de arena y antracita de 1500 mm, una carrera de filtración mínima de 24 h, y velocidades de lavado con agua de 55 m<sup>3</sup>/m<sup>2</sup>.h durante 20 minutos y de lavado con aire de entre 40 y 70 m<sup>3</sup>/m<sup>2</sup>.h durante 7 minutos.

#### 5.6.1. FILTROS ABIERTOS CONVENCIONALES

En una alternativa convencional de filtración, el lavado de filtros se realiza con agua filtrada, almacenada en un tanque específicamente para dicha finalidad, bombeando con el caudal necesario para alcanzar la velocidad requerida y durante el tiempo suficiente. Suelen dimensionarse con una relación máxima largo/ancho de 6 - 6,5.

Para cumplir con los requerimientos del presente proyecto con filtros convencionales, según cálculo, se necesitan 6 filtros dobles de 9 x 32 m, es decir, 288 m<sup>2</sup> de filtración por unidad, como se observa en la Figura 12. Para alcanzar la velocidad de lavado de 55 m<sup>3</sup>/m<sup>2</sup>.h, se necesitará un caudal de 15.840 m<sup>3</sup>/h, que será impulsado desde el tanque de agua filtrada por cuatro (3+1) bombas de 5.300 m<sup>3</sup>/h a 10 m.c.a. Para el lavado con aire se utilizarán tres (2+1) soplantes de 8.400 m<sup>3</sup>/h a 7 m.c.a., para alcanzar los 60 m<sup>3</sup>/m<sup>2</sup>.h necesarios durante 7 minutos. El volumen total de agua consumida por lavado por filtro será de 5.300 m<sup>3</sup>, por lo que, para almacenar el agua suficiente para un lavado, se diseñó un tanque de almacenamiento de agua filtrada de 48 x 25 x 4,50 m, consiguiéndose un volumen de 5.400 m<sup>3</sup>. Pueden consultarse más datos sobre el dimensionamiento en la Tabla 30 de los Anexos.

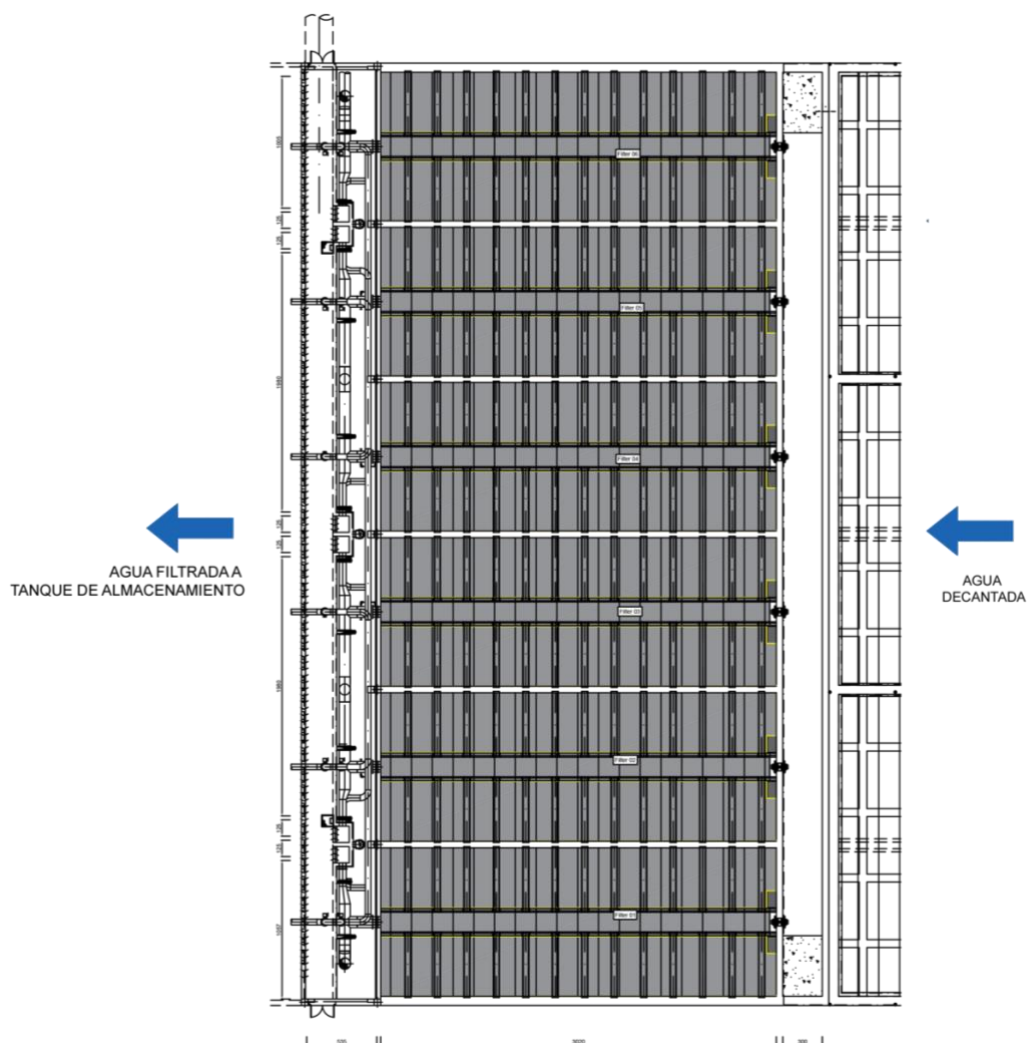


Figura 12. Filtros abiertos convencionales. (Fuente: Elaboración propia).

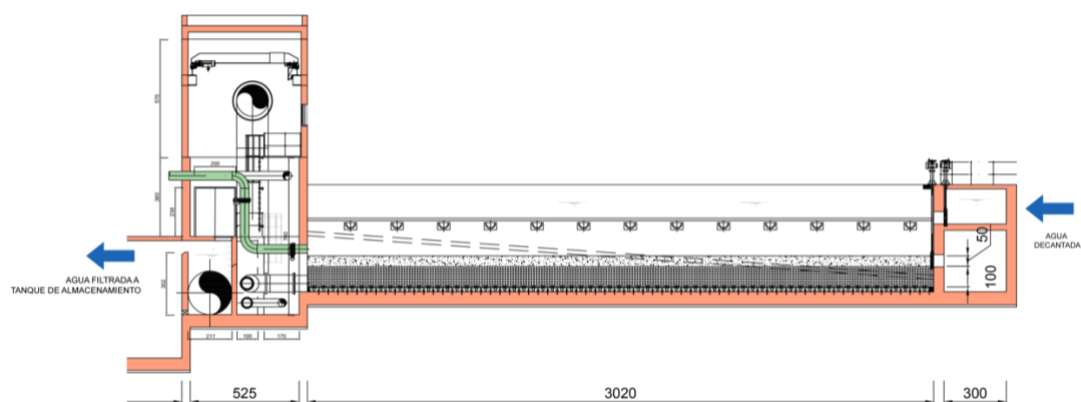


Figura 13. Sección filtros convencionales. (Fuente: Elaboración propia).

### 5.6.2. FILTROS DE TASA DECLINANTE Y LAVADO MUTUO

La opción adoptada para conseguir un proceso de bajo consumo energético, son los filtros de tasa declinante y lavado mutuo. Este tipo de filtros, además de su bajo consumo energético, presentan otras características beneficiosas:

- No requieren una carga hidráulica muy grande para operar, ésta suele ser una carga similar a la que se necesitaría si estuviera operando con tasa constante, dividida por el número de filtros que componen la batería.
- No tienen galería de tubos, si no que el transporte de agua se realiza mediante canales.
- No requieren de un tanque de lavado ni de un sistema de bombeo para el retrolavado de un filtro, sino que a través del canal de interconexión y debido a un especial diseño hidráulico del sistema, el agua producida por lo menos por tres filtros retrolava a una unidad. Esto implica ahorros en materia de equipos mecánicos y, en consecuencia, de consumo energético.
- No requieren instrumentación sofisticada, para su operación, sólo es necesario un sistema de apertura y cierre de válvulas y sensores de nivel.
- Operan bajo el principio de vasos comunicantes, ya que todas las unidades están interconectadas entre sí. Por esta característica, las unidades presentan todas los mismos niveles y es posible controlar el nivel máximo de toda la batería, con un solo vertedero-aliviadero en el canal de entrada (CPIS/OPS 2004a).

Sin embargo, para poder alcanzar las velocidades de lavado con la propia hidráulica, es necesario que la superficie unitaria de cada filtro sea inferior que en un filtro convencional donde el agua de lavado ingresa bombeada. Por lo tanto, implica un coste superior en materia de obra civil para su construcción.

Como puede verse en la Figura 14, un filtro de tasa declinante está formado por:

- **Caja del filtro:** conformada por el falso fondo, el lecho filtrante, las canaletas secundarias de lavado, y el canal principal de lavado que recibe el agua de retrolavado recolectada por las canaletas secundarias. Por encima de este nivel se ubican las cargas de agua necesarias para el funcionamiento de la batería (carga hidráulica para el lavado y para el proceso de filtrado), que determinarán

la profundidad total de la caja del filtro y se limitan mediante vertederos. (CPIS/OPS 2004a).

- **Canal de distribución del agua decantada:** Alimenta las cajas de los filtros a través de las válvulas de entrada de cada unidad. En la parte superior de este canal se ubica el vertedero que limita la carga hidráulica máxima disponible para la operación con tasa declinante de la batería de filtros. (CPIS/OPS 2004a).
- **Canal de desagüe del agua de retrolavado:** Ubicado debajo el anterior, recibe el agua del retrolavado de los filtros. En este canal se suelen reunir también los desagües de los decantadores y floculadores, por lo que constituye el canal emisor de la planta (CPIS/OPS 2004a).
- **Canal de aislamiento:** Tiene por función aislar una unidad del resto de la batería, cerrando la válvula de entrada y la compuerta de salida que comunica con el canal de interconexión ubicado a su izquierda. Este canal se localiza contiguo a la caja del filtro y se comunica con ella a través del canal del falso fondo en toda su sección, lo que permite una distribución pareja del agua de lavado a todo lo ancho del drenaje (CPIS/OPS 2004a).
- **Canal de interconexión de la batería de filtros:** Durante la operación de filtración, reúne el efluente de todos los filtros y lo saca a través del vertedero que controla la carga hidráulica del lavado. Durante la operación de lavado de una unidad, al bajar el nivel del agua por debajo del vertedero de salida, facilita que se derive automáticamente el agua filtrada producida por las otras unidades en operación (tres unidades) hacia el filtro que se encuentra en posición de lavado (CPIS/OPS 2004a).



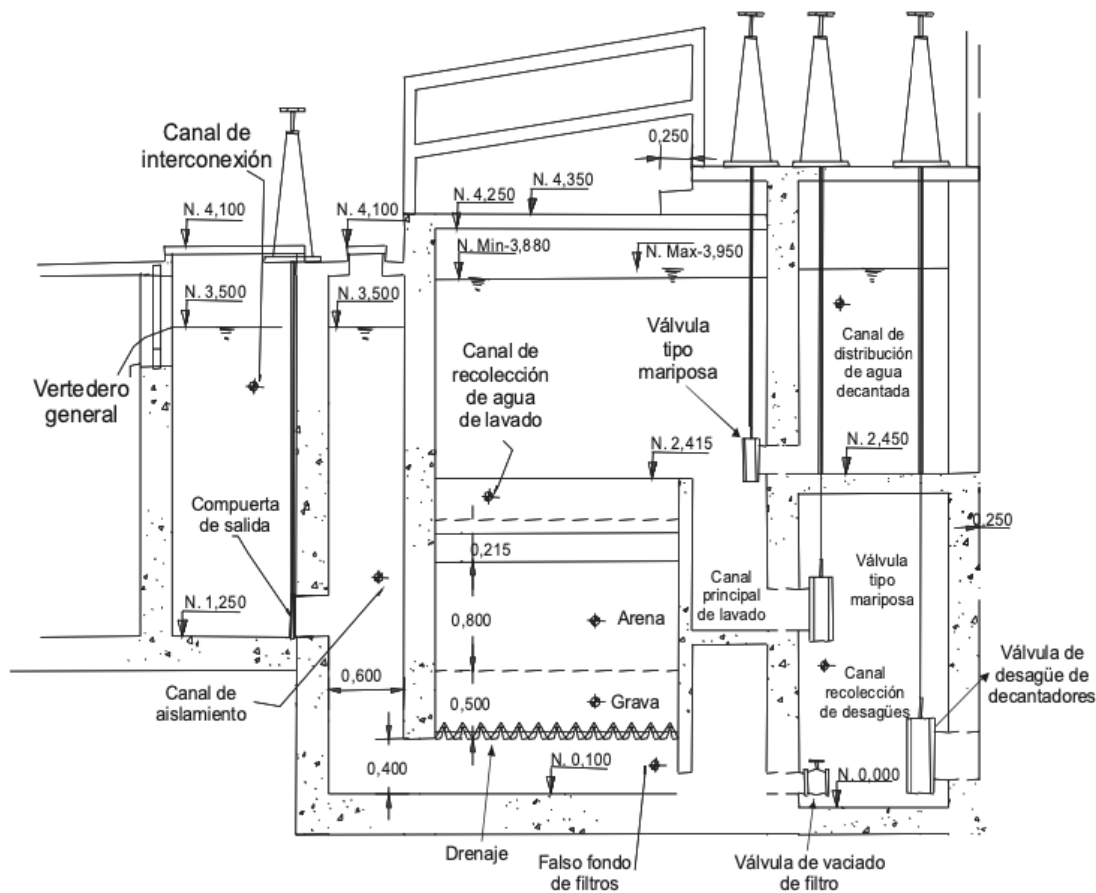


Figura 14. Sección de un filtro de tasa declinante. (Fuente: CPIS/OPS 2004).

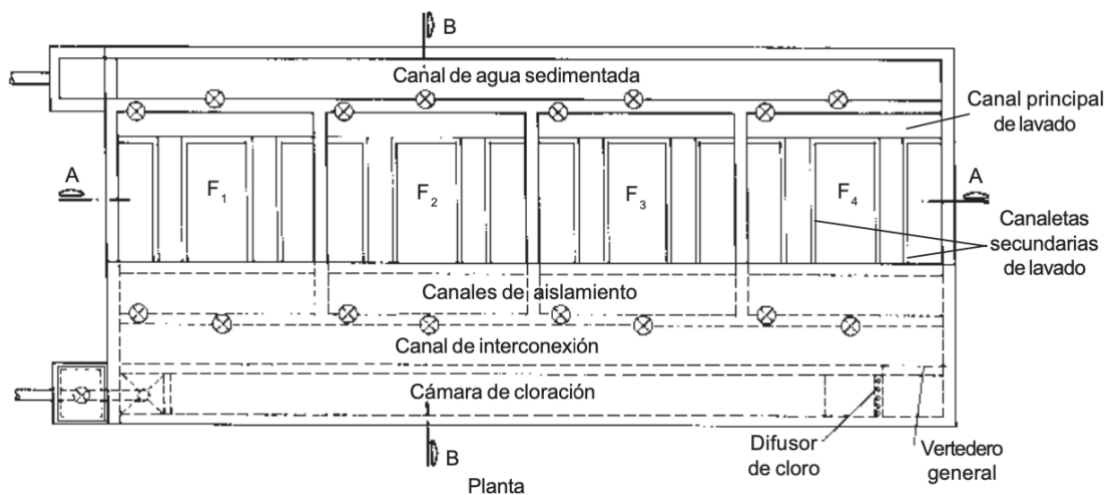


Figura 15. Planta de una batería de filtros de tasa declinante. (Fuente: CPIS/OPS 2004).



A diferencia de los filtros de caudal constante, los de tasa declinante operan con un nivel de agua constante común a todos los filtros mientras que la tasa de flujo en cada uno de ellos varía dependiendo de la cantidad de sólidos acumulados. El agua fluye normalmente desde un canal común y entra a cada filtro a un nivel que se establece por debajo del nivel mínimo de agua, para garantizar que todos operen al mismo nivel. La cantidad de agua que puede recibir cada filtro dependerá de su suciedad. El filtro más limpio de la batería es el que filtrará más agua y el más sucio el que filtrará menos agua. Es decir, la tasa de filtración de cada filtro disminuye progresivamente desde el máximo (inmediatamente después del retrolavado) hasta el mínimo (cuando se lo considera sucio y debe lavarse). El nivel del agua sube durante la operación comúnmente para todos los filtros, en respuesta a la pérdida de carga acumulada entre los diferentes filtros que se encuentran en diferentes etapas de operación (García-Ávila et al. 2020).

Existe un número mínimo de cuatro unidades de filtración idénticas, que está determinado por la necesidad de que el caudal de lavado que requiere un filtro pueda ser suplido por los demás filtros del sistema, los cuales se lavan siempre en estricto orden consecutivo. El nivel del agua después del retrolavado de uno de los filtros desciende inmediatamente en todos los filtros, lo que de algún modo provoca un cambio en el régimen de flujo en cada uno de los filtros dependiendo de su etapa de operación. El filtro lavado más recientemente ahora lleva el caudal más alto, mientras que el resto de los otros filtros verán reducido su caudal como resultado (Tiruneh et al. 2019).

Este modo de operación facilita un funcionamiento más largo del filtro, ya que los filtros con condiciones obstruidas pueden operar a tasas de flujo bajas, lo que evitará el desarrollo de una mayor pérdida de carga. El funcionamiento a un caudal bajo con el desarrollo de una baja pérdida de carga asociada permite que los filtros sigan funcionando durante un período más largo antes de que se retiren para su limpieza. A medida que los filtros se acumulan con depósitos, su capacidad para aceptar caudal y filtrar sólidos disminuye. Por lo tanto, el filtro de tasa declinante tiene en cuenta dicha limitación en el rendimiento y reduce las tasas de flujo en los filtros sucios para que puedan continuar operando con la misma eficiencia de filtración. El flujo rechazado por los filtros sucios se distribuye a los filtros limpios y, debido a esto, se requiere un mínimo de cuatro filtros para hacer funcionar el sistema y que permita solo un aumento moderado en la tasa de filtración como resultado de compartir el exceso de flujo rechazado durante la limpieza por los otros tres filtros que están en funcionamiento (Tiruneh et al. 2019).

Los filtros de tasa de flujo constante a menudo requieren un retrolavado frecuente debido al tiempo limitado de funcionamiento y debido al rápido desarrollo de la pérdida de carga y al deterioro de la calidad del filtrado. Tal retrolavado frecuente da como resultado la interrupción del proceso de filtración y requiere un mayor volumen de agua necesario para el retrolavado. Los filtros de tasa declinante, en cambio, reducen la frecuencia de interrupción al permitir un funcionamiento más prolongado del filtro y, al mismo tiempo, minimizan la cantidad de agua necesaria para el retrolavado en un tiempo determinado. Además, ofrecen una ventaja económica de producir más agua por carrera de filtrado debido al privilegio de un período prolongado de operación de filtros (Tiruneh et al. 2019).

Sin embargo, también tienen algunas desventajas. La falta de flexibilidad operativa es un inconveniente de este tipo de filtros, aunque también pueda ser una ventaja, ya que se minimiza la intervención operativa, siempre que la operación sea constante. Sin embargo, cuando cambia el caudal, debido a un cambio en las condiciones de diseño o cuando uno de los filtros tiene que dejar de funcionar para fines de mantenimiento, la condición de operación cambia y puede estar lejos de lo que se requiere para ser la condición óptima para el desempeño satisfactorio de los filtros. No existe un medio operativo simple para adaptarse a estas nuevas condiciones sin recurrir a modificaciones importantes en el diseño estructural de los filtros.

Otra desventaja de los filtros de tasa decreciente es la fluctuación de las tasas de flujo durante el retrolavado, después del retrolavado y a medida que avanza el filtro hacia el final de su carrera de filtrado. El cambio repentino en la tasa de filtración se observa en todos los filtros inmediatamente después de que un filtro ha sido retrolavado y vuelto a poner en funcionamiento. Tal cambio rápido en la filtración, junto con la existencia de sólidos residuales en el filtro recién lavado, puede dar como resultado una alteración de las condiciones de almacenamiento de sólidos en el lecho y el deterioro de la calidad del filtrado en particular.

La falta de flexibilidad operativa y la fluctuación repentina de la tasa de flujo en respuesta al retrolavado de los filtros puede provocar un deterioro de la calidad del agua filtrada y puede requerir un reajuste estructural importante cada vez que cambia la tasa de flujo o cambia la calidad del agua bruta. Por lo tanto, los filtros de tasa decreciente se consideran óptimos en su desempeño solo con respecto a condiciones operativas estrictamente definidas.

Para cumplir con los requisitos de filtrado del agua decantada entrante y con los requerimientos hidráulicos de los filtros de tasa declinante, se diseñó una batería de 16 filtros dobles de 7,60 x 11,00 m, con un lecho de 1.500 mm de arena y antracita, dispuestos en líneas de a cuatro y separados por los canales de recolección de agua y de interconexión (Véase Figura 16, Figura 17 y Figura 18). La superficie unitaria de filtrado es de 83,6 m<sup>2</sup>, la necesaria para alcanzar las velocidades de lavado con la propia hidráulica. Es decir, la filtración se diseñó de forma tal de poder alcanzar los 55 m<sup>3</sup>/m<sup>2</sup>.h de lavado incluso operando con el mínimo caudal, de 100 MLD, que será el escenario más desfavorable, como se expresa en la Tabla 5.

**Tabla 5. Velocidades de filtración. (Fuente: Elaboración propia).**

| PARÁMETRO                                                  | 100 MLD | 300 MLD | UNIDAD                            |
|------------------------------------------------------------|---------|---------|-----------------------------------|
| Filtros en operación                                       | 8       | 16      | Uds.                              |
| Dimensiones                                                |         |         |                                   |
| Ancho                                                      | 7,60    | 7,60    | m                                 |
| Largo                                                      | 11,00   | 11,00   | m                                 |
| Velocidad de filtración con todos los filtros en operación | 6,90    | 10,10   | m/h                               |
| Velocidad de filtración con 1 filtro fuera de servicio     | 7,90    | 10,80   | m/h                               |
| Velocidad de filtración con 2 filtros fuera de servicio    | 9,20    | 11,60   | m/h                               |
| Velocidad de filtración específica                         | 55,30   | 81,10   | m <sup>3</sup> /m <sup>2</sup> .h |
| Velocidad de filtración específica requerida               | 55,00   | 55,00   | m <sup>3</sup> /m <sup>2</sup> .h |

Efectuarán una carrera máxima de 24 horas y por lo tanto habrá 16 lavados diarios. Al igual que el resto de las etapas del proceso, se los calculó de forma tal que puedan garantizar el funcionamiento a plena capacidad incluso con una línea en reserva. El sistema de retrolavado es automático y se dará de a un filtro a la vez, cumpliendo con la duración de 20 minutos. Se realizará, además, el lavado con aire de 7 minutos de duración con dos (1+1) soplantes de 5.600 m<sup>3</sup>/h, alcanzando los 60 m<sup>3</sup>/m<sup>2</sup>.h. La turbidez del agua filtrada será inferior a 2,50 NTU. Pueden consultarse más datos sobre su dimensionamiento en la Tabla 29 de los Anexos.

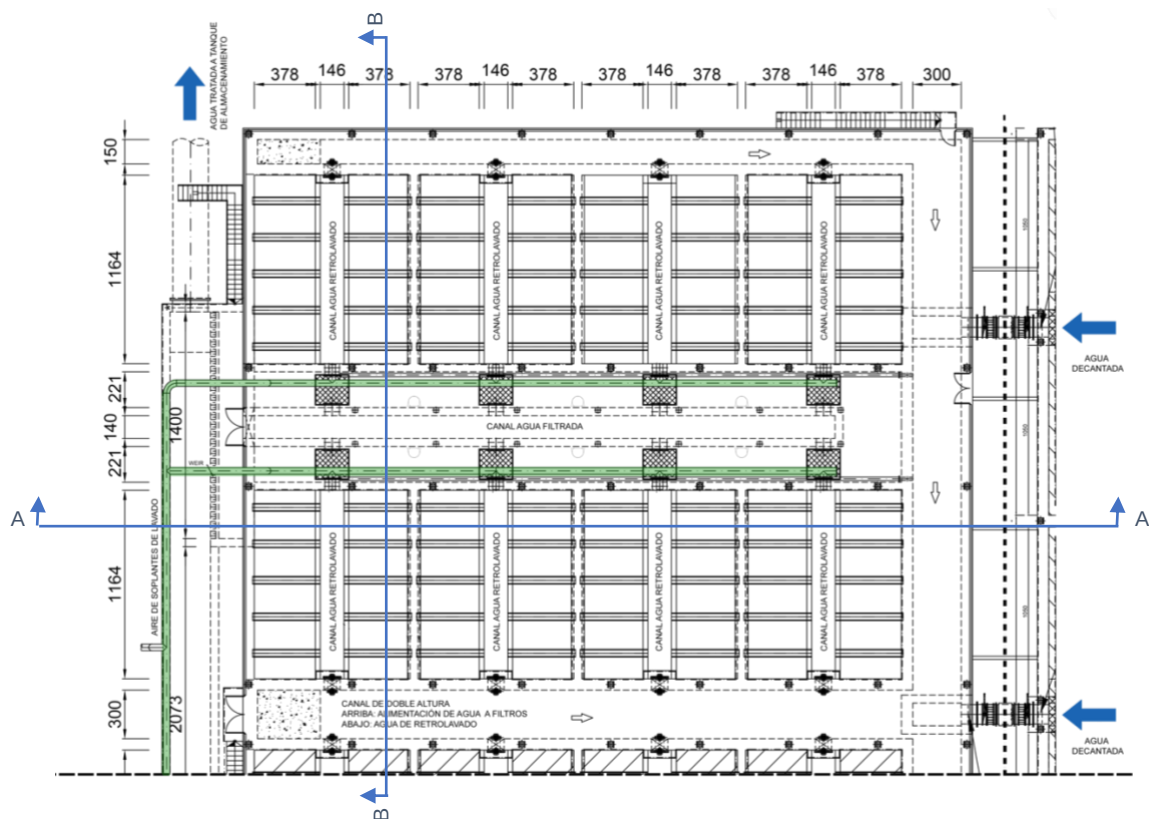


Figura 16. Disposición filtros tasa declinante. (Fuente: Elaboración propia).

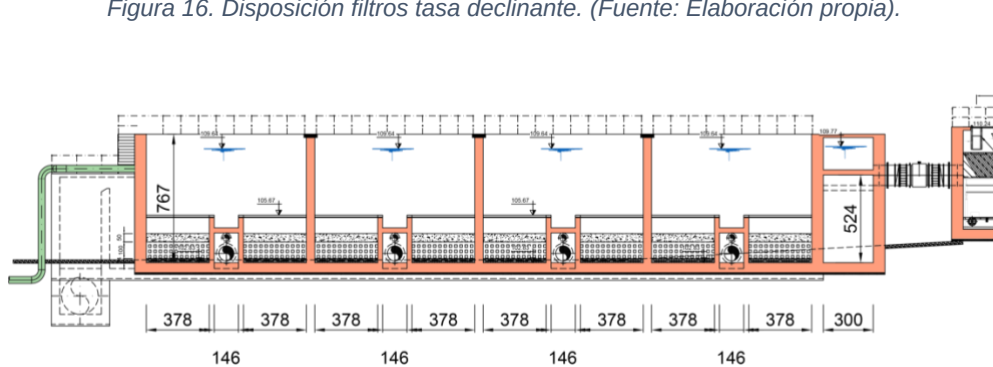


Figura 17. Sección A-A filtros tasa declinante. (Fuente: Elaboración propia).

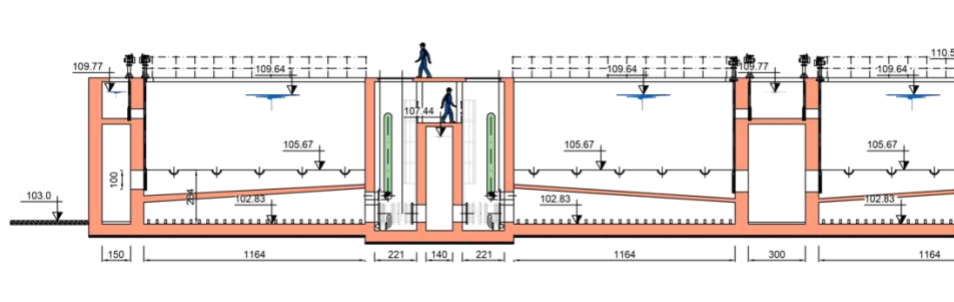


Figura 18. Sección B-B filtros tasa declinante. (Fuente: Elaboración propia).

## 5.7. ALMACENAMIENTO DEL AGUA TRATADA

En ambas alternativas, el agua filtrada se recoge en un canal a la salida de los filtros y se la conduce al tanque de almacenamiento de agua tratada. Dentro del mismo tanque de almacenamiento, se proyectó también la cloración final. El tiempo de contacto de esta última cloración será de 30 minutos y se realizará a través de un laberinto formado por pantallas deflectoras con el objetivo dotar al agua del cloro residual necesario para su distribución. El cloro residual final del agua deberá estar entre 0,90 – 1,50 mg/L. El almacenamiento de agua tratada tendrá lugar en dos tanques contiguos de 18,00 x 20,50 m y 9,50 m de altura útil, permitiendo almacenar un máximo de 48 MLD, garantizando unas 4 a 12 horas de reserva de agua (Véanse Figura 19 y Figura 20). Contarán con un sistema de limpieza autónomo sin necesidad del acceso de personal y un sistema de drenaje que permitirá su vaciado en menos de ocho horas. La tubería de alivio de estos tanques conducirá la descarga a un arroyo cercano y será de diámetro DN600. Desde estos tanques saldrán las tuberías de DN1600 que conducirán el agua tratada a las estaciones de bombeo correspondientes para su posterior distribución.

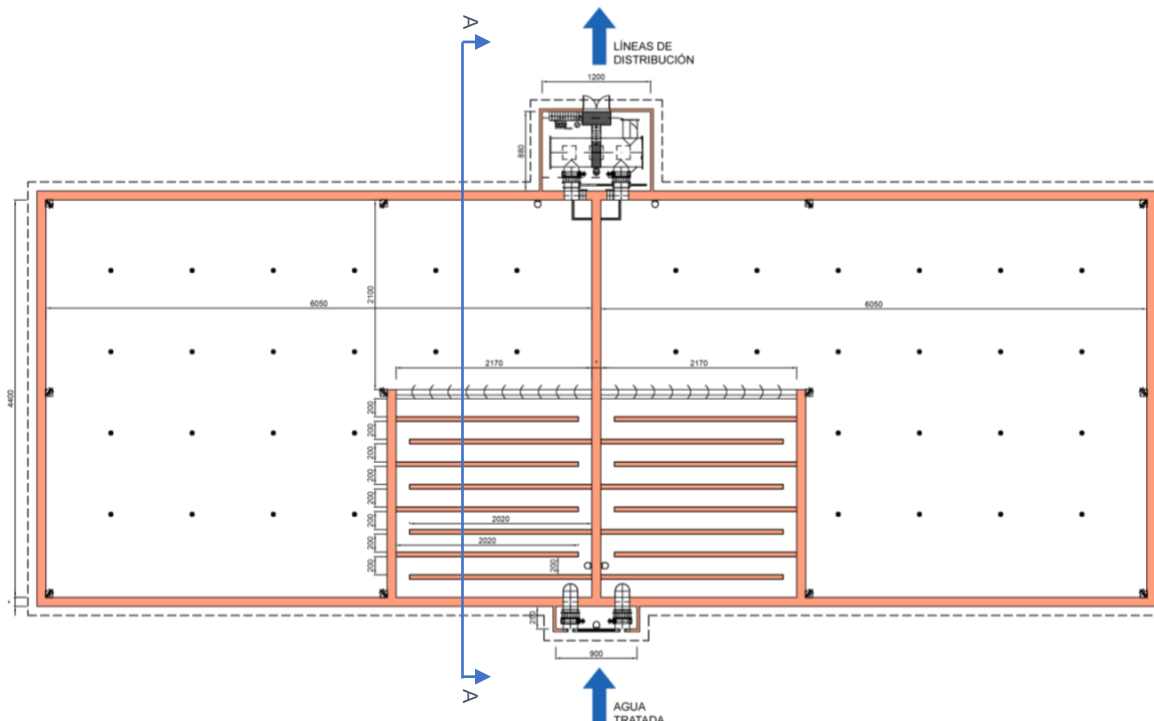


Figura 19. Diseño tanque de almacenamiento de agua tratada. (Fuente: Elaboración propia).

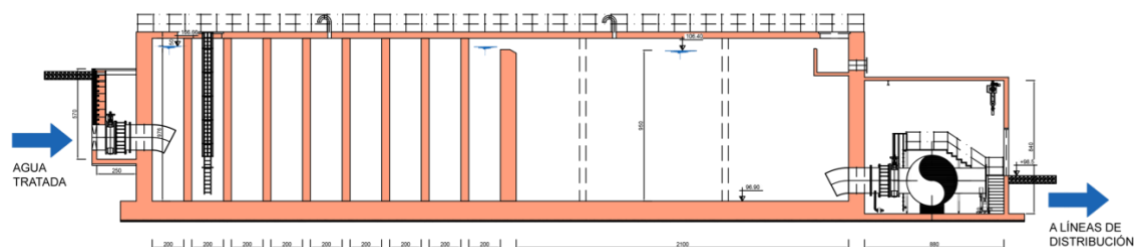


Figura 20. Sección A-A tanque de almacenamiento de agua tratada. (Fuente: Elaboración propia).

## 5.8. RECUPERACIÓN DE LAS AGUAS DE LIMPIEZA

El agua de lavado de los filtros se conducirá a través de una tubería DN1400 hasta los tanques de retrolavado. Éstos tendrán un funcionamiento de tipo *batch* asociado al tiempo de operación de los filtros, presentando un período de llenado de 20 minutos, uno de sedimentación de 130 minutos y uno de drenaje de 30 minutos. Los fangos sedimentados se bombearán al tanque de homogeneización de fangos y el sobrenadante se conducirá a un tanque de concentrados junto con los sobrenadantes de las mesas espesadoras y filtros banda para luego ser enviados a cabecera de planta. El caudal de aguas de lavado de filtros que llegará al tanque será de  $1.483 \text{ m}^3$  por lavado, es decir,  $23.735 \text{ m}^3/\text{d}$  considerando 16 lavados diarios a caudal máximo.

El tanque de retrolavado estará dividido en dos cámaras con un volumen unitario de  $2.000 \text{ m}^3$ , de forma tal de almacenar un lavado por cámara. Como explicado anteriormente, habrá dos bombes, el de fangos y el de agua recuperada. Las bombas de fangos están dimensionadas para trabajar en 1+1 unidades por depósito, mientras que las de recuperación de agua, trabajarán 2+1, compartiendo la cámara de bombeo y pudiendo elegir la zona de bombeo a través de compuertas automáticas, como se detalla en la Figura 21 y Figura 22.

Puede consultarse más información sobre el dimensionamiento en la Tabla 31 de los Anexos.

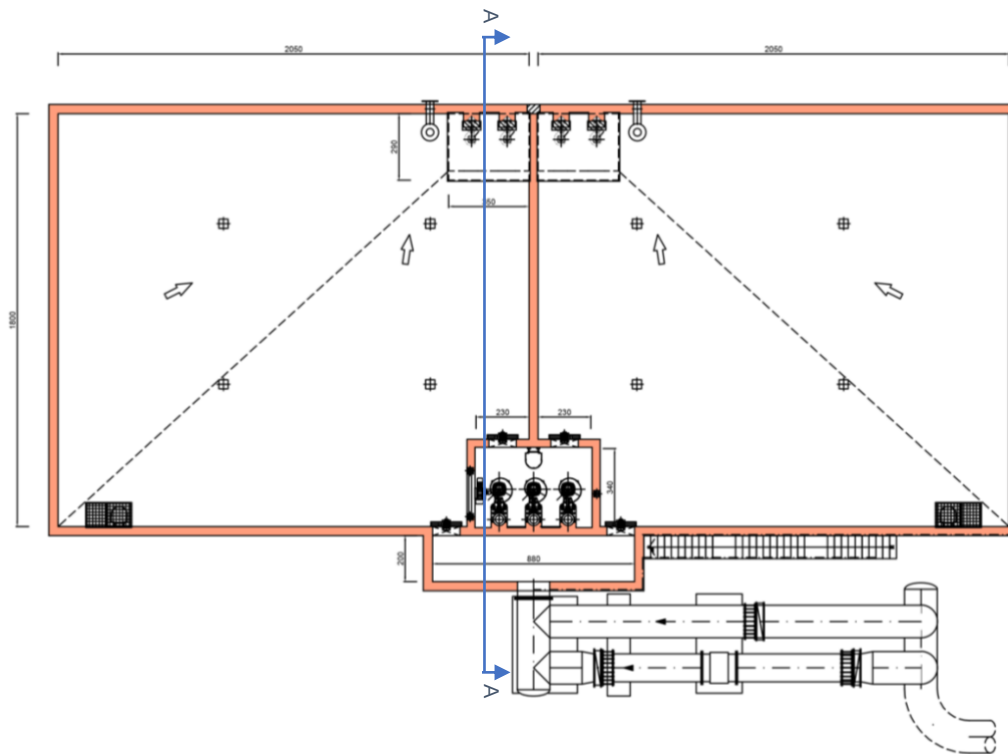


Figura 21. Tanque de retrolavado de filtros. (Fuente: Elaboración propia).

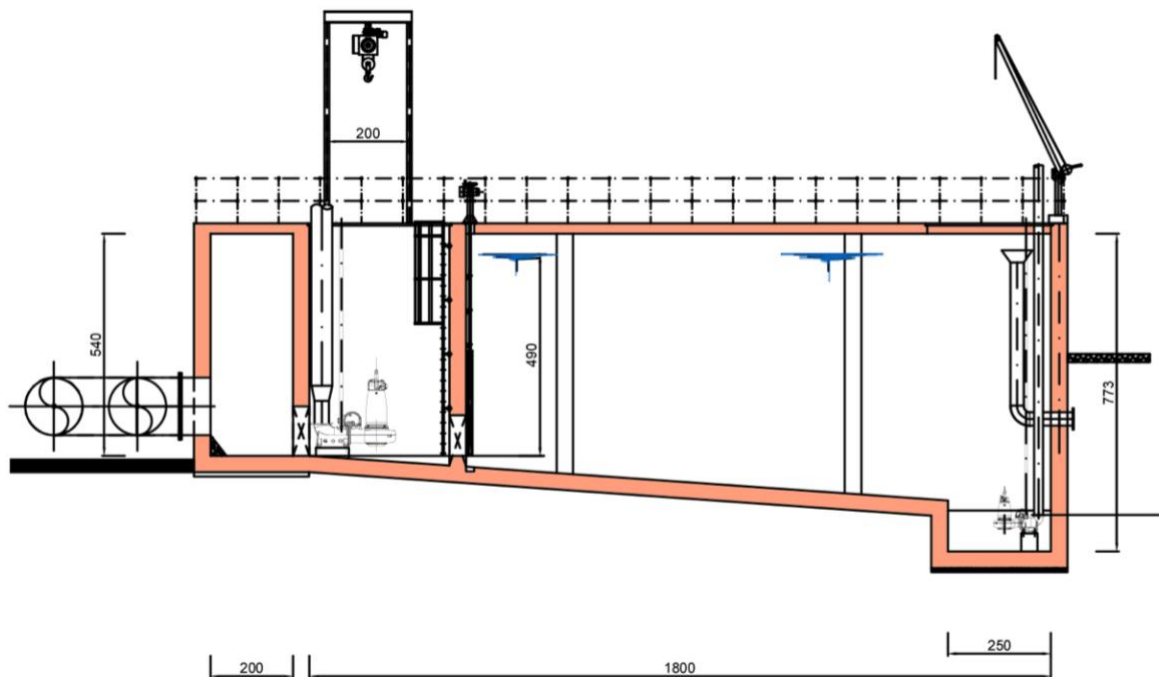


Figura 22. Sección A-A tanque de retrolavado de filtros. (Fuente: Elaboración propia).

## 5.9. DOSIFICACIÓN DE REACTIVOS

Según fue explicado en las diversas etapas del proceso de la planta, los reactivos se dosificarán y almacenarán de la siguiente manera:

### COAGULANTES

#### - Policloruro de aluminio al 10%

Coagulante primario, a dosificarse cuando la turbidez del agua no supere los 20 NTU. Contribuye a la remoción de sólidos suspendidos, color, turbidez y partículas orgánicas. Desestabiliza los microorganismos y las partículas coloidales permitiendo que se junten entre sí, formando coágulos que posteriormente se aglomerarán para conformar flóculos de mayor tamaño.

Considerando una dosis media de 5 mg/L y una dosis máxima de 40 mg/L, se realizaron los cálculos de necesidades de dosificación concluyendo en que se utilizarán entre 525,21 y 4.201,68 L/h a través de tres (2+1) bombas de tornillo de 2.000 L/h a 2 bar de presión con variador de frecuencia que serán reguladas a través de caudalímetros en línea. El producto comercial, de densidad 1,19 kg/dm<sup>3</sup>, será almacenado en 2 tanques verticales de 110 m<sup>3</sup>, los cuales darán una autonomía de abastecimiento de entre 2 y 17 días. Puede consultarse más información sobre los cálculos en la Tabla 18 de los Anexos.

#### - Sulfato de alúmina al 8%

Coagulante primario, a dosificarse cuando los valores de turbidez del agua superen los 20 NTU. Tiene un accionar similar al policloruro de aluminio, formando coágulos con las partículas coloidales presentes en el agua.

Considerando una dosis media de 5 mg/L y una dosis máxima de 40 mg/L, su dosificación al mezclador estático variará entre 550,18 L/h y 4.401,41 L/h a través de tres (2+1) bombas de tornillo de 2.500 L/h a 2 bar de presión con variador de frecuencia, que serán reguladas a través de caudalímetros en línea. El producto comercial será almacenado en 2 tanques verticales de 110 m<sup>3</sup>, los cuales darán una autonomía de abastecimiento de entre 2 y 17 días. Pueden consultarse los cálculos en la Tabla 19 de los Anexos.



## AJUSTE DE pH

### - Ácido sulfúrico al 98%

Se utiliza para reducir el pH en aquellos momentos en que se requiera. Considerando una dosis media de 2 mg/L y una dosis máxima de 8 mg/L, su dosificación variará entre los 5,20 L/h y 55,46 L/h y se realizará a través de dos (1+1) bombas centrífugas de 70 L/h a 2 bar de presión con variador de frecuencia, que serán reguladas a través de caudalímetros en línea. El producto comercial será almacenado en 2 tanques verticales de 6 m<sup>3</sup>, los cuales otorgarán una autonomía de abastecimiento de entre 9 y 36 días. Pueden consultarse los cálculos en la Tabla 20 de los Anexos.

### - Hidróxido de sodio al 50%

Se utilizará, al contrario que el ácido sulfúrico, para elevar el pH en aquellos momentos en que se lo requiera. Con una dosis media de 0,2 mg/L y una dosis máxima de 2,5 mg/L, su dosificación variará entre los 1,23 y 41,12 L/h y se realizará a través de dos (1+1) bombas centrífugas de 50 L/h a 2 bar de presión con variador de frecuencia reguladas a través de caudalímetros en línea. El producto comercial será almacenado en 2 tanques verticales de 3 m<sup>3</sup> que otorgarán una autonomía de entre 3 y 38 días. Pueden consultarse los cálculos en la Tabla 21 de los Anexos.

## OXIDACIÓN Y DESINFECCIÓN

### - Cloro

La oxidación del agua se realizará utilizando cloro gas. El proceso de cloración se realizará en 3 etapas: una pre-cloración, previa a la coagulación para oxidar algunos de los compuestos orgánicos e inorgánicos y favorecer la decantación, una cloración intermedia después de la sedimentación para reponer el cloro usado y una cloración posterior a la filtración para garantizar cloro residual en todo el sistema de distribución.

La pre-cloración se llevará a cabo en la etapa de coagulación, para la cual se deberá aplicar una dosis de 1,25 mg/L, y para lo cual se utilizarán bombas de 20 L/h a 2 bar con variador de frecuencia, cuya dosis será regulada a través de caudalímetros en línea.

Una vez completada la sedimentación, se realizará la cloración intermedia, que se llevará a cabo en un canal de distribución previo al ingreso a los filtros. La dosis de cloro será de 0,75 mg/L y se realizará con bombas dosificadoras de 20 kg/h.

La cloración final, requiere de un tiempo de contacto de 30 minutos y se realizará a través de un laberinto formado por pantallas deflectoras en el tanque de almacenamiento de agua tratada. El objetivo es el de dotar al agua del cloro residual necesario para su distribución. Se aplicará una dosis de 1,50 mg/L, ya que el cloro residual final del agua para distribución deberá estar entre 0,90 – 1,50 mg/L.

Se diseñó un edificio para el sistema de dosificación y almacenamiento del cloro gas que permitirá tener una autonomía de 30 días. Pueden consultarse los cálculos de dosificación del cloro gas en la Tabla 22 de los Anexos.

## FLOCULANTES

### - PolyDADMAC al 20%

Polielectrolito catiónico utilizado para mejorar la aglomeración de los coágulos formados en el mezclador estático y así formar flóculos de mayor tamaño y mejorar el proceso de decantación. Considerando una dosis media de 0,2 mg/L y una dosis máxima de 0,5 mg/L, la dosificación de su solución variará entre los 12,50 - 31,25 L/h y se realizará a través de dos (1+1) bombas centrífugas de 35 L/h a 2 bar de presión con variador de frecuencia, instaladas en un equipo compacto automático de preparación y dosificación que será regulado a través de caudalímetros en línea. Se almacenarán al menos 1000 L de producto comercial para garantizar una autonomía de operación de entre 14 y 33 días. Pueden consultarse los cálculos en la Tabla 23 de los Anexos.

## OXIDANTES

### - Permanganato potásico

Se dosificará junto con el floculante, previo al ingreso del agua a la floculación para oxidar el hierro y el manganeso remanentes en el agua. Los valores finales deberán ser inferiores a 0,40 mg/L y 0,021 mg/L respectivamente. Con una dosis media de 1,0 mg/L y una dosis máxima de 2,6 mg/L, la solución variará entre los 230,40 L/h y 599,10 L/h y se realizará a través de dos (1+1) bombas centrífugas de 700 L/h a 2 bar de presión con variador de frecuencia que serán regulada a través de caudalímetros en línea. El producto comercial se será dosificado para su preparación a través de *Big bags* con tornillos de dosificación a los depósitos de mezcla. Éstos tendrán una capacidad de 5 m<sup>3</sup>, y un sistema de agitación y calefacción continuo. Pueden consultarse los cálculos en la Tabla 24 de los Anexos.

## 6. DISEÑO DEL PROCESO: LÍNEA DE FANGOS

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Los fangos generados en el proceso de tratamiento del agua deberán ser procesados previo a su disposición final. Se considerarán dos corrientes de fangos en todo el proceso:

- Fangos provenientes del tanque de retrolavado de filtros
- Fangos de la decantación

Con el objetivo de unificar esos fangos previo a su tratamiento, se proyectó un tanque de homogeneización antes de las etapas de espesamiento y deshidratación.

### 6.1. DEPÓSITO DE HOMOGENEIZACIÓN

El depósito de homogeneización estará conformado por dos compartimentos iguales para permitir la operatividad durante los períodos de limpieza y mantenimiento. Tendrá también un sistema de bombeo de drenaje que permitirá vaciarlo en menos de ocho horas en caso de emergencia. Contará con dos agitadores de acero inoxidable en cada compartimento que mezclarán constantemente el fango para garantizar que la mezcla presente una calidad constante para su tratamiento posterior.

A estos depósitos, llegará un caudal máximo de 6.890 m<sup>3</sup>/d desde los decantadores, con una concentración de 8,0 Kg/m<sup>3</sup> y de 1.750 m<sup>3</sup>/d desde el tanque de retrolavado con una concentración de 5,0 Kg/m<sup>3</sup>, sumando un caudal total de 8.643 m<sup>3</sup>/d.

El depósito se diseñó en dos compartimentos de 10,80 x 6,00 m con un volumen útil de 420 m<sup>3</sup> por cámara. Los fangos una vez homogeneizados serán bombeados por cuatro (3+1) bombas de tornillo de 140 m<sup>3</sup>/h a 12 m.c.a. con variador de frecuencia, continuamente a las mesas espesadoras. La concentración de dicha mezcla de fangos será de 7,4 Kg/m<sup>3</sup>. Pueden consultarse los cálculos en la Tabla 32.

### 6.2. ESPESAMIENTO MECÁNICO

El espesamiento de los fangos se llevará a cabo con mesas espesadoras, equipos que realizan un espesamiento mecánico continuo de los fangos. Son de tecnología eficiente y sencilla, permitiendo reducir el volumen de fangos en al menos cuatro veces. Tienen

un consumo energético bajo, y su control y mantenimiento resultan muy sencillos. Se las utiliza como reemplazo de los espesadores estáticos por gravedad o flotación, como etapa previa a la deshidratación. Las mesas espesadoras cuentan con un tanque de repartición de fango, una zona de espesamiento por gravedad, y una zona de prensado, todo contenido en un equipo mecánico compacto.

El caudal máximo que llegará a las mesas espesadoras será de 8.643 m<sup>3</sup>/d, con unos sólidos en suspensión totales (SST) máximos de 63.869,74 Kg/d. Los fangos espesados tendrán un 3% en peso de SST. Se utilizarán cuatro (3+1) mesas espesadoras de 1000 Kg/h que funcionarán 24 h/d 7 d/s con un rendimiento de eliminación de SST del 90%.

Para mejorar el espesamiento, previo al ingreso del fango a las mesas espesadoras, se le adicionará polielectrolito. La dosificación se realizará a través de dos (1+1) equipos compactos de 5.500 L de capacidad con bombas dosificadoras de 120 – 1200 L/h con variador de frecuencia. Pueden consultarse los cálculos del espesamiento en la Tabla 33 de los Anexos.

### 6.3. TANQUE DE FANGOS ESPESADOS

Una vez espesados los fangos, se almacenarán en un tanque que servirá a modo de *buffer* para almacenar los fangos espesados durante los períodos en que la deshidratación no esté en funcionamiento. Este tanque se dimensionó de forma tal de poder almacenar los fangos al menos 8 horas al día, ya que la deshidratación funcionará durante 16 h/d. Considerando que el caudal máximo de fangos espesados que llegará al tanque será de 1.916,10 m<sup>3</sup>/d, el tanque resultante estará formado por dos cámaras iguales de 10,80 x 4,60 m y 6,50 m de altura útil, lo que resulta en un volumen total del tanque de 650 m<sup>3</sup>. Los fangos almacenados serán bombeados a los filtros banda de la deshidratación por cuatro (3+1) bombas de tornillo de 30 m<sup>3</sup>/h a 8 m.c.a. en los horarios de funcionamiento de la deshidratación. Pueden consultarse los cálculos del espesamiento en la Tabla 34 de los Anexos.

**Tabla 6. Tanque de fangos espesados. (Fuente: Elaboración propia).**

| PARÁMETRO                      | 100 MLD | 300 MLD  | UNIDAD            |
|--------------------------------|---------|----------|-------------------|
| Concentración fangos espesados | 30      | 30       | Kg/m <sup>3</sup> |
| Caudal diario fangos espesados | 653,10  | 1.916,10 | m <sup>3</sup> /d |

| PARÁMETRO                       | 100 MLD | 300 MLD | UNIDAD            |
|---------------------------------|---------|---------|-------------------|
| Caudal horario fangos espesados | 79,84   | 27,21   | m <sup>3</sup> /h |
| Tiempo almacenamiento           | 8       | 8       | horas             |
| Volumen de tanque necesario     | 639     | 218     | m <sup>3</sup>    |
| Volumen tanque adoptado         | 650     | 325     | m <sup>3</sup>    |

## 6.4. DESHIDRATACIÓN

La última etapa del tratamiento de fangos se llevará a cabo con cuatro (3+1) filtros banda con capacidad de hasta 780 kg MS/h por unidad o 26 m<sup>3</sup>/h. Éstos funcionarán 16 h/d y 7 d/sem. El caudal máximo que llegará a ellos será de 1.916,10 m<sup>3</sup>/d, por lo que en los períodos de condiciones máximas se operará también con el filtro banda de reserva. El rendimiento de eliminación de estos equipos será del 95%, por lo que la sequedad alcanzada será del 20% y su densidad de 1.150 Kg/m<sup>3</sup>.

Para la deshidratación también se adicionará polielectrolito con el objetivo de mejorar el proceso. Al igual que en el espesamiento, se instalarán dos (1+1) equipos compactos de preparación y dosificación de 5.500 L de capacidad con bombas dosificadoras de 120 – 1200 L/h con variador de frecuencia. Pueden consultarse los cálculos de la deshidratación en la Tabla 35 de los Anexos.

## 6.5. DESTINO FINAL FANGOS DESHIDRATADOS

El caudal máximo de fangos deshidratados será de 240 m<sup>3</sup>/d, que equivalen a un peso de 282 t/d. Serán enviados por un sistema de tornillos transportadores a un elevador de Cangilones de 16 m<sup>3</sup>/h de capacidad desde el cual se verterán en ocho silos cilíndricos de 150 m<sup>3</sup> de capacidad unitaria que permiten una autonomía de almacenamiento de 5 días. Desde allí serán recogidos por camiones para trasladar a su destino final, vertedero.

A continuación, en la Figura 23, Figura 24, Figura 25 y Figura 26 se detalla la configuración del edificio de tratamiento de fangos:

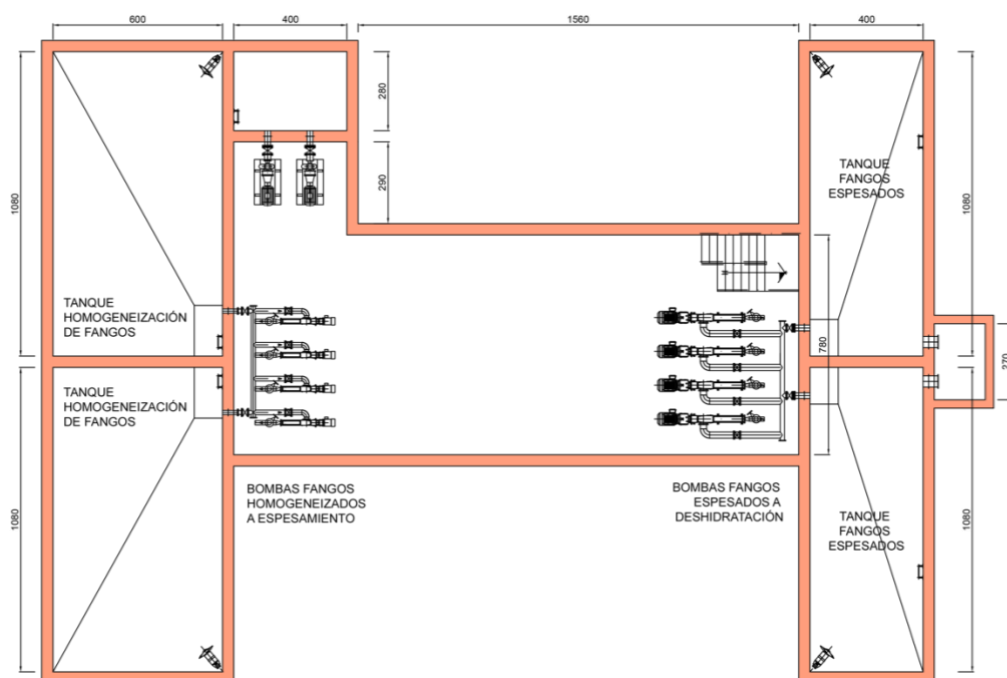


Figura 23. Edificio de tratamiento de fangos. Nivel subsuelo. (Fuente: Elaboración propia).

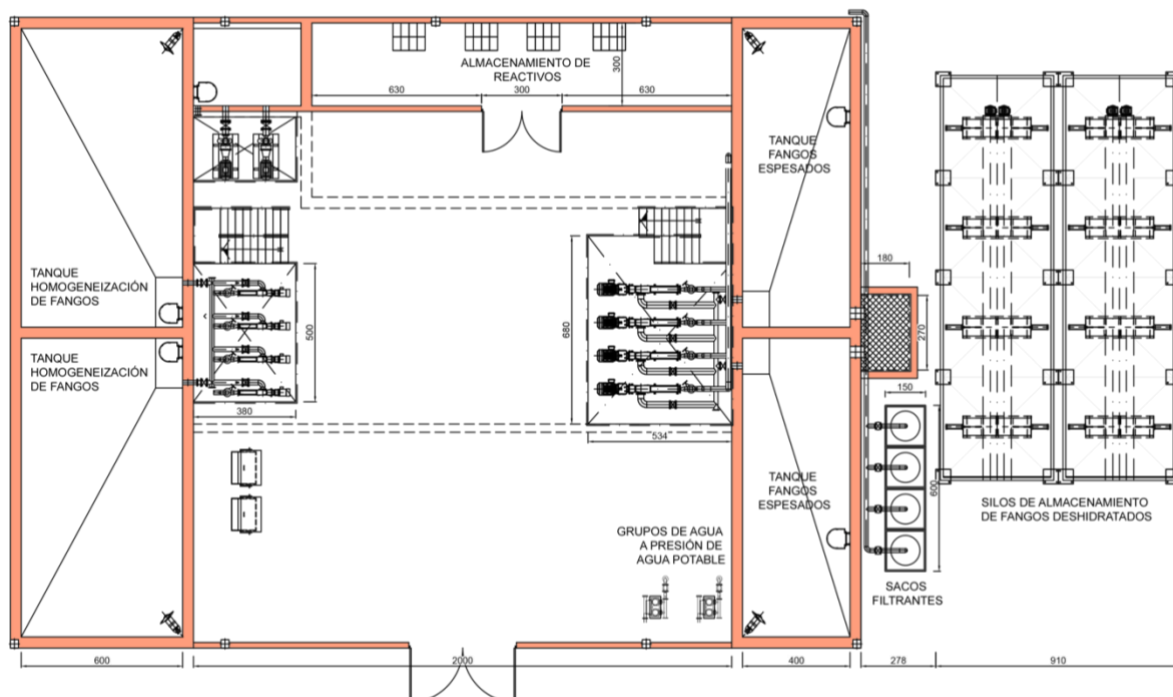


Figura 24. Edificio de tratamiento de fangos. Nivel planta baja. (Fuente: Elaboración propia).

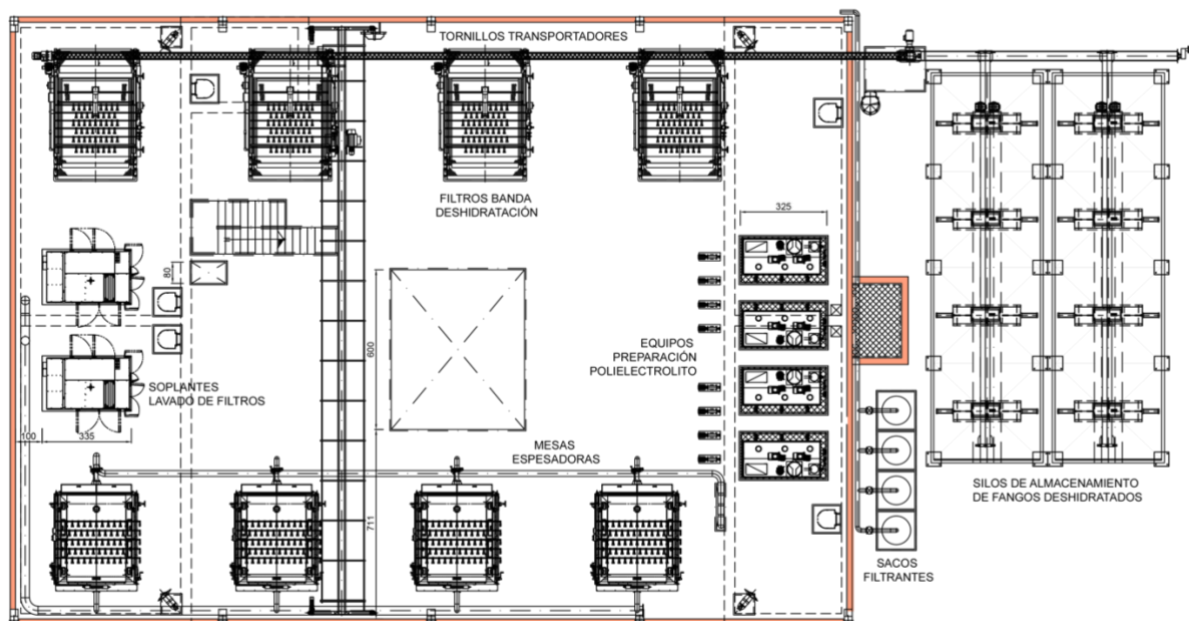


Figura 25. Edificio de tratamiento de fangos. Nivel 1. (Fuente: Elaboración propia).

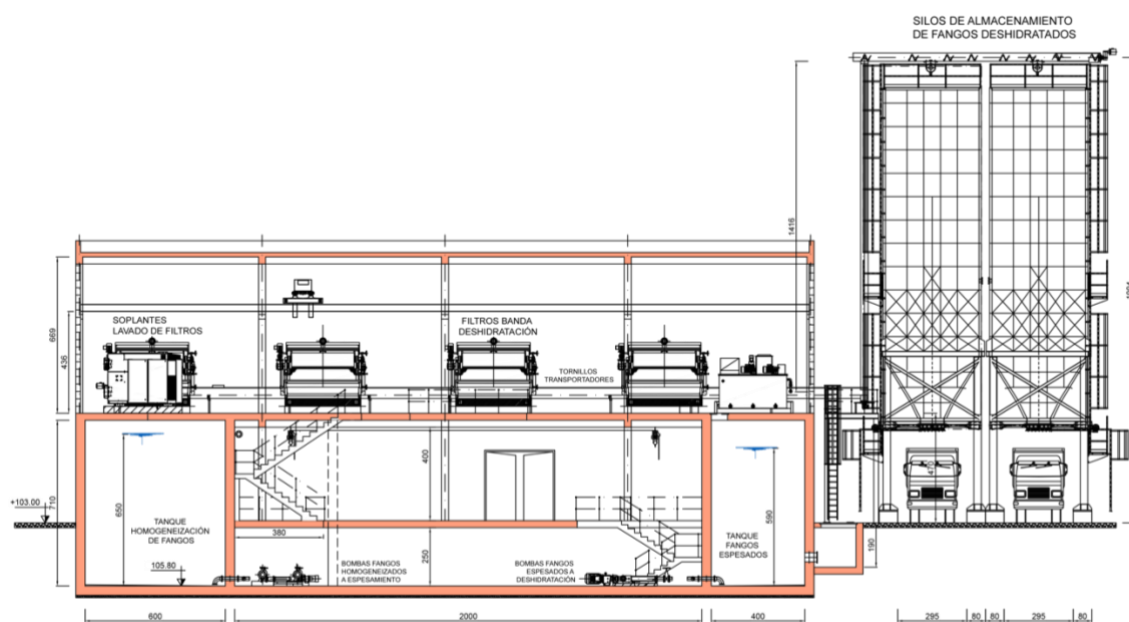


Figura 26. Edificio de tratamiento de fangos. Sección. (Fuente: Elaboración propia).

## 7. ESTUDIO COMPARATIVO DE CONSUMOS Y COSTES

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Se realizó un estudio comparativo de las dos alternativas de proceso proyectados con el propósito de cuantificar los ahorros tanto energéticos como económicos que pueden obtenerse con el proceso de bajo consumo.

### 7.1. CONSUMO ENERGÉTICO

En España, el binomio compuesto por agua y energía es cada vez más importante debido a la tendencia creciente de los precios de la energía con un horizonte tarifario que no ayuda a la confianza y a la actual situación de incertidumbre desde el punto de vista energético. Dado que el agua se ha convertido en un recurso cada vez más escaso en relación con la demanda de la creciente población y la economía urbana, se ha intensificado la competencia por este recurso en todos los sectores productivos (Lee et al 2015).

Con el propósito de evaluar los consumos energéticos de los dos diseños, se realizó un inventario de todos los accionamientos eléctricos de ambas alternativas de proceso. Puede verse en detalle dicho inventario en la Tabla 36 y Tabla 37 de los Anexos. A partir de dicho registro, se estudiaron los consumos de ambas instalaciones distribuidos por etapas del tratamiento.

#### 7.1.1. PUNTOS DE CONSUMO DE LOS EQUIPOS

En la Tabla 7 se resumen las principales características necesarias para el análisis energético de los equipos que forman parte de la línea de agua de la planta. Las diferencias entre un proceso y otro se dan fundamentalmente en el incremento de equipos mecánicos que implica el proceso convencional en comparación con el de bajo consumo. Si bien hay equipos cuya incidencia es muy baja en el consumo energético global, ya sea por un consumo individual muy bajo o porque funcionan muy pocas veces en el año, se los ha incluido en la tabla a efectos de comprender la totalidad de equipos necesarios en cada una de las etapas del tratamiento. En color naranja se observan aquellos equipos que solo están presentes en la alternativa convencional, en color azul aquellos que solo pertenecen a la alternativa bajo consumo, y en negro aquellos que se encuentran en ambos procesos.



**Tabla 7. Puntos de consumo de los equipos de la línea de aguas. (Fuente: Elaboración propia).**

| Equipo                                                                | Unidades |         | Operación   |              | Potencia       |                | ETAP CONVENCIONAL                  |                                       | ETAP BAJO CONSUMO                  |                                       |
|-----------------------------------------------------------------------|----------|---------|-------------|--------------|----------------|----------------|------------------------------------|---------------------------------------|------------------------------------|---------------------------------------|
|                                                                       | Activas  | Reserva | Días al año | Horas al día | Absorbida [kW] | Instalada [kW] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA [kWh/m³] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA [kWh/m³] |
| <b>COAGULACIÓN</b>                                                    |          |         |             |              |                |                |                                    |                                       |                                    |                                       |
| Bombas transferencia policloruro de aluminio (110 m³/h a 9 mca)       | 1        |         | 12          | 1            | 2,50           | 3,00           | 2,88                               | 0,000010                              | 2,88                               | 0,000010                              |
| Bombas dosificadoras policloruro de aluminio (2.500 L/h a 2 bar)      | 2        | 1       | 365         | 24           | 1,83           | 2,20           | 109,55                             | 0,000365                              | 109,55                             | 0,000365                              |
| Bombas dosificadoras sulfato de alúmina (2.500 L/h a 3 bar)           | 2        | 1       | 365         | 24           | 1,83           | 2,20           | 109,55                             | 0,000365                              | 109,55                             | 0,000365                              |
| Bombas dosificadoras ácido sulfúrico (70 L/h a 2 bar)                 | 1        | 1       | 365         | 24           | 0,19           | 0,24           | 8,93                               | 0,000030                              | 8,93                               | 0,000030                              |
| Bombas dosificadoras hidróxido de sodio (50 L/h a 2 bar)              | 1        | 1       | 365         | 24           | 0,19           | 0,24           | 8,93                               | 0,000030                              | 8,93                               | 0,000030                              |
| Agitador eje vertical mezcla                                          | 3        |         | 365         | 24           | 9,17           | 11,00          | 715,06                             | 0,002384                              |                                    |                                       |
| <b>TOTAL COAGULACIÓN</b>                                              |          |         |             |              |                |                | <b>954,90</b>                      | <b>0,003183</b>                       | <b>239,84</b>                      | <b>0,000799</b>                       |
| <b>FLOCULACIÓN</b>                                                    |          |         |             |              |                |                |                                    |                                       |                                    |                                       |
| Compuertas murales motorizadas (1400 x 1400 mm)                       | 9        |         | 20          | 0,1          | 0,60           | 0,75           | 0,67                               | 0,000002                              | 0,67                               | 0,000002                              |
| Rompe bóvedas dosificador permanganato potásico                       | 2        |         | 365         | 24           | 0,60           | 0,75           | 35,56                              | 0,000119                              | 35,56                              | 0,000119                              |
| Stand descargador de big-bag                                          | 2        |         | 365         | 24           | 0,14           | 0,18           | 10,12                              | 0,000034                              | 10,12                              | 0,000034                              |
| Sistema de calefacción permanganato potásico                          | 2        |         | 365         | 24           | 0,20           | 0,25           | 14,06                              | 0,000047                              | 14,06                              | 0,000047                              |
| Agitado vertical permanganato potásico                                | 2        |         | 365         | 24           | 1,29           | 1,55           | 72,18                              | 0,000241                              | 72,18                              | 0,000241                              |
| Bombas dosificadoras permanganato potásico (700 L/h a 2 bar)          | 1        | 1       | 365         | 24           | 0,30           | 0,37           | 12,00                              | 0,000040                              | 12,00                              | 0,000040                              |
| Equipo compacto preparación polielectrolito floculación (1.200 L)     | 1        | 1       | 365         | 24           | 0,74           | 0,92           | 21,10                              | 0,000070                              | 21,10                              | 0,000070                              |
| Bombas dosificadoras polielectrolito (floculación) (40 L/h a 2 bar)   | 1        | 1       | 365         | 16           | 0,19           | 0,24           | 5,95                               | 0,000020                              | 5,95                               | 0,000020                              |
| Agitador eje vertical floculación                                     | 3        |         | 365         | 16           | 4,33           | 5,20           | 233,71                             | 0,000779                              |                                    |                                       |
| <b>TOTAL FLOCULACIÓN</b>                                              |          |         |             |              |                |                | <b>405,34</b>                      | <b>0,001351</b>                       | <b>171,63</b>                      | <b>0,000572</b>                       |
| <b>DECANTACIÓN</b>                                                    |          |         |             |              |                |                |                                    |                                       |                                    |                                       |
| Rascadores                                                            | 6        |         | 365         | 24           | 0,30           | 0,37           | 58,87                              | 0,000196                              | 58,87                              | 0,000196                              |
| Válvulas motorizadas DN400 (fangos)                                   | 14       |         | 20          | 0,1          | 2,50           | 3,00           | 4,03                               | 0,000013                              | 4,03                               | 0,000013                              |
| Válvulas motorizadas DN1200 (caudalímetros)                           | 6        |         | 20          | 0,1          | 2,50           | 3,00           | 1,73                               | 0,000006                              | 1,73                               | 0,000006                              |
| Polipasto 1.500 Kg                                                    | 1        |         | 20          | 0,1          | 1,98           | 2,37           | 0,23                               | 0,000001                              | 0,23                               | 0,000001                              |
| Bombas vaciado (500 m³/h a 10 mca)                                    | 1        | 1       | 2           | 8            | 16,03          | 22,00          | 137,44                             | 0,000458                              | 137,44                             | 0,000458                              |
| Bombas purga fangos (140 m³/h a 12 mca)                               | 2        | 1       | 365         | 4            | 10,61          | 18,50          | 95,30                              | 0,000317                              | 95,30                              | 0,000317                              |
| Motor arrastre espesador                                              | 3        |         | 365         | 24           | 6,25           | 7,50           | 503,92                             | 0,001680                              |                                    |                                       |
| Bombas recirculación fangos (200 m³/h a 8 mca)                        | 3        | 1       | 365         | 12           | 7,27           | 7,85           | 296,92                             | 0,000990                              |                                    |                                       |
| <b>TOTAL DECANTACIÓN</b>                                              |          |         |             |              |                |                | <b>1.098,45</b>                    | <b>0,003661</b>                       | <b>297,61</b>                      | <b>0,000992</b>                       |
| <b>FILTRACIÓN</b>                                                     |          |         |             |              |                |                |                                    |                                       |                                    |                                       |
| Compuertas murales motorizadas (entrada agua) (600 x 600 mm)          | 16       |         | 20          | 0,1          | 0,16           | 0,20           | 0,37                               | 0,000001                              | 0,37                               | 0,000001                              |
| Compuertas murales motorizadas (retrolavado filtros) (1100 x 1100 mm) | 16       |         | 20          | 0,1          | 0,16           | 0,20           | 0,37                               | 0,000001                              | 0,37                               | 0,000001                              |

| Equipo                                           | Unidades |         | Operación   |              | Potencia       |                | ETAP CONVENCIONAL                  |                                       | ETAP BAJO CONSUMO                  |                                       |
|--------------------------------------------------|----------|---------|-------------|--------------|----------------|----------------|------------------------------------|---------------------------------------|------------------------------------|---------------------------------------|
|                                                  | Activas  | Reserva | Días al año | Horas al día | Absorbida [kW] | Instalada [kW] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA [kWh/m³] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA [kWh/m³] |
| Polipasto 3.000 Kg                               | 2        |         | 20          | 0,1          | 3,27           | 3,93           | 0,75                               | 0,000003                              | 0,75                               | 0,000003                              |
| Válvulas motorizadas DN400 (ingreso aire)        | 16       |         | 20          | 0,1          | 2,50           | 3,00           | 4,61                               | 0,000015                              | 4,61                               | 0,000015                              |
| Válvulas motorizadas DN90 (vaciado)              | 16       |         | 20          | 0,1          | 2,50           | 3,00           | 4,61                               | 0,000015                              | 4,61                               | 0,000015                              |
| Válvulas motorizadas DN200 (salida agua)         | 16       |         | 20          | 0,1          | 2,50           | 3,00           | 4,61                               | 0,000015                              | 4,61                               | 0,000015                              |
| Soplantes lavado de filtros (5600 Nm³/h a 7 mca) | 1        | 1       | 365         | 2,7          | 160,00         | 165,00         |                                    |                                       | 454,14                             | 0,001514                              |
| Soplantes lavado de filtros (8300 Nm³/h a 7 mca) | 2        | 1       | 365         | 2,7          | 190,00         | 202,00         | 1.085,53                           | 0,003618                              |                                    |                                       |
| Bombas lavado filtros (5.300 m³/h a 10 mca)      | 3        | 1       | 365         | 8            | 171,00         | 200,00         | 5.133,34                           | 0,01711                               |                                    |                                       |
| TOTAL FILTRACIÓN                                 |          |         |             |              |                |                | 6.234,20                           | 0,02078                               | 469,47                             | 0,001565                              |

### 7.1.2. DISTRIBUCIÓN DEL CONSUMO ENERGÉTICO

El consumo energético calculado para la ETAP de bajo consumo es de 8.478.011,37 kWh/año y de 11.477.651,17 kWh/año para la ETAP convencional, lo que indica que, con el proceso de bajo consumo, se consigue una reducción del consumo energético en un 26%. El gasto energético específico por volumen de agua tratada entonces es de 0,082 kWh/m³ y 0,104 kWh/m³ respectivamente.

A partir de dichos consumos, se analizaron las emisiones de Gases de Efecto Invernadero (GEI) correspondientes al consumo energético. Para ello, se consideró un factor de emisión de 0,25 kg CO<sub>2</sub>/kWh, correspondiente al valor medio de las empresas comercializadoras sin Garantías de Origen (GdO), lo que indica que el origen de la energía eléctrica generada no proviene de fuentes renovables ni de sistemas de cogeneración, obtenida de la Calculadora de huella de Carbono de organización del Ministerio para la Transición Ecológica y el Reto Demográfico (MITECO) (Ministerio para la Transición Ecológica y el Reto Demográfico 2020). Las emisiones de GEI correspondientes al consumo energético para la ETAP serán de 2.869.412,75 kg CO<sub>2</sub> en la alternativa convencional y de 2.119.502,75 kg CO<sub>2</sub> en la de bajo consumo, lo que indica una reducción de 749.910 kg CO<sub>2</sub>/año.

En la distribución porcentual del diseño de bajo consumo, la línea de agua constituye el 55% del consumo total de la planta, mientras que en el proceso convencional constituye el 65%, siendo el consumo específico de dicha línea, de 0,045 kWh/m³ en la alternativa de bajo consumo, y de 0,068 kWh/m³ en la convencional.

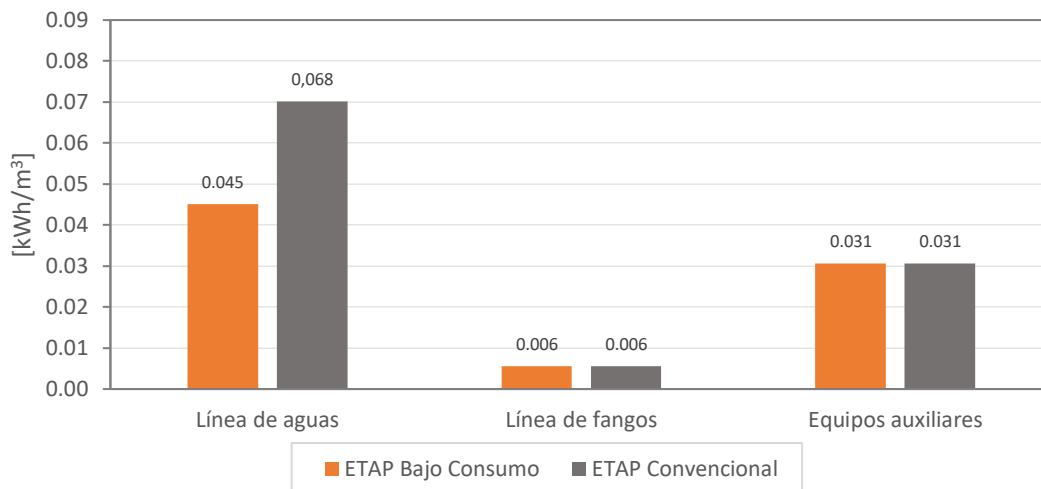


Figura 27. Consumo energético específico por sectores de planta. (Fuente: Elaboración propia).

Considerando que las variaciones en ambos diseños se encuentran únicamente en la línea de agua, se procederá a evaluar únicamente las etapas comprendidas en ésta, dejando a un lado tanto la línea de fangos como los equipos auxiliares y el bombeo de entrada, ya que sus valores son idénticos para ambas alternativas de proceso.

Si se analiza el consumo específico por proceso de tratamiento, podemos observar que si bien se consigue una economía en todas las etapas, la filtración es aquella en la que se consiguen mayores resultados, como puede verse en la Figura 28, llegando a un 77% de ahorro. En la decantación, el ahorro es del 73%, y en la floculación y coagulación, del 58% y 75% respectivamente.

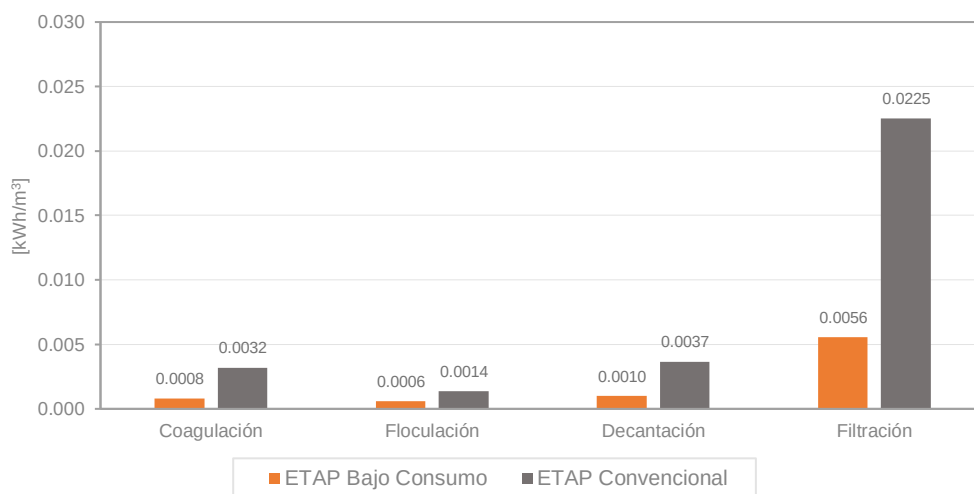


Figura 28. Consumo energético específico por proceso de tratamiento. (Fuente: Elaboración propia).

## 7.2. COSTE ENERGÉTICO

Para realizar el cálculo del coste de la energía eléctrica, se tomaron las metodologías de cálculo de los peajes de transporte y distribución de la electricidad y de los cargos del sistema eléctrico, publicadas en la Circular 3/2020 de la Comisión Nacional de los Mercados y la Competencia (CNMC) y el Real Decreto 148/2021 respectivamente.

Considerando el consumo simultáneo de la planta, se seleccionó la tarifa 6.1TD, de aplicación a los suministros conectados a tensiones superiores a 1 kV e inferiores a 30 kV, nivel de tensión tarifario NT1 y segmento tarifario 3. Dicha tarifa consta de seis términos de potencia contratada y seis términos de energía consumida correspondientes a los períodos horarios de facturación (P1 a P6) en función de la temporada, el día de la semana y la hora del día.

El coste energético estará conformado, además, por un término de facturación por potencia contratada y un término de facturación por energía activa consumida, tanto para los peajes de transporte y distribución como para los cargos del sistema eléctrico:

### TÉRMINO DE POTENCIA CONTRATADA

Expresado en euros, será la sumatoria resultante de multiplicar el precio del término de potencia correspondiente a cada período horario expresado en euros por kWh al año y la potencia contratada para dicho período, expresada en kW y año según la siguiente fórmula:

$$FP = \sum_{p=1}^{p=i} T_{pp} \cdot P_{cp}$$

Donde,  $FP$  es el término de facturación por potencia contratada (EUR);  $T_{pp}$  el precio del término de potencia del período horario  $p$  (EUR/kW/año);  $P_{cp}$  la potencia contratada en el período horario  $p$  (kW/año); e  $i$  el número de períodos horarios del segmento tarifario de cargos al que corresponde el suministro.

### TÉRMINO DE ENERGÍA ACTIVA CONSUMIDA

Expresado en euros, será la sumatoria resultante de multiplicar el precio del término de energía correspondiente a cada período horario expresado en euros por kWh y la energía consumida en dicho período, expresada en kWh de acuerdo con la siguiente fórmula:

$$FE = \sum_{p=1}^{p=i} Tep \cdot Ep$$

Donde,  $FE$  es el término de facturación por energía activa consumida (EUR);  $Tep$  el precio del término de energía del período horario  $p$  (EUR/kWh);  $Ep$  la energía consumida en el período horario  $p$  (kWh), e  $i$  el número de períodos horarios del segmento tarifario de cargos al que corresponde el suministro.

Se deben considerar, además, los coeficientes de pérdida para traspasar la energía suministrada en el contador a la energía suministrada en barras de central, para cada uno de los períodos horarios, según se detalla en la Tabla 8.

**Tabla 8. Coeficientes de pérdida de energía. (Fuente: Circular 3/2020 CNMC).**

| Nivel de tensión | Períodos horarios |      |      |      |      |      |
|------------------|-------------------|------|------|------|------|------|
|                  | P1                | P2   | P3   | P4   | P5   | P6   |
| 6.1TD            | 6,7%              | 6,8% | 6,5% | 6,5% | 4,3% | 7,7% |

Para el cálculo del término de potencia, se determinó la potencia a contratar de cada una de la plantas a partir del consumo simultáneo de todos los equipos de la planta, siendo la misma de 2.100 kWh para la alternativa de bajo consumo, y de 3.100 kWh para la convencional.

Por otro lado, para el término de energía activa consumida, se realizó el cálculo del consumo total anual para cada uno de los seis períodos, estimando los horarios de funcionamiento de cada equipo. Dichos cálculos pueden consultarse en las Tabla 38 y Tabla 39. Se calculó el coste final anual para ambas alternativas de planta en base a los precios correspondientes a peajes de transporte y distribución de la electricidad y cargos del sistema eléctrico publicados en la Resolución del 18 de marzo de 2021 de la CNMC y la Orden TED/371/2021, respectivamente.

Puede verse en detalle estos cálculos en la Tabla 9 y Tabla 10.

**Tabla 9. Coste de la energía ETAP Convencional Año 1. (Fuente: Elaboración propia).**

| Circular 3/2020 CNMC |                                     | Orden TED/371/2021              |                                                 | ETAP CONVENCIONAL                           |                          |                                |                         |                                     |                                    |
|----------------------|-------------------------------------|---------------------------------|-------------------------------------------------|---------------------------------------------|--------------------------|--------------------------------|-------------------------|-------------------------------------|------------------------------------|
| Período              | Peaje término potencia [EUR/kW/año] | Peaje término energía [EUR/kWh] | Sistema eléctrico término potencia [EUR/kW/año] | Sistema eléctrico término energía [EUR/kWh] | Potencia contratada [kW] | Energía activa consumida [kWh] | Coefficiente de pérdida | Facturación Potencia (FP) [EUR/año] | Facturación Energía (FE) [EUR/año] |
| P1                   | 21,2452                             | 0,1884                          | 9,2906                                          | 0,0321                                      | 3100                     | 1.285.647,88                   | 6,70%                   | 101.003,25                          | 304.202,63                         |
| P2                   | 21,2452                             | 0,1548                          | 4,6495                                          | 0,0237                                      | 3100                     | 1.513.360,90                   | 6,80%                   | 85.732,19                           | 289.338,82                         |
| P3                   | 11,5307                             | 0,0091                          | 3,3784                                          | 0,0128                                      | 3100                     | 1.459.066,84                   | 6,50%                   | 49.222,56                           | 34.223,40                          |
| P4                   | 8,7160                              | 0,0058                          | 3,3784                                          | 0,0064                                      | 3100                     | 1.639.550,42                   | 6,50%                   | 39.929,82                           | 21.367,18                          |
| P5                   | 0,5603                              | 0,0003                          | 3,3784                                          | 0,0041                                      | 3100                     | 640.625,58                     | 4,30%                   | 12.734,87                           | 2.964,68                           |
| P6                   | 0,5603                              | 0,0003                          | 1,5484                                          | 0,0026                                      | 3100                     | 4.939.399,54                   | 7,70%                   | 7.040,29                            | 15.418,51                          |
|                      |                                     |                                 |                                                 |                                             |                          |                                |                         | <b>295.662,98</b>                   | <b>667.515,22</b>                  |
|                      |                                     |                                 |                                                 |                                             |                          |                                |                         | <b>TOTAL</b>                        | <b>963.178,20 EUR/año</b>          |

**Tabla 10. Coste de la energía ETAP Bajo consumo Año 1. (Fuente: Elaboración propia).**

| Circular 3/2020 CNMC |                                     | Orden TED/371/2021              |                                                 | ETAP BAJO CONSUMO                           |                          |                                |                         |                                     |                                    |
|----------------------|-------------------------------------|---------------------------------|-------------------------------------------------|---------------------------------------------|--------------------------|--------------------------------|-------------------------|-------------------------------------|------------------------------------|
| Período              | Peaje término potencia [EUR/kW/año] | Peaje término energía [EUR/kWh] | Sistema eléctrico término potencia [EUR/kW/año] | Sistema eléctrico término energía [EUR/kWh] | Potencia contratada [kW] | Energía activa consumida [kWh] | Coefficiente de pérdida | Facturación Potencia (FP) [EUR/año] | Facturación Energía (FE) [EUR/año] |
| P1                   | 21,2452                             | 0,1884                          | 9,2906                                          | 0,0321                                      | 2100                     | 925.710,89                     | 6,70%                   | 68.421,56                           | 219.544,72                         |
| P2                   | 21,2452                             | 0,1548                          | 4,6495                                          | 0,0237                                      | 2100                     | 1.121.622,63                   | 6,80%                   | 58.076,64                           | 214.644,81                         |
| P3                   | 11,5307                             | 0,0091                          | 3,3784                                          | 0,0128                                      | 2100                     | 1.063.704,98                   | 6,50%                   | 33.344,31                           | 24.989,13                          |
| P4                   | 8,7160                              | 0,0058                          | 3,3784                                          | 0,0064                                      | 2100                     | 1.203.019,15                   | 6,50%                   | 27.049,24                           | 15.698,59                          |
| P5                   | 0,5603                              | 0,0003                          | 3,3784                                          | 0,0041                                      | 2100                     | 487.033,51                     | 4,30%                   | 8.626,85                            | 2.253,89                           |
| P6                   | 0,5603                              | 0,0003                          | 1,5484                                          | 0,0026                                      | 2100                     | 3.991.438,30                   | 7,70%                   | 4.769,23                            | 12.465,91                          |
|                      |                                     |                                 |                                                 |                                             |                          |                                |                         | <b>200.287,83</b>                   | <b>489.597,05</b>                  |
|                      |                                     |                                 |                                                 |                                             |                          |                                |                         | <b>TOTAL</b>                        | <b>689.884,87 EUR/año</b>          |

## 7.3. COSTES DE INVERSIÓN

Los costes de inversión o *Capital Expenditure* (CAPEX) son la agrupación de costes de inversión de la infraestructura, las conexiones hidráulicas, equipos eléctricos y mecánicos de una planta de tratamiento.

Para conocer el CAPEX de ambas alternativas de planta, se realizaron los presupuestos de las dos opciones con valores de mercado actuales.

### 7.3.1. CAPEX ETAP CONVENCIONAL

En el caso de la alternativa de la ETAP convencional, el coste de inversión final calculado fue de 77.035.698,92 EUR, de los cuales un 73% corresponde a obra civil

(OC) y un 27% a equipos mecánicos, eléctricos, instrumentación y automatización (MEICA), como se detalla en la Tabla 11. Puede verse el presupuesto completo en la Tabla 40 de los anexos.

**Tabla 11. CAPEX ETAP Convencional. (Fuente: Elaboración propia).**

| ETAP CONVENCIONAL  |                          |     |
|--------------------|--------------------------|-----|
| Total OC           | 55.887.149,17 EUR        | 73% |
| Total MEICA        | 21.148.549,75 EUR        | 27% |
| <b>CAPEX TOTAL</b> | <b>77.035.698,82 EUR</b> |     |

### 7.3.2. CAPEX ETAP BAJO CONSUMO

El coste de inversión final calculado para la ETAP de bajo coste es de 73.821.675,22 EUR, siendo un 71% OC y un 29% a MEICA, como se detalla en la Tabla 12. Puede verse el presupuesto completo en la Tabla 41 de los Anexos.

**Tabla 12. CAPEX ETAP Bajo Consumo. (Fuente: Elaboración propia).**

| ETAP BAJO CONSUMO  |                          |     |
|--------------------|--------------------------|-----|
| Total OC           | 52.668.416,67 EUR        | 71% |
| Total MEICA        | 21.153.258,55 EUR        | 29% |
| <b>CAPEX TOTAL</b> | <b>73.821.675,22 EUR</b> |     |

## 7.4. COSTES OPERACIONALES

Los costes de operación u *Operational Expenditures* (OPEX) son la agrupación de los costes de Operación y Mantenimiento, dentro de los cuales se incluyen principalmente los costes de energía, personal, administración, mantenimiento y reparaciones, productos químicos y análisis de laboratorio.

Dentro de los costes operacionales, están aquellos denominados “Fijos”, es decir, que su valor no varía en el tiempo, y aquellos denominados “Variables”, ya que su valor final depende de un consumo. Dentro de los costes de explotación fijos se agrupan los sueldos del personal, los gastos administrativos, la prevención de riesgos laborales, el mantenimiento y las analíticas de laboratorio de las muestras de agua. En los costes variables, en cambio, se encuentran los costes energéticos, los insumos químicos y la gestión de los fangos generados.

#### 7.4.1. COSTES OPERACIONALES FIJOS

Para el cálculo de los costes fijos, se toman las siguientes consideraciones:

- **Personal:** Se estiman 13 trabajadores necesarios para la operación de la planta, de los cuales, un jefe de planta, diez operarios, un encargado de mantenimiento y un encargado de laboratorio. Se considera que dado que la envergadura de ambos procesos es el mismo, la cantidad mínima de trabajadores necesarios para la operación se establece igual para ambas alternativas. Se toman valores de salarios actuales de España.
- **Gastos administrativos:** Se los estima como el 50% del coste de personal.
- **Mantenimiento / Reparaciones:** Se estima un 1% del valor del CAPEX al año.
- **Analíticas de laboratorio:** Valores de mercado actuales.
- **Prevención de riesgos laborales (PRL):** Se estima el 1,5 - 2% del OPEX total.

En la Tabla 13, se detallan los costes de operación fijos calculados para el Año 1.

Tabla 13. Costes de operación fijos para el año 1. (Fuente: Elaboración propia).

| OPEX FIJO                                      | Cantidad | Coste unitario anual | ETAP BAJO CONSUMO   | ETAP CONVENCIONAL   |
|------------------------------------------------|----------|----------------------|---------------------|---------------------|
|                                                |          |                      | Coste anual total   |                     |
| <b>Personal</b>                                |          |                      |                     |                     |
| JEFE DE PLANTA                                 | 1        | 42.395,23 EUR        | 42.395,23 EUR       | 42.395,23 EUR       |
| OPERADOR PLANTA                                | 10       | 24.703,94 EUR        | 247.039,40 EUR      | 247.039,40 EUR      |
| ENCARGADO MANTENIMIENTO                        | 1        | 26.130,78 EUR        | 26.130,78 EUR       | 26.130,78 EUR       |
| ENCARGADO LABORATORIO                          | 1        | 31.420,78 EUR        | 31.420,78 EUR       | 31.420,78 EUR       |
| <b>PRL</b>                                     |          |                      | 101.980,18 EUR      | 107.604,57 EUR      |
| <b>Analíticas laboratorio</b>                  |          |                      | 205.129,76 EUR      | 205.129,76 EUR      |
| <b>Gastos Administrativos</b>                  |          |                      | 173.493,10 EUR      | 173.493,10 EUR      |
| <b>Mantenimiento / Limpieza / Reparaciones</b> |          |                      | 738.216,75 EUR      | 770.356,99 EUR      |
| <b>OPEX FIJO TOTAL AÑO 1 [EUR/año]</b>         |          |                      | <b>1.565.805,97</b> | <b>1.603.570,60</b> |

#### 7.4.2. COSTES OPERACIONALES VARIABLES

Para el cálculo de los costes variables, se tomaron las siguientes consideraciones:

- **Reactivos:** Se tomaron valores de mercado actuales.
- **Consumo energético:** Se tomaron los precios de la tarifa 6.1TD, según explicado en el apartado 7.1.
- **Gestión de los fangos producidos:** Se toma un valor de 55 EUR/t en concepto de transporte y tasas de vertedero.



En la Tabla 14 y Tabla 15 , se detallan los costes de operación variables calculados para el Año 1 para ambas alternativas de diseño.

**Tabla 14. Costes de operación variables para el año 1 ETAP Convencional. (Fuente: Elaboración propia).**

| OPEX VARIABLE                  | Cantidad         | Coste unitario      | Coste anual         |
|--------------------------------|------------------|---------------------|---------------------|
| <b>Reactivos</b>               | <b>[Kg/año]</b>  | <b>[EUR/Kg]</b>     |                     |
| <i>Policloruro de aluminio</i> | 1.825.000,00     | 0,31                | 560.091,428         |
| <i>Sulfato de alúmina</i>      | 2.281.250,00     | 0,54                | 1.225.199,999       |
| <i>Ácido sulfúrico</i>         | 37.244,60        | 0,50                | 18.574,312          |
| <i>Hidróxido sódico</i>        | 2.400,00         | 0,46                | 1.104,838           |
| <i>Cloro gas</i>               | 240.900,00       | 0,30                | 71.159,616          |
| <i>PolyDADMAC</i>              | 109.500,00       | 2,10                | 229.987,543         |
| <i>Permanganato potásico</i>   | 109.500,00       | 3,84                | 420.068,571         |
| <i>Polielectrolito fangos</i>  | 12.063,25        | 2,34                | 28.229,308          |
|                                |                  |                     |                     |
| <b>Energía eléctrica</b>       |                  |                     |                     |
| <b>Término potencia</b>        | <b>[kW]</b>      | <b>[EUR/kW/año]</b> |                     |
| <i>Período 1</i>               | 3307,7           | 30,536              | 101.003,249         |
| <i>Período 2</i>               | 3310,8           | 25,895              | 85.732,189          |
| <i>Período 3</i>               | 3301,5           | 14,909              | 49.222,555          |
| <i>Período 4</i>               | 3301,5           | 12,094              | 39.929,823          |
| <i>Período 5</i>               | 3233,3           | 3,939               | 12.734,869          |
| <i>Período 6</i>               | 3338,7           | 2,109               | 7.040,293           |
|                                |                  |                     |                     |
| <b>Término energía</b>         | <b>[kWh/año]</b> | <b>[EUR/kWh]</b>    |                     |
| <i>Período 1</i>               | 995.970,31       | 0,2204              | 304.202,626         |
| <i>Período 2</i>               | 1.202.269,68     | 0,1785              | 289.338,819         |
| <i>Período 3</i>               | 1.139.443,18     | 0,0219              | 34.223,403          |
| <i>Período 4</i>               | 1.287.508,28     | 0,0122              | 21.367,185          |
| <i>Período 5</i>               | 507.975,95       | 0,0044              | 2.964,681           |
| <i>Período 6</i>               | 4.310.480,21     | 0,0029              | 15.418,508          |
|                                |                  |                     |                     |
| <b>Gestión de fangos</b>       | <b>[t/año]</b>   | <b>[EUR/t]</b>      |                     |
| <i>Vertedero</i>               | 8395             | 55                  | 461.725,000         |
| <b>TOTAL [EUR/año]</b>         |                  |                     | <b>3.979.318,82</b> |

**Tabla 15. Costes de operación variables para el año 1 ETAP Bajo consumo. (Fuente: Elaboración propia).**

| OPEX VARIABLE                  | Cantidad        | Coste unitario  | Coste anual   |
|--------------------------------|-----------------|-----------------|---------------|
| <b>Reactivos</b>               | <b>[Kg/año]</b> | <b>[EUR/Kg]</b> |               |
| <i>Policloruro de aluminio</i> | 1.825.000,00    | 0,31            | 560.091,428   |
| <i>Sulfato de alúmina</i>      | 2.281.250,00    | 0,54            | 1.225.199,999 |
| <i>Ácido sulfúrico</i>         | 37.244,60       | 0,50            | 18.574,312    |
| <i>Hidróxido sódico</i>        | 2.400,00        | 0,46            | 1.104,838     |
| <i>Cloro gas</i>               | 240.900,00      | 0,30            | 71.159,616    |
| <i>PolyDADMAC</i>              | 109.500,00      | 2,10            | 229.987,543   |
| <i>Permanganato potásico</i>   | 109.500,00      | 3,84            | 420.068,571   |
| <i>Polielectrolito fangos</i>  | 12.063,25       | 2,34            | 28.229,308    |
|                                |                 |                 |               |

| OPEX VARIABLE            | Cantidad         | Coste unitario      | Coste anual         |
|--------------------------|------------------|---------------------|---------------------|
| <b>Energía eléctrica</b> |                  |                     |                     |
| <b>Término potencia</b>  | <b>[kW]</b>      | <b>[EUR/kW/año]</b> |                     |
| Período 1                | 2242,8           | 30,536              | 68.485,681          |
| Período 2                | 2242,8           | 25,895              | 58.076,644          |
| Período 3                | 2236,5           | 14,909              | 33.344,312          |
| Período 4                | 2236,5           | 12,094              | 27.049,235          |
| Período 5                | 2190,3           | 3,939               | 8.626,847           |
| Período 6                | 2261,7           | 2,109               | 4.769,231           |
| <b>Término energía</b>   | <b>[kWh/año]</b> | <b>[EUR/kWh]</b>    |                     |
| Período 1                | 995.970,31       | 0,2204              | 217.933,451         |
| Período 2                | 1.202.269,68     | 0,1785              | 213.951,385         |
| Período 3                | 1.139.443,18     | 0,0219              | 24.860,729          |
| Período 4                | 1.287.508,28     | 0,0122              | 15.630,497          |
| Período 5                | 507.975,95       | 0,0044              | 2.253,889           |
| Período 6                | 4.310.480,21     | 0,0029              | 12.435,878          |
| <b>Gestión de fangos</b> | <b>[t/año]</b>   | <b>[EUR/t]</b>      |                     |
| Vertedero                | 8395             | 55                  | 461.725,000         |
| <b>TOTAL [EUR/año]</b>   |                  |                     | <b>3.706.089,61</b> |

## 7.5. COMPARATIVA

Una vez calculados tanto los costes de inversión como de operación de las dos alternativas de planta, se procede a realizar un análisis comparativo de los resultados obtenidos. Sin embargo, para ello, en primer lugar, es necesario llevar los costes operacionales de toda la vida útil de la planta a un Valor Actual Neto (VAN).

Considerando una vida útil de la planta de 20 años, se realizó una actualización de los valores calculados de OPEX para el año 1, estimando un IPC del 2% a 20 años. A continuación, se llevó dichos valores al VAN, a partir de la siguiente fórmula:

$$VAN = \sum_{t=0}^n \frac{V_t}{(1+k)^t} - I_0$$

Donde,  $V_t$  representa los flujos en cada período  $t$ ;  $I_0$  es el valor de la inversión inicial,  $n$  el número de períodos considerados, y  $k$  la tasa de descuento, la cual se consideró del 8%. Los resultados obtenidos se detallan en la Tabla 16.

**Tabla 16. Valor actual neto OPEX. (Fuente: elaboración propia).**

|                 | ETAP BAJO CONSUMO |               | ETAP CONVENCIONAL |               |
|-----------------|-------------------|---------------|-------------------|---------------|
| <b>VAN OPEX</b> | EUR               | 59.852.942,08 | EUR               | 63.383.720,65 |

El coste final de cada planta se obtiene a partir de la suma del coste de inversión y el valor actual neto de los costes de operación. Para calcular tanto el CAPEX como el OPEX específico de la planta durante los veinte años de operación, se calculó el “VAN” del caudal máximo de agua a tratar en los veinte años de operación de la planta, a fin de obtener un caudal de tratamiento estimado que permita realizar comparaciones.

Como se detalla en la Tabla 17, con la alternativa de bajo consumo, se obtiene un ahorro del 4% en costes de inversión y del 6% en costes de operación respecto a la alternativa convencional. Las tarifas finales de tratamiento calculadas para ambos procesos fueron 0,124 EUR/m<sup>3</sup> para la alternativa de bajo consumo y 0,131 EUR/m<sup>3</sup> para el convencional, lo que indica que con la opción de bajo consumo se obtiene un ahorro del 5,34%.

**Tabla 17. Coste final inversión y operación de ambas alternativas. (Fuente: Elaboración propia).**

|                          | ETAP BAJO CONSUMO     | ETAP CONVENCIONAL     | Ahorro              | Unidad                   |
|--------------------------|-----------------------|-----------------------|---------------------|--------------------------|
| CAPEX                    | 73.821.675,22         | 77.035.698,92         | 3.214.023,70        | EUR                      |
| VAN OPEX                 | 59.852.942,08         | 63.383.720,65         | 3.530.778,57        | EUR                      |
| <b>TOTAL</b>             | <b>133.674.617,29</b> | <b>140.419.419,57</b> | <b>6.744.802,27</b> | <b>EUR</b>               |
|                          |                       |                       |                     |                          |
| “VAN” Caudal Tratamiento | 1.075.087.141,12      | 1.075.087.141,12      |                     | m <sup>3</sup>           |
|                          |                       |                       |                     |                          |
| CAPEX específico         | 0,069                 | 0,072                 | 4 %                 | EUR/m <sup>3</sup>       |
| VAN OPEX específico      | 0,056                 | 0,059                 | 6 %                 | EUR/m <sup>3</sup>       |
| <b>TOTAL</b>             | <b>0,124</b>          | <b>0,131</b>          | <b>5,34%</b>        | <b>EUR/m<sup>3</sup></b> |

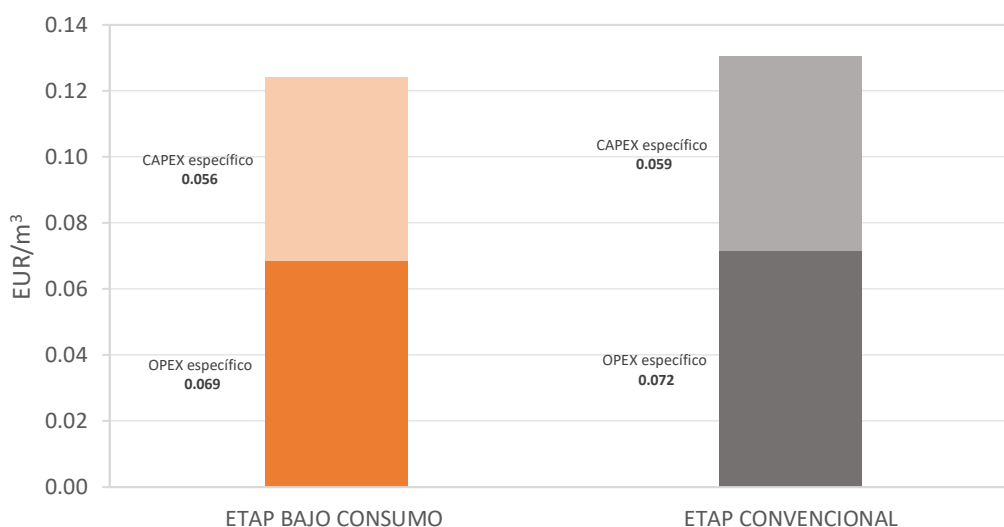


*Figura 29. CAPEX y VAN OPEX por volumen de agua tratada. (Fuente: Elaboración propia).*

Los costes de operación y mantenimiento constituyen el 45% del valor total de la planta en ambas alternativas. En la convencional, el coste de la energía representa el 17% de ese OPEX, como se muestra en la Figura 30. Es decir, el gasto energético compone el 8% del valor total de la planta en sus 20 años de vida útil.

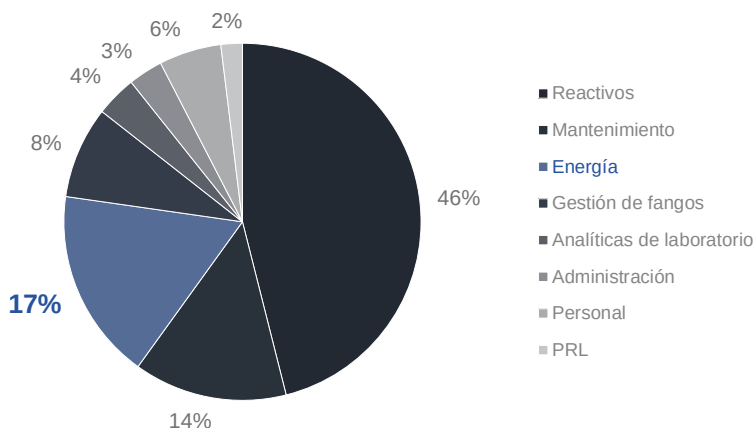


Figura 30. Distribución OPEX en ETAP Convencional. (Fuente: Elaboración propia).

Las modificaciones propuestas en la alternativa de bajo consumo permitirían reducir ese coste energético en un 28% anual, pasando del 17% al 13% de los OPEX de la ETAP, como se ve en la Figura 31.

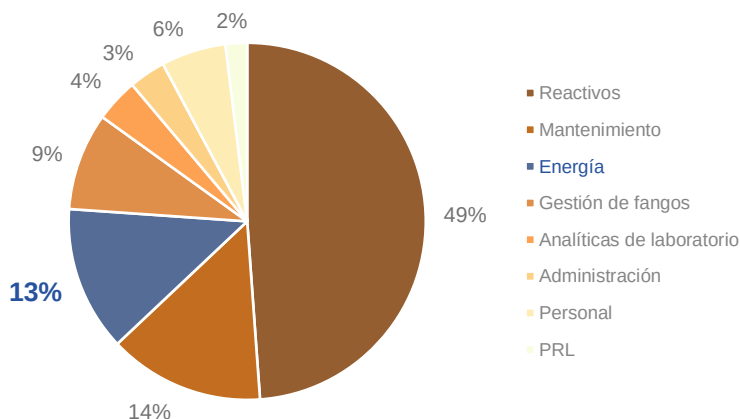


Figura 31. Distribución OPEX en ETAP de Bajo consumo. (Fuente: Elaboración propia).

## 8. CONCLUSIONES

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En el presente trabajo, se buscó analizar el ahorro energético que supone la utilización de tecnologías existentes, sencillas, típicas de países en vías de desarrollo, en comparación con el proceso convencional de tratamiento que suele utilizarse en España.

Para ello, se tomó como base el diseño de un proceso de tratamiento para una ETAP en Filipinas, y se lo redimensionó en su línea de aguas para adaptarlo al proceso convencional de las plantas españolas. A continuación, se analizó el consumo energético que suponen ambas alternativas de tratamiento, y se estimó el coste económico que dichos consumos implican en España con las tarifas energéticas actuales. Se realizó además un presupuesto estimado de construcción para las dos opciones de proceso, como así también una valoración de los costes que supone la operación y el mantenimiento de la planta durante veinte años de vida útil.

De esta comparación, se llegó al resultado de que solo con la aplicación de pequeñas adaptaciones al sistema convencional, y únicamente en la línea de agua, se consigue reducir el consumo energético de la planta en un 26% y un ahorro en costes del 28%. Esta reducción representa un ahorro en emisiones de GEI correspondientes a electricidad, que asciende a 749.910 kg CO<sub>2</sub>/año.

Debe considerarse que en el análisis se realizó una actualización futura de los costes de la energía con base en un IPC constante del 2%. Sin embargo, teniendo en cuenta la inestabilidad actual de los costes energéticos y la tendencia de los últimos años, éstos podrían verse incrementados en un porcentaje mayor, alcanzándose ahorros económicos finales superiores.

Con relación a los costes finales de inversión y operación se obtiene un ahorro del 4% y del 6% , respectivamente, respecto a la alternativa convencional. Esto resulta en una reducción final del 5,34% en la tarifa de tratamiento.

Puede concluirse entonces que las adaptaciones planteadas al proceso convencional de tratamiento de agua para consumo humano, para una calidad de agua sin contaminantes de importancia y un caudal de agua medio, resultan en una reducción de importancia del consumo energético.

En el caso de los costes constructivos y operacionales, en cambio, el ahorro no es muy elevado, y debe considerarse que puede variar significativamente de un país a otro.

Esta reducción de consumo energético es primordial en el panorama energético actual, ya que contribuye al objetivo común de conseguir un modelo económico global más sostenible y basado en las bajas emisiones de carbono.

La eficiencia energética y la gestión de la energía están muy extendidas hoy en día en la industria, y es por ello que es muy importante conocer el perfil de los consumos energéticos en una instalación para poder identificar y valorar los posibles ahorros desde el punto de vista técnico y económico.

En cuanto a la gestión agua respecta, la energía está presente en todo su ciclo y supone un factor determinante para el abastecimiento de agua de calidad a la población. Desde el diseño de las plantas de tratamiento de agua, promover procesos que garanticen el mínimo consumo energético es fundamental. Dado el carácter de servicio público de las instalaciones de tratamiento de agua potable, el objetivo de lograr una mayor eficiencia energética del sector debería ser impulsado por los organismos estatales, para poder contribuir a un modelo económico sostenible, económico, basado en el respeto al medio ambiente y que mantenga la seguridad del suministro eléctrico.

En conclusión, puede decirse que existen infinidad de mejoras que podrían potenciar la eficiencia energética del ciclo del agua, ya sea en su fase de tratamiento como de captación, distribución y depuración. Estas medidas son responsabilidad tanto de la población como de las administraciones y organismos competentes. De todos depende el poder optimizar un recurso indispensable para la vida: el agua.

## 8.1. FUTURAS LÍNEAS DE ANÁLISIS

Del análisis comparativo realizado, surgen una serie de cuestiones que no fueron abordadas por quedar fuera del alcance del presente trabajo. Debe tenerse en cuenta que el estudio planteado se basa en un caso particular, a partir del cual se obtuvieron conclusiones que aplicarían a casos de envergadura semejante, y para calidades de agua bruta afines. A continuación, se detallan los puntos principales que se proponen como líneas de investigación futuras:

- Realizar un análisis de sensibilidad frente al precio de la energía.

- Realizar un análisis de sensibilidad para evaluar el impacto de la magnitud del caudal a tratar en el ahorro energético final.
- Profundizar el alcance del proceso de bajo consumo energético valorando alternativas para reducir el consumo energético en la línea de fangos.
- Comparar el diseño de bajo consumo planteado con otros procesos de tratamiento de agua para consumo humano.
- Repetir el estudio considerando diferentes calidades de agua bruta entrante, especialmente para diferentes concentraciones de sólidos en suspensión.

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# PARTE 2

# ANEXOS

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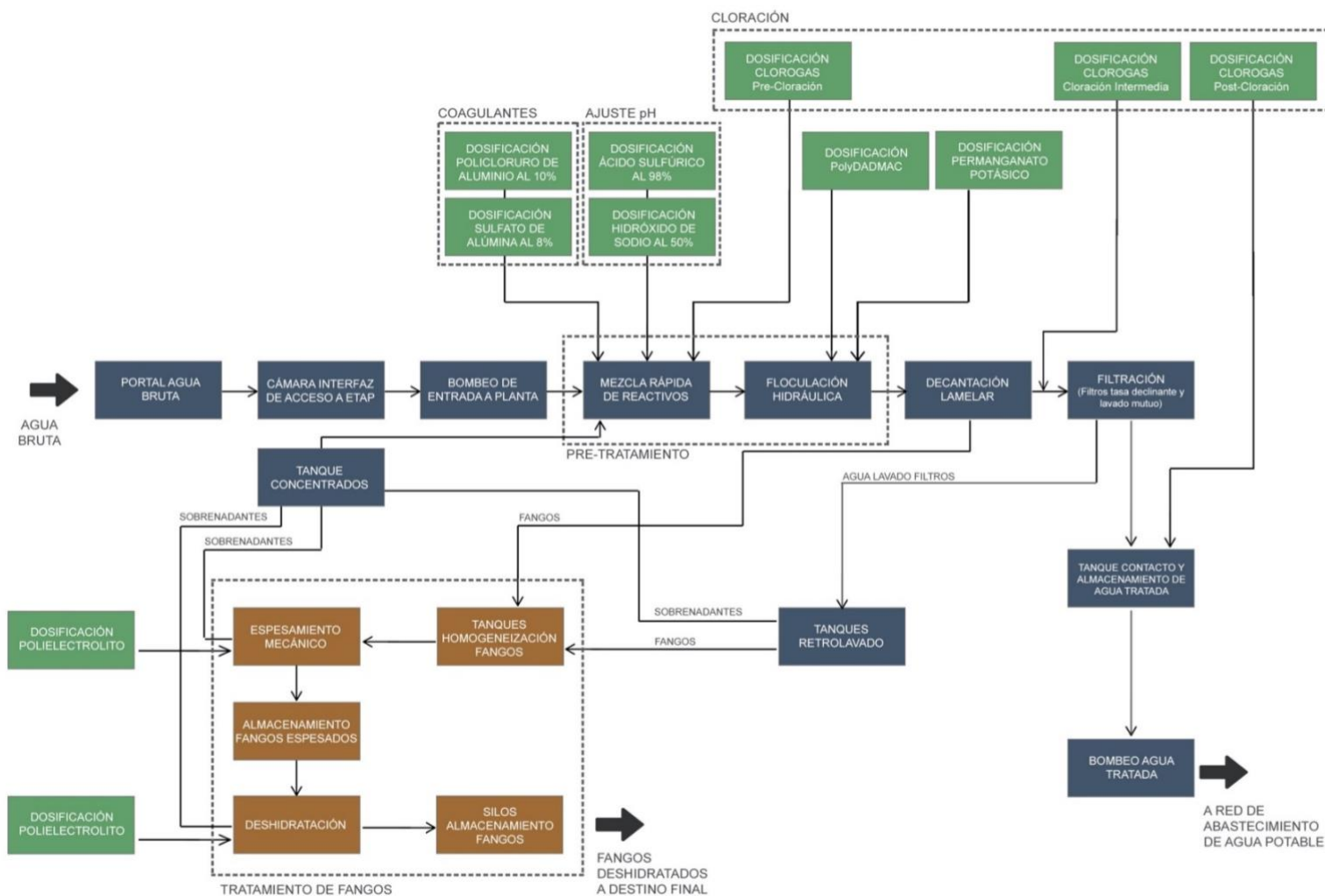
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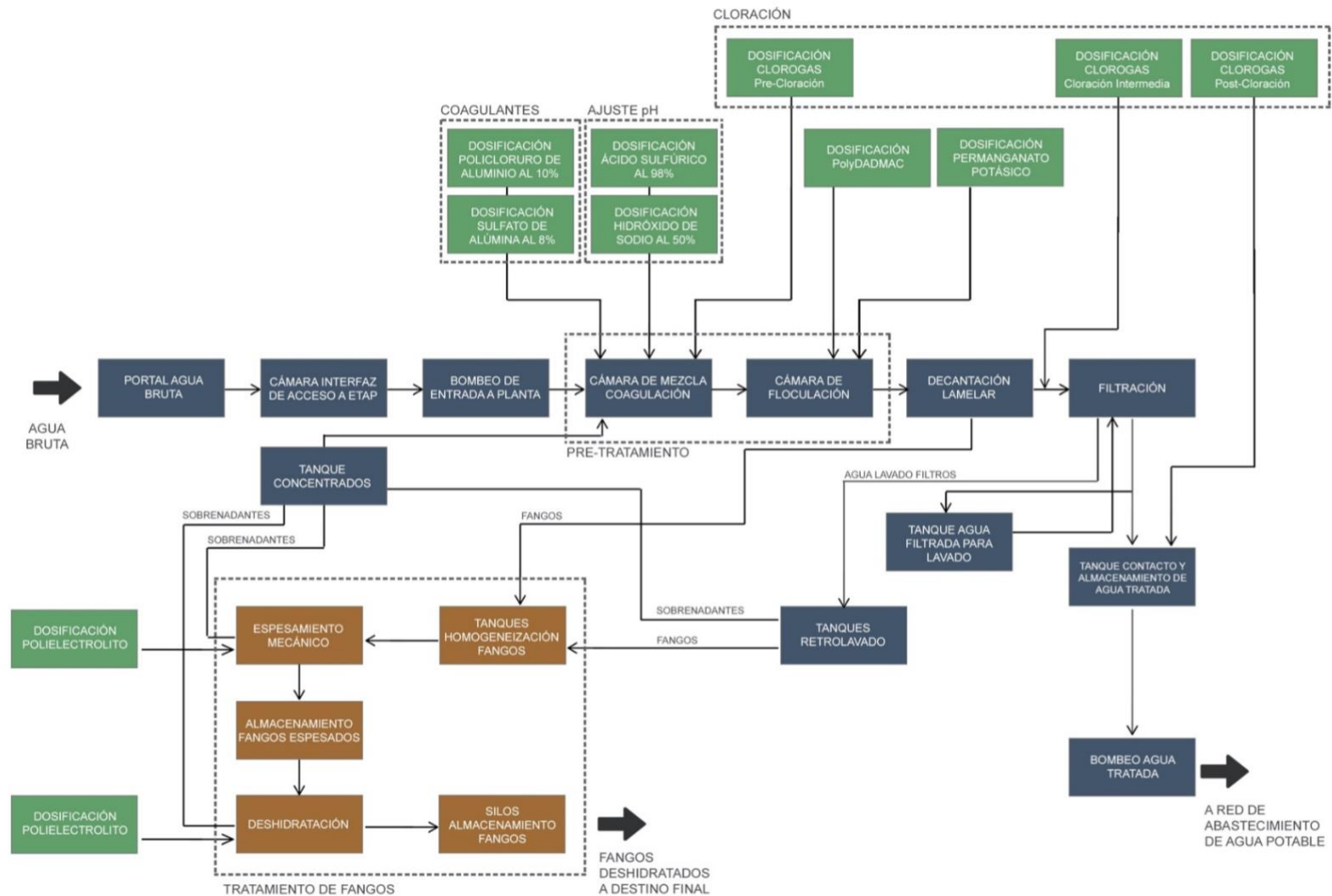
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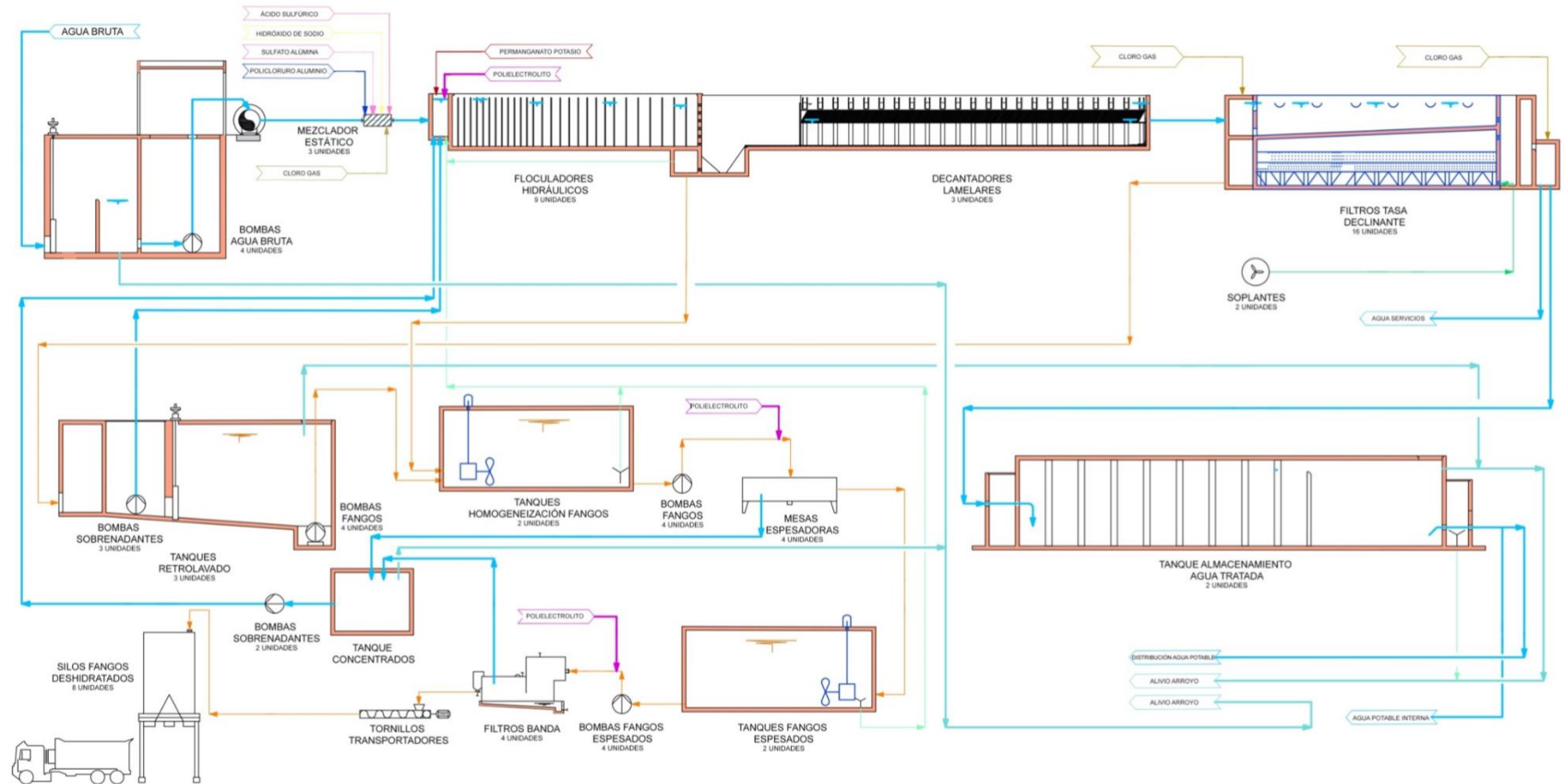
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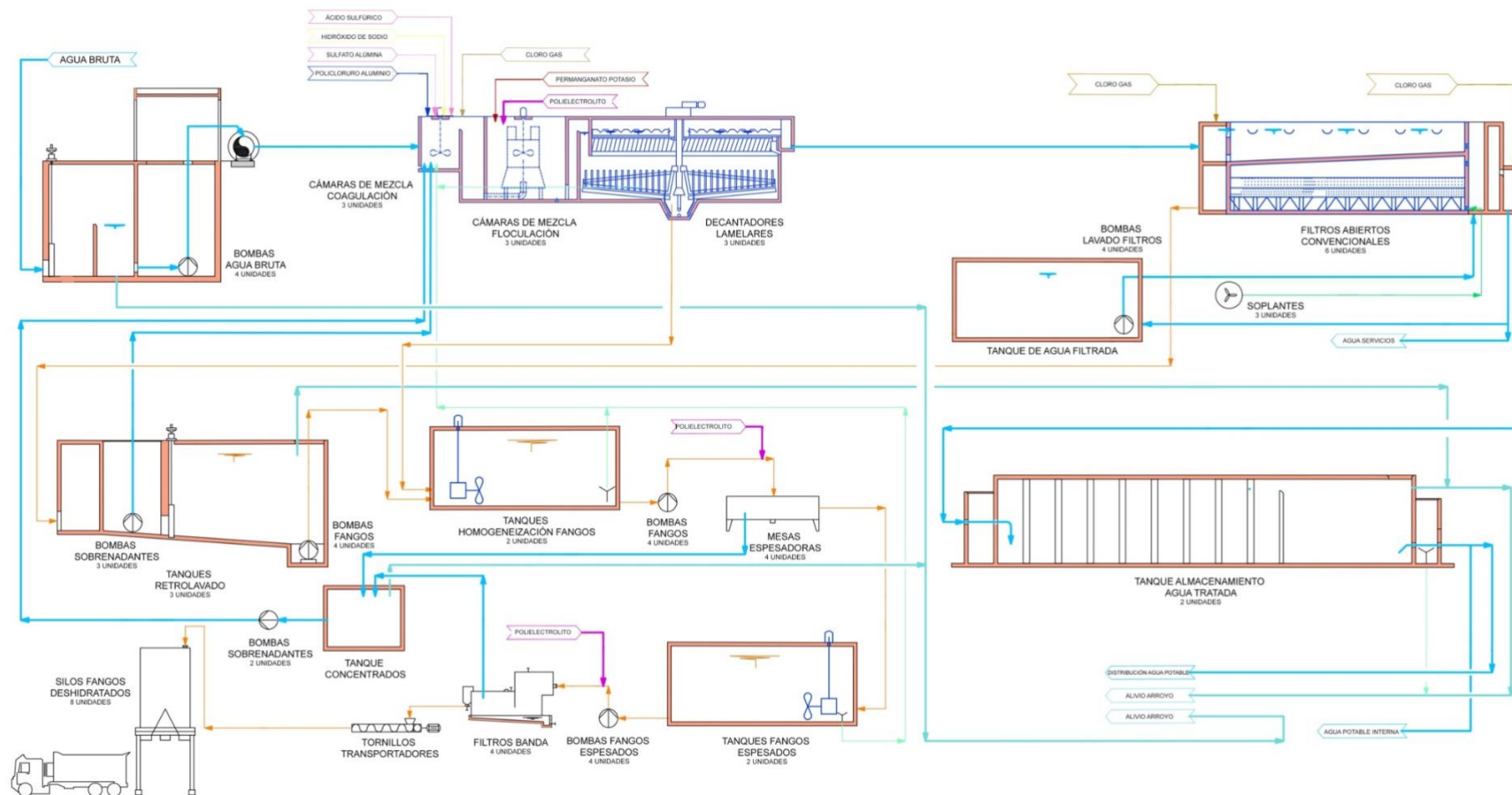
## 2.2. DIAGRAMA DE BLOQUES ETAP CONVENCIONAL



## 2.3. DIAGRAMA DE FLUJOS ETAP BAJO CONSUMO



## 2.4. DIAGRAMA DE FLUJOS ETAP CONVENCIONAL





## 2.5. CÁLCULOS DE DIMENSIONAMIENTO

**Tabla 18. Cálculo dosificación y almacenamiento Policloruro de Aluminio. (Fuente: Elaboración propia).**

| Reactivo               | Policloruro de aluminio al 10% |         | Unidad |
|------------------------|--------------------------------|---------|--------|
| Caudal agua de entrada | 100 MLD                        | 300 MLD |        |
| Dosis media            | 5                              | 5       | mg/L   |
| Dosis máx.             | 40                             | 40      | mg/L   |

|                       |          |           |      |
|-----------------------|----------|-----------|------|
| Consumo medio horario | 23,24    | 62,50     | kg/h |
| Consumo medio diario  | 562,52   | 1.500,00  | kg/d |
| Consumo horario máx.  | 187,51   | 500,00    | kg/h |
| Consumo diario máx.   | 4.500,16 | 12.000,00 | kg/d |

|                             |      |      |                    |
|-----------------------------|------|------|--------------------|
| Riqueza producto comercial  | 10   | 10   | %                  |
| Densidad producto comercial | 1,19 | 1,19 | kg/dm <sup>3</sup> |

|                                     |           |            |                   |
|-------------------------------------|-----------|------------|-------------------|
| Consumo de prod com medio diario    | 5.625,20  | 15.000,00  | kg/d              |
| Consumo volumétrico diario prod com | 4,73      | 12,61      | m <sup>3</sup> /d |
| Consumo de prod com máx. diario     | 45.001,60 | 120.000,00 | kg/d              |
| Consumo volumétrico diario prod com | 37,82     | 100,84     | m <sup>3</sup> /d |

|                                   |       |       |                |
|-----------------------------------|-------|-------|----------------|
| Almacenamiento condiciones medias | 30    | 30    | días           |
| Volumen almacenamiento necesario  | 141,8 | 378,2 | m <sup>3</sup> |
| Almacenamiento condiciones máx.   | 2     | 2     | días           |
| Volumen almacenamiento necesario  | 75,6  | 201,7 | m <sup>3</sup> |

|                   |     |     |                |
|-------------------|-----|-----|----------------|
| Número de tanques | 2   | 2   | Uds.           |
| Volumen unitario  | 110 | 110 | m <sup>3</sup> |

|                                           |      |      |      |
|-------------------------------------------|------|------|------|
| Tiempo almacenamiento condiciones medias  | 46,5 | 17,5 | días |
| Tiempo almacenamiento condiciones máximas | 5,8  | 2,2  | días |

|                          |         |         |     |
|--------------------------|---------|---------|-----|
| Caudal dosificación mín. | 196,96  | 525,21  | L/h |
| Caudal dosificación máx. | 1575,69 | 4201,68 | L/h |

|                         |         |         |      |
|-------------------------|---------|---------|------|
| Bombas activas          | 1       | 2       | Uds. |
| Bombas reserva          | 2       | 1       | Uds. |
| Caudal mínimo por bomba | 196,96  | 262,61  | L/h  |
| Caudal máx. por bomba   | 1575,69 | 2100,84 | L/h  |

|                                      |      |      |     |
|--------------------------------------|------|------|-----|
| Caudal bombas dosificadoras adoptado | 2000 | 2000 | L/h |
|--------------------------------------|------|------|-----|

**Tabla 19. Cálculo dosificación y almacenamiento Sulfato de Alúmina. (Fuente: Elaboración propia).**

| Reactivo                                  | Sulfato de alúmina al 8% |            | Unidad             |
|-------------------------------------------|--------------------------|------------|--------------------|
| Caudal agua de entrada                    | 100 MLD                  | 300 MLD    |                    |
| Dosis media                               | 5                        | 5          | mg/L               |
| Dosis máx.                                | 40                       | 40         | mg/L               |
| Consumo medio horario                     | 23,44                    | 62,50      | kg/h               |
| Consumo medio diario                      | 562,52                   | 1.500,00   | kg/d               |
| Consumo horario máx.                      | 187,51                   | 500,00     | kg/h               |
| Consumo diario máx.                       | 4.500,16                 | 12.000,00  | kg/d               |
| Riqueza producto comercial                | 8                        | 8          | %                  |
| Densidad producto comercial               | 1,42                     | 1,42       | kg/dm <sup>3</sup> |
| Consumo de prod com medio diario          | 7.031,50                 | 18.750,00  | kg/d               |
| Consumo volumétrico diario prod com       | 4,95                     | 13,20      | m <sup>3</sup> /d  |
| Consumo de prod com máx. diario           | 56.252,00                | 150.000,00 | kg/d               |
| Consumo volumétrico diario prod com       | 39,61                    | 105,63     | m <sup>3</sup> /d  |
| Almacenamiento condiciones medias         | 30                       | 30         | días               |
| Volumen almacenamiento necesario          | 148,6                    | 396,1      | m <sup>3</sup>     |
| Almacenamiento condiciones máx.           | 2                        | 2          | días               |
| Volumen almacenamiento necesario          | 79,2                     | 211,3      | m <sup>3</sup>     |
| Número de tanques                         | 2                        | 2          | Uds.               |
| Volumen unitario                          | 110                      | 110        | m <sup>3</sup>     |
| Tiempo almacenamiento condiciones medias  | 44,43                    | 16,66      | días               |
| Tiempo almacenamiento condiciones máximas | 5,55                     | 2,08       | días               |
| Caudal dosificación mín.                  | 206,32                   | 550,18     | L/h                |
| Caudal dosificación máx.                  | 1.650,59                 | 4.401,41   | L/h                |
| Bombas activas                            | 1                        | 2          | Uds.               |
| Bombas reserva                            | 2                        | 1          | Uds.               |
| Caudal mínimo por bomba                   | 206,32                   | 275,09     | L/h                |
| Caudal máx. por bomba                     | 1.650,59                 | 2.200,70   | L/h                |
| Caudal bombas dosificadoras adoptado      | 2500                     | 2500       | L/h                |

**Tabla 20. Cálculo dosificación y almacenamiento Ácido Sulfúrico. (Fuente: Elaboración propia).**

| Reactivo                             | Ácido sulfúrico al 98% |          | Unidad             |
|--------------------------------------|------------------------|----------|--------------------|
| Caudal agua de entrada               | 100 MLD                | 300 MLD  |                    |
| Dosis media                          | 2                      | 2        | mg/L               |
| Dosis máx.                           | 8                      | 8        | mg/L               |
| Consumo medio horario                | 9,38                   | 25,00    | kg/h               |
| Consumo medio diario                 | 225,01                 | 600,00   | kg/d               |
| Consumo horario máx.                 | 37,50                  | 100,00   | kg/h               |
| Consumo diario máx.                  | 900,03                 | 2.400,00 | kg/d               |
| Riqueza producto comercial           | 98                     | 98       | %                  |
| Densidad producto comercial          | 1,84                   | 1,84     | kg/dm <sup>3</sup> |
| Consumo de prod com medio diario     | 229,60                 | 612,24   | kg/d               |
| Consumo volumétrico diario prod com  | 0,12                   | 0,33     | m <sup>3</sup> /d  |
| Consumo de prod com máx. diario      | 918,40                 | 2.448,98 | kg/d               |
| Consumo volumétrico diario prod com  | 0,50                   | 1,33     | m <sup>3</sup> /d  |
| Almacenamiento condiciones medias    | 30                     | 30       | días               |
| Volumen almacenamiento necesario     | 3,74                   | 9,98     | m <sup>3</sup>     |
| Almacenamiento condiciones máx.      | 2                      | 2        | días               |
| Volumen almacenamiento necesario     | 1                      | 2,7      | m <sup>3</sup>     |
| Número de tanques                    | 2                      | 2        | Uds.               |
| Volumen unitario                     | 6                      | 6        | m <sup>3</sup>     |
| Tiempo almacenamiento medio          | 96,17                  | 36,06    | días               |
| Tiempo almacenamiento máx.           | 24,04                  | 9,02     | días               |
| Caudal dosificación mín.             | 5,20                   | 5,20     | L/h                |
| Caudal dosificación máx.             | 20,80                  | 55,46    | L/h                |
| Bombas activas                       | 1                      | 1        | Uds.               |
| Bombas reserva                       | 1                      | 1        | Uds.               |
| Caudal mínimo por bomba              | 5,20                   | 5,20     | L/h                |
| Caudal máx. por bomba                | 20,80                  | 55,46    | L/h                |
| Caudal bombas dosificadoras adoptado | 70                     | 70       | L/h                |

**Tabla 21. Cálculo dosificación y almacenamiento Hidróxido Sódico. (Fuente: Elaboración propia).**

| Reactivo                             | Hidróxido de sodio al 50% |          | Unidad             |
|--------------------------------------|---------------------------|----------|--------------------|
|                                      | Caudal agua de entrada    |          |                    |
|                                      | 100 MLD                   | 300 MLD  |                    |
| Dosis media                          | 0,2                       | 0,2      | mg/L               |
| Dosis máx.                           | 2,5                       | 2,5      | mg/L               |
| Consumo medio horario                | 0,94                      | 2,50     | kg/h               |
| Consumo medio diario                 | 22,50                     | 60,00    | kg/d               |
| Consumo horario máx.                 | 11,72                     | 31,25    | kg/h               |
| Consumo diario máx.                  | 281,26                    | 750,00   | kg/d               |
| Densidad producto comercial          | 1,52                      | 1,52     | kg/dm <sup>3</sup> |
| Consumo de prod com medio diario     | 45,00                     | 120,00   | kg/d               |
| Consumo volumétrico diario prod com  | 0,03                      | 0,08     | m <sup>3</sup> /d  |
| Consumo de prod com máx. diario      | 562,52                    | 1.500,00 | kg/d               |
| Consumo volumétrico diario prod com  | 0,37                      | 0,99     | m <sup>3</sup> /d  |
| Almacenamiento condiciones medias    | 30                        | 30       | días               |
| Volumen almacenamiento necesario     | 0,89                      | 2,37     | m <sup>3</sup>     |
| Almacenamiento condiciones máx.      | 2                         | 2        | días               |
| Volumen almacenamiento necesario     | 0,74                      | 1,97     | m <sup>3</sup>     |
| Número de tanques                    | 1                         | 1        | Uds.               |
| Volumen unitario                     | 3                         | 3        | m <sup>3</sup>     |
| Tiempo almacenamiento medio          | 101,33                    | 38,00    | días               |
| Tiempo almacenamiento máx.           | 8,11                      | 3,04     | días               |
| Caudal dosificación mín.             | 1,23                      | 1,23     | L/h                |
| Caudal dosificación máx.             | 15,42                     | 41,12    | L/h                |
| Bombas activas                       | 1                         | 1        | Uds.               |
| Bombas reserva                       | 1                         | 1        | Uds.               |
| Caudal mínimo por bomba              | 1,23                      | 1,23     | L/h                |
| Caudal máx. por bomba                | 15,42                     | 41,12    | L/h                |
| Caudal bombas dosificadoras adoptado | 50                        | 50       | L/h                |

Tabla 22. Cálculo dosificación Cloro gas. (Fuente: Elaboración propia).

| Reactivo                             | Cloro gas |            |        |         |            |        | Unidad |
|--------------------------------------|-----------|------------|--------|---------|------------|--------|--------|
| Caudal agua entrada                  | 100 MLD   |            |        | 300 MLD |            |        |        |
| Cloración                            | Pre       | Intermedia | Post   | Pre     | Intermedia | Post   |        |
| Dosificación media                   | 1,25      | 0,75       | 1,50   | 1,25    | 0,75       | 1,25   | mg/L   |
| Consumo medio diario                 | 140,58    | 82,59      | 146,93 | 412,48  | 242,32     | 446,37 | kg/d   |
| Consumo medio horario                | 5,86      | 3,44       | 6,12   | 17,19   | 10,10      | 18,60  | kg/h   |
|                                      |           |            |        |         |            |        |        |
| Riqueza comercial                    | 99        | 99         | 99     | 99      | 99         | 99     | % w/w  |
| Densidad comercial                   | 2,49      | 2,49       | 2,49   | 2,49    | 2,49       | 2,49   | kg/dm³ |
| Concentración en peso                | 0,06      | 0,06       | 0,06   | 0,06    | 0,06       | 0,06   | %      |
|                                      |           |            |        |         |            |        |        |
| Consumo medio diario prod. com.      | 142,00    | 83,42      | 148,40 | 416,60  | 244,77     | 450,90 | kg/d   |
| Consumo medio horario prod. com.     | 0,06      | 0,03       | 0,06   | 0,17    | 0,10       | 0,18   | m³/d   |
| Tiempo de almacenamiento             | 30        |            |        | 30      |            |        | días   |
| Volumen almacenamiento               | 4.631     |            |        | 14.045  |            |        | m³     |
|                                      |           |            |        |         |            |        |        |
| Caudal bombeo medio                  | 4,6       | 4,6        | 9,2    | 1,5     | 1,5        | 3,1    | L/h    |
| Caudal bombeo máx.                   | 18,4      | 9,2        | 18,4   | 6,2     | 3,1        | 6,2    | L/h    |
|                                      |           |            |        |         |            |        |        |
| Bombas activas                       | 1         | 1          | 1      | 1       | 1          | 1      | Uds.   |
| Bombas reserva                       | 1         | 1          | 1      | 1       | 1          | 1      | Uds.   |
|                                      |           |            |        |         |            |        |        |
| Presión bombeo                       | 2         | 2          | 2      | 2       | 2          | 2      | bar    |
| Caudal bombas dosificadoras adoptado | 20        | 20         | 20     | 20      | 20         | 20     | L/h    |

**Tabla 23. Cálculo dosificación y almacenamiento PolyDADMAC al 20%. (Fuente: Elaboración propia).**

| Reactivo                             | PolyDADMAC al 20%      |         | Unidad             |
|--------------------------------------|------------------------|---------|--------------------|
|                                      | Caudal agua de entrada |         |                    |
|                                      | 100 MLD                | 300 MLD |                    |
| Dosis media                          | 0,2                    | 0,2     | mg/L               |
| Dosis máx.                           | 0,5                    | 0,5     | mg/L               |
| Consumo medio horario                | 0,94                   | 2,50    | kg/h               |
| Consumo medio diario                 | 22,50                  | 60,00   | kg/d               |
| Consumo horario máx.                 | 2,34                   | 6,25    | kg/h               |
| Consumo diario máx.                  | 56,25                  | 150,00  | kg/d               |
| Riqueza producto comercial           | 20                     | 20      | %                  |
| Densidad producto comercial          | 1,00                   | 1,00    | kg/dm <sup>3</sup> |
| Consumo de prod com medio diario     | 112,50                 | 300,00  | kg/d               |
| Consumo volumétrico diario prod com  | 0,11                   | 0,30    | m <sup>3</sup> /d  |
| Consumo de prod com máx. diario      | 281,26                 | 750,00  | kg/d               |
| Consumo volumétrico diario prod com  | 0,28                   | 0,75    | m <sup>3</sup> /d  |
| Almacenamiento condiciones medias    | 30                     | 30      | días               |
| Volumen almacenamiento necesario     | 3,38                   | 9,00    | m <sup>3</sup>     |
| Número de tanques                    | 3                      | 10      | Uds.               |
| Volumen unitario                     | 1,00                   | 1,00    | m <sup>3</sup>     |
| Tiempo almacenamiento medio          | 26,67                  | 33,33   | días               |
| Tiempo almacenamiento máx.           | 10,67                  | 13,33   | días               |
| Caudal dosificación mín.             | 4,69                   | 12,50   | L/h                |
| Caudal dosificación máx.             | 11,72                  | 31,25   | L/h                |
| Bombas activas                       | 1                      | 1       | Uds.               |
| Bombas reserva                       | 1                      | 1       | Uds.               |
| Caudal mínimo por bomba              | 4,69                   | 12,50   | L/h                |
| Caudal máx. por bomba                | 11,72                  | 31,25   | L/h                |
| Caudal bombas dosificadoras adoptado | 35                     | 35      | L/h                |

**Tabla 24. Cálculo dosificación y almacenamiento Permanganato potásico al 5%. (Fuente: Elaboración propia).**

| Reactivo                             | Permanganato potásico al 5% |           | Unidad             |
|--------------------------------------|-----------------------------|-----------|--------------------|
|                                      | Caudal agua de entrada      |           |                    |
|                                      | 100 MLD                     | 300 MLD   |                    |
| Forma de comercialización            | Polvo                       | Polvo     |                    |
| Concentración                        | 98                          | 98        | %                  |
| Dosis media                          | 1                           | 1         | mg/L               |
| Dosis máx.                           | 2,6                         | 2,6       | mg/L               |
| Consumo medio horario                | 4,69                        | 12,50     | kg/h               |
| Consumo medio diario                 | 112,50                      | 300,00    | kg/d               |
| Consumo horario máx.                 | 12,19                       | 32,50     | kg/h               |
| Consumo diario máx.                  | 292,51                      | 780,00    | kg/d               |
| Concentración de la solución         | 5                           | 5         | %                  |
| Densidad producto comercial          | 2,70                        | 2,70      | kg/dm <sup>3</sup> |
| Consumo de prod com medio diario     | 2.250,08                    | 6.000,00  | kg/d               |
| Consumo volumétrico diario prod com  | 2,07                        | 5,53      | m <sup>3</sup> /d  |
| Consumo de prod com máx. diario      | 5.850,21                    | 15.600,00 | kg/d               |
| Consumo volumétrico diario prod com  | 5,39                        | 14,38     | m <sup>3</sup> /d  |
| Tanques de preparación               | 2                           | 2         | Uds.               |
| Volumen unitario tanques             | 5,00                        | 5,00      | m <sup>3</sup>     |
| Tiempo en tanque de preparación      | 115,73                      | 43,40     | h                  |
| Tiempo en tanque de preparación      | 4,82                        | 1,81      | días               |
| Número de Big-bags                   | 3                           | 10        | Uds.               |
| Almacenamiento por Big-bag           | 1                           | 1         | t                  |
| Tiempo almacenamiento medio          | 26,67                       | 33,33     | días               |
| Tiempo almacenamiento máx.           | 10,26                       | 12,82     | días               |
| Caudal dosificación mín.             | 86,41                       | 230,41    | L/h                |
| Caudal dosificación máx.             | 224,66                      | 599,08    | L/h                |
| Bombas activas                       | 1                           | 1         | Uds.               |
| Bombas reserva                       | 1                           | 1         | Uds.               |
| Caudal mínimo por bomba              | 86,41                       | 230,41    | L/h                |
| Caudal máx. por bomba                | 224,66                      | 599,08    | L/h                |
| Caudal bombas dosificadoras adoptado | 700                         | 700       | L/h                |

**Tabla 25. Dimensionamiento Cámara de mezcla coagulación convencional. (Fuente: Elaboración propia).**

| PARÁMETRO                              |         |           | Unidad            |
|----------------------------------------|---------|-----------|-------------------|
| Caudal para tratar                     | 100 MLD | 300 MLD   |                   |
| Caudal medio horario                   | 4166.7  | 12500     | m <sup>3</sup> /h |
| Tiempo de retención a caudal medio     | 1       | 1         | min.              |
| Número de líneas                       | 1       | 3         | Uds.              |
|                                        |         |           |                   |
| Volumen necesario por línea            | 69,44   | 69,44     | m <sup>3</sup>    |
| Número de cámaras por línea            | 1       | 1         | Uds.              |
| Volumen necesario por cámara           | 69,44   | 69,44     | m <sup>3</sup>    |
| Dimensiones cámara                     |         |           |                   |
| - Ancho adoptado                       | 4,00    | 4,00      | m                 |
| - Longitud                             | 4,00    | 4,00      | m                 |
| - Profundidad adoptada                 | 4,50    | 4,50      | m                 |
| - Volumen por cámara                   | 72,00   | 72,00     | m <sup>3</sup>    |
| Volumen por línea                      | 72,00   | 72,00     | m <sup>3</sup>    |
| Volumen total                          | 72,00   | 216,00    | m <sup>3</sup>    |
|                                        |         |           |                   |
| <b>Agitación</b>                       |         |           |                   |
| Potencia específica mínima             | 150-200 | 150 - 200 | W/m <sup>3</sup>  |
| N.º de agitadores adoptados por cámara | 1       | 1         | Uds.              |
| Potencia adoptada por agitador         | 11      | 11        | kW                |
| Rendimiento motor                      | 73      | 73        | %                 |
| Potencia total instalada               | 11      | 33,00     | kW                |
|                                        |         |           |                   |
| Tiempo de retención real               | 1,04    | 1,04      | min               |
| Potencia específica neta               | 112     | 112       | W/m <sup>3</sup>  |



**Tabla 26. Dimensionamiento Floculador-Decantador convencional. (Fuente: Elaboración propia).**

| PARÁMETRO                                           |         |         | Unidad                           |
|-----------------------------------------------------|---------|---------|----------------------------------|
| Caudal para tratar                                  | 100 MLD | 300 MLD |                                  |
| SS agua bruta diseño                                | 165     | 165     | g/m <sup>3</sup>                 |
| N.º de unidades en funcionamiento                   | 1       | 3       | Uds.                             |
| Velocidad ascensional zona lamelar ≤ (según pliego) | 13      | 13      | m <sup>3</sup> /h.m <sup>2</sup> |
|                                                     |         |         |                                  |
| <b>Tiempos de retención hidráulica</b>              |         |         |                                  |
| Zona de floculación contacto                        | 10      | 10      | min                              |
| Zona de floculación maduración                      | 10      | 10      | min                              |
| Zona de decantación y espesamiento                  | 48      | 48      | min                              |
|                                                     |         |         |                                  |
| Concentración de SS en floculación                  | 1,35    | 1,28    | Kg/m <sup>3</sup>                |
| Concentración de SS en recirculación                |         |         |                                  |
| máxima                                              | 25      | 25      | Kg/m <sup>3</sup>                |
| media                                               | 15      | 15      | Kg/m <sup>3</sup>                |
|                                                     |         |         |                                  |
| Superficie de decantación lamelar:                  | 320,5   | 961,5   | m <sup>2</sup>                   |
|                                                     |         |         |                                  |
| Volumen unitario mínimo floculación contacto        | 694,4   | 694,4   | m <sup>3</sup>                   |
| Volumen unitario mínimo floculación maduración      | 694,4   | 694,4   | m <sup>3</sup>                   |
| Volumen unit. Decantación + espesamiento            | 3.333,3 | 3.333,3 | m <sup>3</sup>                   |
|                                                     |         |         |                                  |
| <b>Recirculaciones</b>                              |         |         |                                  |
| R media                                             | 5,0     | 5,0     | %                                |
| R máx.                                              | 8,0     | 8,0     | %                                |
|                                                     |         |         |                                  |
| Caudal de recirculación medio por clarificador      | 209     | 196     | m <sup>3</sup> /h                |
| Caudal de recirculación máximo por clarificador     | 362     | 339     | m <sup>3</sup> /h                |
|                                                     |         |         |                                  |
| Número de bombas por clarificador                   |         |         |                                  |
| activas                                             | 3       | 3       | Uds.                             |
| en reserva                                          | 1       | 1       | Uds.                             |
|                                                     |         |         |                                  |
| Caudal unitario necesario                           | 196     | 196     | m <sup>3</sup> /h                |
| Caudal unitario adoptado                            | 200     | 200     | m <sup>3</sup> /h                |
|                                                     |         |         |                                  |
| <b>Zona espesamiento y lamelar</b>                  |         |         |                                  |
| Superficie unitaria espesador mínima                | 353     | 353     | m <sup>2</sup>                   |
| Diámetro mínimo necesario (Ø)                       | 21,19   | 21,19   | m <sup>2</sup>                   |
| Diámetro adoptado (Ø)                               | 21,5    | 21,5    | m                                |
|                                                     |         |         |                                  |
| Superficie unit. zona espesador adoptada            | 363,05  | 363,05  | m <sup>2</sup>                   |

| PARÁMETRO                                              |         |         | Unidad         |
|--------------------------------------------------------|---------|---------|----------------|
| Caudal para tratar                                     | 100 MLD | 300 MLD |                |
| Superficie total zona espesamiento                     | 363,05  | 1089,15 | m <sup>2</sup> |
|                                                        |         |         |                |
| Ancho exterior pasarela (C)                            | 1,2     | 1,2     | m              |
| Ancho 1/2 zona lamelar (B)                             | 10,15   | 10,15   | m              |
| Longitud zona lamelar necesaria (A)                    | 15,79   | 15,79   | m              |
| Longitud adoptada (A)                                  | 15,8    | 15,8    | m              |
| Superficie lamelar resultante:                         |         |         |                |
| unitaria                                               | 320,74  | 320,74  | m <sup>2</sup> |
| total                                                  | 320,74  | 962,22  | m <sup>2</sup> |
| Profundidad de agua adoptada (H)                       | 5,4     | 5,4     | m              |
| Profundidad total (Ht)                                 | 5,8     | 5,8     | m              |
|                                                        |         |         |                |
| <b>Zona de Floculación maduración</b>                  |         |         |                |
| Ancho 1ª zona de maduración (G)                        | 2       | 2       | m              |
| Volumen unitario útil resultante                       | 208,98  | 208,98  | m <sup>3</sup> |
| Volumen necesario 2ª zona maduración                   | 485     | 485     | m <sup>3</sup> |
|                                                        |         |         |                |
| Ancho resultante 2ª zona de maduración (F)             | 4,00    | 4,00    | m              |
| Volumen unitario adoptado 2ª zona maduración           | 464     | 464     | m <sup>3</sup> |
|                                                        |         |         |                |
| Volumen unitario adoptado para maduración              | 673     | 673     | m <sup>3</sup> |
| Volumen total zona maduración                          | 673     | 2.020   | m <sup>3</sup> |
|                                                        |         |         |                |
| <b>Zona de floculación contacto</b>                    |         |         |                |
| Lado x ancho de la cámara (J)                          | 1,5     | 11,5    | m              |
| Volumen resultante unitario                            | 714,2   | 714,2   | m <sup>3</sup> |
| Volumen resultante total                               | 714,2   | 2.142   | m <sup>3</sup> |
|                                                        |         |         |                |
| Volumen resultante floculación (contacto + maduración) | 1.388   | 4.163   | m <sup>3</sup> |
|                                                        |         |         |                |
| <b>Resumen dimensiones</b>                             |         |         |                |
| Volumen floculación contacto                           | 714     | 2.142   | m <sup>3</sup> |
| Volumen floculación maduración                         | 673     | 2.020   | m <sup>3</sup> |
| Volumen zona lamelar                                   | 1.834   | 5.503   | m <sup>3</sup> |
| <b>Volumen total aparato</b>                           | 3.222   | 9.666   | m <sup>3</sup> |
| Superficie espesamiento                                | 363     | 1.089   | m <sup>2</sup> |
|                                                        |         |         |                |
| <b>Condiciones de funcionamiento resultantes</b>       |         |         |                |
|                                                        |         |         |                |
| Tiempo de retención en floculación contacto            | 10      | 10      | min            |
| Tiempo de retención en floculación maduración          | 10      | 10      | min            |
| Tiempo de retención total                              | 48      | 48      | min            |

| PARÁMETRO                                  |         |         | Unidad                            |
|--------------------------------------------|---------|---------|-----------------------------------|
| Caudal para tratar                         | 100 MLD | 300 MLD |                                   |
| Velocidad ascensional lamelar              | 12,90   | 12,90   | m <sup>3</sup> /m <sup>2</sup> .h |
| Carga superficial espesador                |         |         |                                   |
| Con R media                                | 16,3    | 15,4    | kg/m <sup>2</sup> .h              |
| Con R máx.                                 | 16,8    | 15,9    | kg/m <sup>2</sup> .h              |
| <b>Agitación en floculación</b>            |         |         |                                   |
| Potencia específica máxima                 | 10,00   | 10,00   | W/m <sup>3</sup>                  |
| Potencia máxima a adoptar                  | 7,14    | 7,14    | kW                                |
| N.º de agitadores adoptados por cámara     | 1       | 1       | Uds.                              |
| Potencia adoptada por agitador             | 5,20    | 5,20    | kW                                |
| Rendimiento motor                          | 73      | 73      | %                                 |
| Potencia unitaria instalada                | 5,20    | 5,20    | kW                                |
| Tiempo de retención real                   | 10,28   | 10,28   | min                               |
| <b>Diseño de las lamelas</b>               |         |         |                                   |
| Dimensiones zona lamelar                   |         |         |                                   |
| Ancho sector                               | 10,2    | 10,2    | m                                 |
| N.º sectores                               | 2,0     | 2,0     | Uds.                              |
| Ancho total                                | 20,30   | 20,30   | m                                 |
| Largo                                      | 15,80   | 15,80   | m                                 |
| H. media                                   | 5,40    | 5,40    | m                                 |
| Superficie unitaria adoptada, zona lamelar | 321     | 321     | m <sup>2</sup>                    |
| Longitud de lamela                         | 1,5     | 1,5     | m                                 |
| Separación entre caras                     | 80      | 80      | mm                                |
| Inclinación                                | 55      | 55      | º                                 |
| Radio hidráulico                           | 20      | 20      | mm                                |
| Superficie unitaria sobre lamela           | 20,55   | 20,55   | m <sup>2</sup>                    |
| N.º de lamelas en el decantador adoptado   | 302     | 302     | Uds.                              |
| Volumen unitario, zona lamelar             | 394     | 394     | m <sup>3</sup>                    |
| Longitud unitaria de vertedero             | 302     | 302     | m                                 |
| <b>Condiciones de funcionamiento</b>       |         |         |                                   |
| Velocidad ascensional zona lamelar         | 12,90   | 12,90   | m <sup>3</sup> /m <sup>2</sup> .h |
| Velocidad proyectada zona lamelar          | 1,17    | 1,17    | m <sup>3</sup> /m <sup>2</sup> .h |
| Velocidad crítica. HAZEN                   | 1,98    | 1,98    | m/h                               |
| Velocidad crítica. YAO                     | 2,26    | 2,26    | m/h                               |
| Carga sobre vertedero                      | 13,78   | 13,78   | m <sup>3</sup> /ml/h              |

**Tabla 27. Cálculo floculadores hidráulicos. (Fuente: Elaboración propia).**

| PARÁMETROS                   |         |         | Unidad            |
|------------------------------|---------|---------|-------------------|
| Caudal agua de entrada       | 300 MLD | 100 MLD |                   |
| Líneas en funcionamiento     | 6       | 2       | Uds.              |
| Caudal por línea             | 54.998  | 56.234  | m <sup>3</sup> /d |
|                              | 0,636   | 0,651   | m <sup>3</sup> /s |
| Espesor tabiques deflectores | 40      | 40      | mm                |

| Etapas de floculación          | 1A ETAPA | 2A ETAPA | 3A ETAPA | 1A ETAPA | 2A ETAPA | 3A ETAPA |                   |
|--------------------------------|----------|----------|----------|----------|----------|----------|-------------------|
| Valor G                        | 78,857   | 47,291   | 36,104   | 81,509   | 49,028   | 37,456   | seg <sup>-1</sup> |
| Velocidad                      | 0,265    | 0,189    | 0,157    | 0,271    | 0,193    | 0,161    | m/seg             |
| Tiempo de retención            | 9,826    | 9,788    | 9,387    | 9,611    | 9,556    | 9,159    | min               |
| Sección del canal              | 2,399    | 3,373    | 4,048    | 2,400    | 3,367    | 4,039    | m <sup>2</sup>    |
| Ancho del Canal por cálculo    | 0,400    | 0,587    | 0,716    | 0,400    | 0,587    | 0,716    | m                 |
| Longitud del canal de tabiques | 156,404  | 110,832  | 88,571   | 156,401  | 110,830  | 88,562   | m                 |
| Coefficiente Manning           | 0,013    | 0,013    | 0,013    | 0,013    | 0,013    | 0,013    |                   |

|                                       |        |        |        |        |        |        |                |
|---------------------------------------|--------|--------|--------|--------|--------|--------|----------------|
| Numero de tabiques adoptado:          | 22     | 16     | 13     | 22     | 16     | 13     | Uds.           |
| Distancia entre punta tabique y pared | 0,60   | 0,88   | 1,07   | 0,60   | 0,88   | 1,07   | m              |
| Ancho tanque                          | 7,40   | 7,40   | 7,40   | 7,40   | 7,40   | 7,40   | m              |
| Longitud del tabique                  | 6,80   | 6,52   | 6,33   | 6,80   | 6,52   | 6,33   | m              |
| Numero de canales                     | 23     | 17     | 14     | 23     | 17     | 14     | Uds.           |
| Largo etapa                           | 9,20   | 9,98   | 10,02  | 9,20   | 9,98   | 10,03  | m              |
| Largo etapa con tabiques              | 10,08  | 10,62  | 10,54  | 10,08  | 10,62  | 10,55  | m              |
| Volumen útil tanque                   | 408,38 | 424,34 | 419,35 | 408,45 | 423,57 | 418,40 | m <sup>3</sup> |
| Tiempo de retención calculado         | 10,69  | 11,11  | 10,98  | 10,46  | 10,85  | 10,71  | minutos        |

|                                |         |         |                |
|--------------------------------|---------|---------|----------------|
| Volumen Útil Total:            | 1252,06 | 1250,42 | m <sup>3</sup> |
| Tiempo retención total         | 32,78   | 32,02   | min            |
| Longitud total del tanque      | 31,23   | 31,25   | m              |
| Pérdida de carga total         | 39,49   | 41,33   | cm             |
| Ancho interior de tanque total | 7,40    | 7,40    | m              |

**Tabla 28. Cálculo dimensionado decantación lamelar sin recirculación de fangos.**  
(Fuente: Elaboración propia).

| PARÁMETRO                                        |         |          | Unidad                           |
|--------------------------------------------------|---------|----------|----------------------------------|
| Caudal agua de entrada                           | 100 MLD | 300 MLD  |                                  |
| SS del agua bruta                                | 165,00  | 165,00   | g/m <sup>3</sup>                 |
| <b>Criterios de diseño</b>                       |         |          |                                  |
| Líneas de decantación en funcionamiento          | 1       | 3        | Uds.                             |
| Carga superficial                                | 1,00    | 1,00     | m/h                              |
| Inclinación lamelas                              | 55-60   | 55-60    | °                                |
| Distancia de perfil                              | 60,00   | 60,00    | mm                               |
| TRH min                                          | 20      | 20       | min                              |
| ½ Ancho zona lamelar                             | 10,50   | 10,50    | m                                |
| Longitud zona lamelar necesaria                  | 18,60   | 18,19    | m                                |
| Longitud adoptada                                | 44,20   | 44,20    | m                                |
| <b>Superficie lamelar resultante</b>             |         |          |                                  |
| unitaria                                         | 928,20  | 928,20   | m <sup>2</sup>                   |
| total                                            | 928,20  | 2.784,60 | m <sup>2</sup>                   |
| Profundidad de agua adoptada (H)                 | 5,40    | 5,40     | m                                |
| Profundidad total (Ht)                           | 5,80    | 5,80     | m                                |
|                                                  |         |          |                                  |
| Volumen zona lamelar                             | 5.012   | 15.037   | m <sup>3</sup>                   |
| <b>Condiciones de funcionamiento resultantes</b> |         |          |                                  |
| Caudal de funcionamiento                         | 100.000 | 300.000  | m <sup>3</sup> /d                |
|                                                  | 4.166   | 12.500   | m <sup>3</sup> /h                |
|                                                  | 1,16    | 3,47     | m <sup>3</sup> /s                |
| Velocidad ascensional lamelar                    | 5,05    | 4,94     | m <sup>3</sup> /h.m <sup>2</sup> |
| <b>Diseño de las lamelas</b>                     |         |          |                                  |
| Dimensiones zona lamelar:                        |         |          |                                  |
| Ancho sector                                     | 10,50   | 10,50    | m                                |
| N.º sectores                                     | 2       | 2        | Uds.                             |
| Ancho total                                      | 21,00   | 21,00    | m                                |
| Largo                                            | 44,20   | 44,20    | m                                |
| H. media                                         | 5,40    | 5,40     | m                                |
|                                                  |         |          |                                  |
| Superficie unitaria adoptada, zona lamelar       | 928     | 928      | m <sup>2</sup>                   |
|                                                  |         |          |                                  |
| Longitud de lamela                               | 1,50    | 1,50     | m                                |
| Separación entre caras                           | 64,00   | 64,00    | mm                               |
| Inclinación                                      | 60,00   | 60,00    | °                                |

| PARÁMETRO                                |         |         | Unidad                           |
|------------------------------------------|---------|---------|----------------------------------|
| Caudal agua de entrada                   | 100 MLD | 300 MLD |                                  |
| Radio hidráulico                         | 25,00   | 25,00   | mm                               |
| Superficie unitaria sobre lamela         | 21,26   | 21,26   | m <sup>2</sup>                   |
| Velocidad oblicua                        | 9,88    | 9,67    | cm/min                           |
| N.º de lamelas en el decantador adoptado | 1.172   | 1.172   | Uds.                             |
| Volumen unitario, zona lamelar           | 1.206   | 1.206   | m <sup>3</sup>                   |
| Canales por línea                        | 32      | 32      | Uds.                             |
| Canales total                            | 32      | 96      | Uds.                             |
| Agujeros por canal                       | 1.536   | 4.608   | Uds.                             |
| Longitud unitaria de vertedero           | 723     | 2.170   | m                                |
| Carga sobre vertedero                    | 3       | 3       | m <sup>3</sup> /h.m <sup>2</sup> |

| Condiciones de funcionamiento      |      |      |                                  |
|------------------------------------|------|------|----------------------------------|
| Velocidad ascensional zona lamelar | 5,05 | 4,94 | m <sup>3</sup> /h.m <sup>2</sup> |
| Velocidad critica. HAZEN           | 0,61 | 0,59 | m/h                              |

| Producción de Fangos               |        |          |                       |
|------------------------------------|--------|----------|-----------------------|
| SST entrada máx.                   | 165    | 165      | mg/L                  |
| SST entrada media                  | 12     | 12       | mg/L                  |
|                                    |        |          |                       |
| Rendimiento decantador             | 85     | 85       | %                     |
|                                    |        |          |                       |
| Producción de fangos total         | 18.500 | 55.500   | Kg/d                  |
|                                    |        |          |                       |
| Concentración                      | 8      | 8        | Kg/m <sup>3</sup>     |
| Caudal                             | 1.966  | 5.897    | m <sup>3</sup> /d     |
| Nº de purgas                       | 12     | 12       | Uds.                  |
| Caudal por purga                   | 164    | 491      | m <sup>3</sup> /purga |
| Capacidad para almacenar 2,5 horas | 61     | 1.276,12 | m <sup>3</sup>        |

**Tabla 29. Dimensionamiento filtros tasa declinante y lavado mutuo. (Fuente: Elaboración propia).**

| PARÁMETRO                                                 |         |          | UNIDADES |
|-----------------------------------------------------------|---------|----------|----------|
| Caudal agua entrante                                      | 100 MLD | 300 MLD  |          |
| Datos de Diseño                                           |         |          |          |
| Velocidad nominal de filtración                           | 12      | 12       | m/h      |
| Velocidad máxima de filtración con un filtro lavando      | 10      | 10       | m/h      |
| Carrera mínima del filtro                                 | 24      | 24       | h        |
| Mínima lámina de agua sobre el filtro                     | 2,7     | 2,7      | m        |
| Mínimo espesor de lecho                                   | 1500    | 1500     | mm       |
| N.º de filtros adoptados                                  | 8       | 16       | Uds.     |
|                                                           |         |          |          |
| Superficie unitaria necesaria                             |         |          |          |
| Con un filtro lavando                                     | 57,35   | 84,14    | m²       |
| Todos funcionando                                         | 47,80   | 70,12    | m²       |
| Superficie mínima unitaria necesaria                      | 57,35   | 84,14    | m²       |
| Dimensiones adoptadas                                     |         |          |          |
| ancho simple                                              | 3,78    | 3,78     | m        |
| ancho total                                               | 7,56    | 7,56     | m        |
| largo                                                     | 11      | 11       | m        |
| Altura mínima del lecho                                   | 1,5     | 1,5      | m        |
|                                                           |         |          |          |
| Superficie unitaria adoptada                              | 83,16   | 83,16    | m²       |
| Superficie total adoptada                                 |         |          |          |
| Con todos los filtros en servicio                         | 665,28  | 1.330,60 | m²       |
| Con uno fuera de servicio                                 | 582,12  | 1.247,40 | m²       |
| Con dos fuera de servicio                                 | 499,00  | 1.164,20 | m²       |
|                                                           |         |          |          |
| Condiciones de funcionamiento                             |         |          |          |
| Velocidad de filtración con todos los filtros             | 6,90    | 10,12    | m/h      |
| Velocidad de filtración con un filtro fuera de servicio   | 7,88    | 10,79    | m/h      |
| Velocidad de filtración con dos filtros fuera de servicio | 9,20    | 11,56    | m/h      |
| Velocidad de lavado efectiva                              | 55,17   | 80,94    | m³/m² h  |
| Velocidad de lavado requerida                             | 55      | 55       | m³/m² h  |
|                                                           |         |          |          |
| Lecho filtrante                                           |         |          |          |
| Altura arena                                              | 500     | 500      | mm       |
| Altura antracita                                          | 1000    | 1000     | mm       |
| Altura total del lecho                                    | 1500    | 1500     | mm       |
| Talla efectiva                                            |         |          |          |

| PARÁMETRO                   |         |         | UNIDADES       |
|-----------------------------|---------|---------|----------------|
| Caudal agua entrante        | 100 MLD | 300 MLD |                |
| Arena                       | 0,5     | 0,5     | mm             |
| Antracita                   | 1       | 1       | mm             |
| Coefficiente de uniformidad |         |         |                |
| Arena                       | 1,3     | 1,3     |                |
| Antracita                   | 1,5     | 1,5     |                |
| Volumen por filtro          |         |         |                |
| Arena                       | 41,58   | 41,58   | m <sup>3</sup> |
| Antracita                   | 83,16   | 83,16   | m <sup>3</sup> |
| Peso por filtro             |         |         |                |
| Arena                       | 66,53   | 66,53   | t              |
| Antracita                   | 60,71   | 60,71   | t              |
| Total                       | 127,23  | 127,23  | t              |

| EQUIPOS DE LAVADO             |         |         |                                  |
|-------------------------------|---------|---------|----------------------------------|
| AIRE DE LAVADO                |         |         |                                  |
| Caudal específico de proyecto | 60      | 60      | m <sup>3</sup> /m <sup>2</sup> h |
| Caudal de aire necesario      | 4.989,6 | 4.989,6 | Nm <sup>3</sup> /h               |
| Tiempo de aplicación          | 7       | 7       | min                              |
| Número de compresores:        |         |         |                                  |
| Activos                       | 1       | 1       | Uds.                             |
| Reserva                       | 1       | 1       | Uds.                             |
| Caudal unitario necesario     | 4.989,6 | 4.989,6 | Nm <sup>3</sup> /h               |
| Caudal unitario adoptado      | 5.600   | 5.600   | Nm <sup>3</sup> /h               |

| AGUA DE LAVADO           |         |         |                                  |
|--------------------------|---------|---------|----------------------------------|
| Caudal lavado            | 55      | 55      | m <sup>3</sup> /m <sup>2</sup> h |
| Duración                 | 20      | 20      | min                              |
|                          |         |         |                                  |
| Caudal de agua necesario | 4.573,8 | 4.573,8 | m <sup>3</sup> /h                |



**Tabla 30. Dimensionamiento filtros abiertos convencionales. (Fuente: Elaboración propia).**

| PARÁMETRO                                            |         |         | UNIDADES |
|------------------------------------------------------|---------|---------|----------|
| Caudal agua entrante                                 | 100 MLD | 300 MLD |          |
| <b>Datos de Diseño</b>                               |         |         |          |
| Velocidad nominal de filtración                      | 12      | 12      | m/h      |
| Velocidad máxima de filtración con un filtro lavando | 10      | 10      | m/h      |
| Carrera mínima del filtro                            | 24      | 24      | h        |
| Mínima lámina de agua sobre el filtro                | 2,7     | 2,7     | m        |
| Mínimo espesor de lecho                              | 1500    | 1500    | mm       |
| N.º de filtros adoptados                             | 3       | 6       | Uds.     |

|                                      |        |        |    |
|--------------------------------------|--------|--------|----|
| <b>Superficie unitaria necesaria</b> |        |        |    |
| Con un filtro lavando                | 138,89 | 230,11 | m² |
| Todos funcionando                    | 185,19 | 306,81 | m² |
| Superficie mínima unitaria necesaria | 185,19 | 306,81 | m² |
| <b>Dimensiones adoptadas</b>         |        |        |    |
| ancho simple                         | 4,50   | 4,50   | m  |
| ancho total                          | 9      | 9      | m  |
| largo                                | 32     | 32     | m  |
| Altura mínima del lecho              | 1,5    | 1,5    | m  |
| Superficie unitaria adoptada         | 288    | 288    | m² |
| Superficie total adoptada            |        |        |    |
| Con todos los filtros en servicio    | 864,0  | 1728,0 | m² |
| Con uno fuera de servicio            | 576,0  | 1440,0 | m² |
| Con dos fuera de servicio            | 288    | 1152,0 | m² |

|                                                           |       |       |         |
|-----------------------------------------------------------|-------|-------|---------|
| <b>Condiciones de funcionamiento</b>                      |       |       |         |
| Velocidad de filtración con todos los filtros             | 4,82  | 7,99  | m/h     |
| Velocidad de filtración con un filtro fuera de servicio   | 7,23  | 9,59  | m/h     |
| Velocidad de filtración con dos filtros fuera de servicio | 14,47 | 11,98 | m/h     |
| <b>Velocidad de lavado efectiva</b>                       | 55,29 | 81,07 | m³/m² h |
| <b>Velocidad de lavado requerida</b>                      | 55    | 55    | m³/m² h |

|                        |      |      |    |
|------------------------|------|------|----|
| <b>Lecho filtrante</b> |      |      |    |
| Tipo de lecho:         |      |      |    |
| Altura arena           | 500  | 500  | mm |
| Altura antracita       | 1000 | 1000 | mm |
| Altura total del lecho | 1500 | 1500 | mm |

| PARÁMETRO                   |         |         | UNIDADES       |
|-----------------------------|---------|---------|----------------|
| Caudal agua entrante        | 100 MLD | 300 MLD |                |
| Talla efectiva              |         |         |                |
| Arena                       | 0,5     | 0,5     | mm             |
| Antracita                   | 1       | 1       | mm             |
| Coefficiente de uniformidad |         |         |                |
| Arena                       | 1,3     | 1,3     |                |
| Antracita                   | 1,5     | 1,5     |                |
| Volumen por filtro          |         |         |                |
| arena                       | 144     | 144     | m <sup>3</sup> |
| antracita                   | 288     | 288     | m <sup>3</sup> |
| Peso por filtro             |         |         |                |
| arena                       | 230,40  | 230,40  | t              |
| antracita                   | 210,24  | 210,24  | t              |
| total                       | 440,64  | 440,64  | t              |

|                               |         |         |                                  |
|-------------------------------|---------|---------|----------------------------------|
| <b>EQUIPOS DE LAVADO</b>      |         |         |                                  |
| <b>AIRE DE LAVADO</b>         |         |         |                                  |
| Caudal específico de proyecto | 60      | 60      | m <sup>3</sup> /m <sup>2</sup> h |
| Caudal de aire necesario      | 15840,0 | 15849,0 | Nm <sup>3</sup> /h               |
| Tiempo de aplicación          | 7       | 7       | min                              |
| Número de compresores:        |         |         |                                  |
| Activos                       | 2       | 2       | Uds.                             |
| Reserva                       | 1       | 1       | Uds.                             |
| Caudal unitario necesario     | 7920,0  | 7920,0  | Nm <sup>3</sup> /h               |
| Caudal unitario adoptado      | 8000,0  | 8000,0  | Nm <sup>3</sup> /h               |

|                                   |         |         |                                  |
|-----------------------------------|---------|---------|----------------------------------|
| <b>AGUA DE LAVADO</b>             |         |         |                                  |
| Caudal lavado                     | 55      | 55      | m <sup>3</sup> /m <sup>2</sup> h |
| Duración                          | 20      | 20      | min                              |
| Caudal de agua necesario          | 15840,0 | 15840,0 | m <sup>3</sup> /h                |
| Número de bombas:                 |         |         |                                  |
| Activas                           | 3       | 3       | Uds.                             |
| Reserva                           | 1       | 1       | Uds.                             |
| Caudal unitario necesario         | 5280    | 5280    | m <sup>3</sup> /h                |
| Caudal unitario adoptado          | 5300    | 5300    | m <sup>3</sup> /h                |
| Presión de funcionamiento         | 10      | 10      | mca                              |
| Potencia                          | 170     | 170     | kW                               |
| <b>DEPÓSITO DE AGUA DE LAVADO</b> |         |         |                                  |
| Nº de lavados a almacenar         | 1       | 1       | Uds.                             |
| Volumen necesario                 | 5300    | 5300    | m <sup>3</sup>                   |

| PARÁMETRO                          |         |         | UNIDADES       |
|------------------------------------|---------|---------|----------------|
| Caudal agua entrante               | 100 MLD | 300 MLD |                |
| Dimensiones del depósito adoptadas |         |         |                |
| Longitud                           | 48      | 48      | m              |
| Ancho                              | 25      | 25      | m              |
| Altura de agua                     | 4,50    | 4,50    | m              |
| Volumen del depósito adoptado      | 5400    | 5400    | m <sup>3</sup> |

Tabla 31. Dimensionamiento del tanque de retrolavado. (Fuente: Elaboración propia).

| PARÁMETRO                              |          |         | Unidad                  |
|----------------------------------------|----------|---------|-------------------------|
| Caudal de agua entrada                 | 300 MLD  | 100 MLD |                         |
| Volumen                                | 1483,45  | 1483,45 | m <sup>3</sup>          |
| Tiempo de llenado                      | 20       | 20      | min                     |
| Tiempo de sedimentación                | 130      | 130     | min                     |
| Tiempo de vaciado                      | 30       | 30      | min                     |
| Tiempo total ciclo                     | 180      | 180     | min                     |
| TSS en tanque de retrolavado           | 8.325    | 2.775   | Kg/d                    |
| Retención de sólidos                   | 90       | 90      | %                       |
| TSS a tanque homogeneización           | 7.493    | 2.498   | Kg/d                    |
| TSS sobrenadante a cabecera            | 833      | 278     | Kg/d                    |
| Caudal sobrenadante a cabecera         | 22.237   | 9.885   | m <sup>3</sup> /d       |
| Horas de vaciado tanque retrolavado    | 8        | 8       | horas                   |
| Caudal total de bombeo                 | 2.780    | 1.236   | m <sup>3</sup> /vaciado |
| Número de bombas                       | 2        | 2       | Uds.                    |
| Caudal unitario de bombeo necesario    | 1.390    | 618     | m <sup>3</sup> /h       |
| Caudal unitario de bombeo elegido      | 1.600    | 1.600   | m <sup>3</sup> /h       |
| Concentración fango salida             | 5        | 5       | Kg/m <sup>3</sup>       |
| Caudal a tanque homogeneización fangos | 1.498,50 | 499,50  | m <sup>3</sup> /d       |
| Bombeo 1 Ud.                           | 150      | 150     | m <sup>3</sup> /h       |
| Total Bombeo 1+1 Ud.                   | 300      | 150     | m <sup>3</sup> /h       |

**Tabla 32. Cálculo fangos a Tanque de Homogeneización. (Fuente: Elaboración propia).**

| PARÁMETRO                                |          |          | Unidad |
|------------------------------------------|----------|----------|--------|
| Caudal de agua entrada                   | 300 MLD  | 100 MLD  |        |
| Caudal purga decantación                 | 6.890,50 | 2.348,10 | m³/d   |
| Concentración                            | 8        | 8        | Kg/m³  |
| Caudal fango tanque retrolavado          | 1.750,70 | 596,70   | m³/d   |
| Concentración                            | 5        | 5        | Kg/m³  |
| Concentración Mezcla fangos              | 7,40     | 7,40     | Kg/m³  |
| Caudal total a Tanque de Homogeneización | 8.640,20 | 2.945,80 | m³/d   |

**Tabla 33. Cálculo Espesamiento de fangos. (Fuente: Elaboración propia).**

| PARÁMETRO                                             |                 |                 | Unidad |
|-------------------------------------------------------|-----------------|-----------------|--------|
| Caudal agua entrante                                  | 300 MLD         | 100 MLD         |        |
| Carga de sólidos a espesar                            | 63.869,74       | 21.768,45       | Kg/d   |
| Concentración de los fangos                           | 7,4             | 7,4             | kg/m³  |
| Caudal de fangos a espesar                            | 8.634           | 2.946           | m³/d   |
| Tipo de fango a espesar:                              | Fangos mixtos   | Fangos mixtos   |        |
| <b>Turno de funcionamiento semanal:</b>               | 7               | 7               | d/sem  |
| <b>Turno de funcionamiento diario:</b>                | 24              | 24              | h/d    |
| Caudal de fangos a espesar durante 7 días a la semana | 8.643           | 2.946           | m³/d   |
| Carga de sólidos a espesar durante 7 días a la semana | 63.870          | 21.768          | Kg/d   |
| <b>DOSIFICACION DE REACTIVOS</b>                      |                 |                 |        |
| Reactivo previsto como coagulante:                    | Polielectrolito | Polielectrolito |        |
| Dosis media de aplicación                             | 2               | 2               | Kg/t   |
| Dosis máxima de dimensionamiento:                     | 5               | 5               | Kg/t   |
| Riqueza del producto comercial:                       | 100             | 100             | %      |
| Densidad del producto comercial:                      | 0,8             | 0,8             | Kg/L   |
| Consumo medio diario del producto comercial           |                 |                 |        |
| A dosis media:                                        | 127,74          | 43,54           | Kg/d   |
| A dosis máxima:                                       | 319,35          | 108,84          | Kg/d   |
| Consumo medio horario del producto comercial          |                 |                 |        |
| A dosis media:                                        | 5,32            | 1,81            | Kg/h   |

| PARÁMETRO                                          |              |              | Unidad |
|----------------------------------------------------|--------------|--------------|--------|
| Caudal agua entrante                               | 300 MLD      | 100 MLD      |        |
| A dosis máxima:                                    | 13,31        | 4,54         | Kg/h   |
| <b>Dosificador volumétrico</b>                     |              |              |        |
| Capacidad del dosificador volumétrico:             | 30           | 30           | Kg/h   |
| Volumen de la tolva del dosificador:               | 270          | 270          | L      |
| Autonomía de la tolva (condiciones medias):        | 1,7          | 1,7          | d      |
| Concentración de la solución:                      | 0,5          | 0,5          | %      |
| Densidad de la solución:                           | 1            | 1            | Kg/L   |
| <b>Equipo de preparación</b>                       |              |              |        |
| Caudal medio de solución a dosificar:              | 1.064,50     | 362,80       | L/h    |
| Caudal máximo de solución a dosificar:             | 2.661,20     | 907,00       | L/h    |
| <b>Número de equipos instalados</b>                |              |              |        |
| Servicio                                           | 2            | 1            | Uds.   |
| Reserva                                            | 0            | 0            | Uds.   |
| Capacidad de dosificación unit. necesaria          | 1.330,62     | 907,02       | L/h    |
| <b>Capacidad de dosificación unitaria adoptada</b> | 2.800,00     | 2.800,00     | L/h    |
| <b>Número total de bombas:</b>                     |              |              |        |
| Número de bombas en servicio                       | 4            | 4            | Uds.   |
| Número de bombas en reserva:                       | 3            | 3            | Uds.   |
| Rango de dosificación:                             | 120 - 1200   | 120 - 1200   | L/h    |
| <b>ESPEZAMIENTO</b>                                |              |              |        |
| Caudal horario a deshidratar                       | 360,10       | 122,70       | m³/h   |
| Masa horaria a deshidratar                         | 2.661,20     | 907,00       | Kg/h   |
| <b>N.º de equipos de espesamiento adoptados</b>    |              |              |        |
| Servicio                                           | 3            | 1            | Uds.   |
| Reserva                                            | 1            | 3            | Uds.   |
| Caudal horario unitario necesario                  | 120          | 120          | m³/h   |
| Caudal horario unitario adoptado                   | 135          | 135          | m³/h   |
| <b>Impulsión de fangos a espesar</b>               |              |              |        |
| Tipo de bombas empleadas                           | Helicoidales | Helicoidales |        |
| Número total de bombas:                            | 4            | 4            | Uds.   |
| Número de bombas en servicio:                      | 3            | 1            | Uds.   |
| Número de bombas en reserva:                       | 1            | 3            | Uds.   |

| PARÁMETRO                                                    |           |           | Unidad            |
|--------------------------------------------------------------|-----------|-----------|-------------------|
| Caudal agua entrante                                         | 300 MLD   | 100 MLD   |                   |
| <b>Fangos espesados</b>                                      |           |           |                   |
| Concentración o contenido en sólidos de los fangos espesados | 3         | 3         | %                 |
| Densidad de fangos espesados                                 | 1000      | 1000      | Kg/m <sup>3</sup> |
| Volumen de fangos espesados                                  | 2.128,99  | 1.214,83  | m <sup>3</sup> /d |
| Peso de fangos secos:                                        | 63.869,74 | 21.768,45 | Kg/d              |
| Caudal de líquido filtrado:                                  | 6.833     | 1.840     | m <sup>3</sup> /d |

**Tabla 34. Cálculo dimensionado almacenamiento fangos espesados. (Fuente: Elaboración propia).**

| PARÁMETRO                                             |          |         | Unidad            |
|-------------------------------------------------------|----------|---------|-------------------|
| Caudal de agua entrada                                | 300 MLD  | 100 MLD |                   |
| Concentración fango espesado                          | 30       | 30      | Kg/m <sup>3</sup> |
| Caudal fango espesado diario                          | 1.916,10 | 653,10  | m <sup>3</sup> /d |
| Caudal fango espesado horario                         | 79,84    | 27,21   | m <sup>3</sup> /h |
| Tiempo de almacenamiento                              | 8        | 8       | horas             |
| <b>Volumen Tanque almacenamiento fangos espesados</b> |          |         |                   |
| Necesario                                             | 639      | 218     | m <sup>3</sup>    |
| Adoptado                                              | 650      | 325     | m <sup>3</sup>    |

**Tabla 35. Cálculo deshidratación con Filtros Banda. (Fuente: Elaboración propia).**

| PARÁMETRO                                        |           |           | Unidad            |
|--------------------------------------------------|-----------|-----------|-------------------|
| Caudal de agua entrada                           | 300 MLD   | 100 MLD   |                   |
| Carga de SST a deshidratar                       | 57.482,76 | 19.591,61 | Kg/d              |
| Carga de SSV a deshidratar                       | 34.498,66 | 11.754,96 | Kg/d              |
| Concentración de los fangos                      | 30        | 30        | kg/m <sup>3</sup> |
| Caudal de fangos a deshidratar                   | 1.916,09  | 653,10    | m <sup>3</sup> /d |
|                                                  |           |           |                   |
| <b>Turno de funcionamiento semanal:</b>          | 7         | 7         | d/sem             |
| <b>Turno de funcionamiento diario:</b>           | 16        | 16        | h/d               |
| <b>Caudal de fangos a deshidratar por 7 días</b> | 1.916,10  | 653,10    | m <sup>3</sup> /d |
| Carga de sólidos a deshidratar por hora          | 3.592,67  | 1.224,48  | Kg/h              |
| Caudal de fangos a deshidratar por hora          | 119,76    | 40,82     | m <sup>3</sup> /h |
|                                                  |           |           |                   |
| <b>DOSIFICACIÓN DE REACTIVOS</b>                 |           |           |                   |

| PARÁMETRO                                           |                 |                 | Unidad             |
|-----------------------------------------------------|-----------------|-----------------|--------------------|
| Caudal de agua entrada                              | 300 MLD         | 100 MLD         |                    |
| Reactivo previsto como coagulante:                  | Polielectrolito | Polielectrolito |                    |
| Dosis media:                                        | 4               | 4               | Kg/t               |
| Dosis máxima:                                       | 7               | 7               | Kg/t               |
| Riqueza del producto comercial:                     | 100             | 100             | % w/w              |
| Densidad del producto comercial:                    | 0,80            | 0,80            | Kg/dm <sup>3</sup> |
|                                                     |                 |                 |                    |
| Consumo medio diario del producto comercial         |                 |                 |                    |
| A dosis media:                                      | 23,00           | 7,80            | Kg/d               |
| A dosis máxima:                                     | 402,40          | 137,10          | Kg/d               |
|                                                     |                 |                 |                    |
| <b><u>Preparación de la solución</u></b>            |                 |                 |                    |
| <b><i>Dosificador volumétrico</i></b>               |                 |                 |                    |
| Capacidad del dosificador volumétrico:              | 30              | 30              | Kg/h               |
| Volumen de la tolva del dosificador:                | 270             | 270             | L                  |
| Autonomía de la tolva<br>(condiciones medias):      | 0,9             | 2,6             | d                  |
| Concentración de la solución primaria:              | 0,5             | 0,5             | %                  |
| Densidad de la solución primaria:                   | 1               | 1               | Kg/L               |
|                                                     |                 |                 |                    |
| <b><i>Equipo de preparación</i></b>                 |                 |                 |                    |
| Caudal medio de solución a dosificar:               | 2.874,10        | 979,60          | L/h                |
| Caudal máximo de solución a dosificar:              | 4.311,20        | 1.469,40        | L/h                |
|                                                     |                 |                 |                    |
| <b>Número de equipos instalados</b>                 | 3               | 3               | Uds.               |
| Servicio:                                           | 2               | 2               | Uds.               |
| Reserva:                                            | 1               | 1               | Uds.               |
|                                                     |                 |                 |                    |
| Capacidad de dosificación unitaria necesaria        | 4.311,21        | 1.469,37        | L/h                |
| <b>Capacidad de dosificación unitaria adoptada:</b> | 5.500,00        | 5.500,00        | L/h                |
|                                                     |                 |                 |                    |
| <b><u>Dosificación de la solución</u></b>           |                 |                 |                    |
| <b>Número total de bombas:</b>                      | 2               | 2               | Uds.               |
| Número de bombas en servicio:                       | 1               | 1               | Uds.               |
| Número de bombas en reserva:                        | 1               | 1               | Uds.               |
| <b>Rango de dosificación:</b>                       | 120-1200        | 120-1200        | L/h                |
|                                                     |                 |                 |                    |
| <b><u>EQUIPOS DE DESHIDRATACIÓN</u></b>             |                 |                 |                    |
| <b><u>Filtros banda</u></b>                         |                 |                 |                    |
| Rendimiento del filtro                              | 300             | 300             | Kg/h.m             |

| PARÁMETRO                                           |         |         | Unidad |
|-----------------------------------------------------|---------|---------|--------|
| Caudal de agua entrada                              | 300 MLD | 100 MLD |        |
| Anchura total de banda necesaria                    | 12      | 4,1     | m      |
| Ancho de banda unitario adoptado                    | 2       | 2       | m      |
| N.º de equipos necesarios                           | 0,25    | 0,6     | u      |
| N.º de equipos adoptados:                           |         |         |        |
| Servicio                                            | 4       | 2       | Uds.   |
| Reserva                                             | 0       | 2       | Uds.   |
| <b>Condiciones de funcionamiento</b>                |         |         |        |
| Caudal a deshidratar por máquina:                   | 29,90   | 20,40   | m³/h   |
| Masa a deshidratar por máquina:                     | 449     | 306     | Kg/m h |
|                                                     |         |         |        |
| <b>Impulsión de fangos a deshidratar</b>            |         |         |        |
| <b>Tipo de bombas empleadas</b>                     |         |         |        |
| Número total de bombas:                             | 4       | 4       | Uds.   |
| Número de bombas en servicio:                       | 4       | 2       | Uds.   |
| Número de bombas en reserva:                        | 0       | 2       | Uds.   |
| Capacidad de impulsión unitaria:                    | 2,5-10  | 2,5-10  | m³/h   |
|                                                     |         |         |        |
| <b>Almacenamiento de fangos</b>                     |         |         |        |
| Contenido en sólidos de los fangos secos:           | 20      | 20      | %      |
| Densidad de los fangos secos:                       | 1.175   | 1.175   | kg/m³  |
| Volumen de los fangos deshidratados:                | 240     | 83      | m³/d   |
| Peso de los fangos secos:                           | 282     | 98      | t/d    |
| Caudal de líquido filtrado:                         | 2.021   | 687     | m³/d   |
| <b>Sistema de evacuación final y almacenamiento</b> |         |         |        |
| Autonomía de almacenamiento necesaria               | 5       | 5       | d      |
| Cantidad de silos prevista                          | 8       | 3       | Uds.   |
| Volumen unitario necesario                          | 150     | 139     | m³     |
| Volumen unitario adoptado                           | 150     | 150     | m³     |



## 2.6. CÁLCULOS CONSUMO ENERGÉTICO

Tabla 36. Consumo energético equipos mecánicos ETAP Convencional. (Fuente: Elaboración propia).

| EQUIPO                                                           | UNIDADES |            | VARIABLES DE FRECUENCIA |            | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    |
|------------------------------------------------------------------|----------|------------|-------------------------|------------|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|
|                                                                  | ACTIVAS  | EN RESERVA | ACTIVOS                 | EN RESERVA |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVar] | APARENTE [kVA] | FACTOR DE POTENCIA |
| POZO BOMBEO DE ENTRADA                                           |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Clasificador de arenas                                           | 1        |            | 1                       |            | 460            | 365,00                | 24,00                      | 0,40           | 0,50           | 74,50                 | 0,65                         | 0,21            | 0,69           | 0,95               |
| Bombas arenas (50 m³/h a 12 mca)                                 | 1        |            | 1                       |            | 460            | 365,00                | 24,00                      | 1,92           | 2,50           | 86,80                 | 2,39                         | 0,78            | 2,51           | 0,95               |
| Bombas agua entrada (4.600 m³/h a 8 mca)                         | 3        | 1          | 3                       | 1          | 460            | 365,00                | 23,98                      | 86,98          | 150,00         | 96,40                 | 282,08                       | 92,71           | 296,92         | 0,95               |
| Puente grúa 10.000 Kg                                            | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 9,38           | 11,25          | 92,70                 | 10,11                        | 6,53            | 12,04          | 0,84               |
| Válvulas motorizadas DN1400 (entrada agua)                       | 2        |            |                         |            | 460            | 20,00                 | 0,10                       | 14,00          | 3,00           | 86,80                 | 32,26                        | 25,03           | 40,83          | 0,79               |
| Válvulas motorizadas DN1000/DN800 (Bombeo agua)                  | 8        |            |                         |            | 460            | 20,00                 | 0,10                       | 14,00          | 3,00           | 86,80                 | 129,03                       | 100,14          | 163,33         | 0,79               |
| Válvulas motorizadas DN1200/DN1400 (líneas a floculación)        | 5        |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 14,40                        | 11,18           | 18,23          | 0,79               |
| Bombas vaciado (150 m³/h a 12 mca)                               | 1        |            |                         |            | 460            | 2,00                  | 8,00                       | 5,77           | 7,50           | 89,30                 | 6,46                         | 4,68            | 7,98           | 0,81               |
|                                                                  |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| COAGULACIÓN (CÁMARA MEZCLA RÁPIDA)                               |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Bombas transferencia policloruro de aluminio (110 m³/h a 9 mca)  | 1        |            |                         |            | 460            | 12,00                 | 1,00                       | 2,50           | 3,00           | 86,80                 | 2,88                         | 2,24            | 3,65           | 0,79               |
| Bombas dosificadoras policloruro de aluminio (2.500 L/h a 2 bar) | 2        | 1          | 2                       | 1          | 460            | 365,00                | 24,00                      | 1,83           | 2,20           | 85,90                 | 4,56                         | 1,50            | 4,80           | 0,95               |
| Bombas dosificadoras sulfato de alúmina (2.500 L/h a 3 bar)      | 2        | 1          | 2                       | 1          | 460            | 365,00                | 24,00                      | 1,83           | 2,20           | 85,90                 | 4,56                         | 1,50            | 4,80           | 0,95               |
| Bombas dosificadoras ácido sulfúrico (70 L/h a 2 bar)            | 1        | 1          | 1                       | 1          | 460            | 365,00                | 24,00                      | 0,19           | 0,24           | 68,30                 | 0,37                         | 0,12            | 0,39           | 0,95               |
| Bombas dosificadoras hidróxido de sodio (50 L/h a 2 bar)         | 1        | 1          | 1                       | 1          | 460            | 365,00                | 24,00                      | 0,19           | 0,24           | 68,30                 | 0,37                         | 0,12            | 0,39           | 0,95               |
| Agitador eje vertical mezcla                                     | 3        |            |                         |            | 460            | 365,00                | 24,00                      | 9,17           | 11,00          | 92,30                 | 29,79                        | 19,25           | 35,47          | 0,84               |
|                                                                  |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |

| ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|-----------------------------------|------------------------------------|------------------------------------------|
|                                   |                                    |                                          |
| 5.702,00                          | 15,62                              | 0,00004734                               |
| 20.919,30                         | 57,31                              | 0,00017368                               |
| 2.469.030,75                      | 6.764,47                           | 0,02049839                               |
| 20,23                             | 1,01                               | 0,00000306                               |
| 64,52                             | 3,23                               | 0,00000978                               |
| 258,06                            | 12,90                              | 0,00003910                               |
| 28,80                             | 1,44                               | 0,00000436                               |
| 103,39                            | 51,70                              | 0,00017232                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 34,56                             | 2,88                               | 0,00000873                               |
| 39.985,28                         | 109,55                             | 0,00033197                               |
| 39.985,28                         | 109,55                             | 0,00033197                               |
| 3.259,71                          | 8,93                               | 0,00002706                               |
| 3.259,71                          | 8,93                               | 0,00002706                               |
| 260.996,75                        | 715,06                             | 0,00238353                               |
|                                   |                                    |                                          |

| EQUIPO                                                              | UNIDADES |            | VARIABLES DE FRECUENCIA |            | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    |
|---------------------------------------------------------------------|----------|------------|-------------------------|------------|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|
|                                                                     | ACTIVAS  | EN RESERVA | ACTIVOS                 | EN RESERVA |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVAr] | APARENTE [kVA] | FACTOR DE POTENCIA |
| <b>FLOCULACIÓN CONVENCIONAL</b>                                     |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Compuerta murales motorizadas (1400 x 1400 mm)                      | 9        |            |                         |            | 460            | 20,00                 | 0,10                       | 0,60           | 0,75           | 81,00                 | 6,67                         | 6,24            | 9,13           | 0,73               |
| Rompe bóvedas dosificador permanganato potásico                     | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 0,60           | 0,75           | 81,00                 | 1,48                         | 1,39            | 2,03           | 0,73               |
| Stand descargar de big-bag                                          | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 0,14           | 0,18           | 68,30                 | 0,42                         | 0,31            | 0,52           | 0,81               |
| Sistema de calefacción permanganato potásico                        | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 0,20           | 0,25           | 68,30                 | 0,59                         | 0,42            | 0,72           | 0,81               |
| Agitado vertical permanganato potásico                              | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 1,29           | 1,55           | 85,90                 | 3,01                         | 2,41            | 3,86           | 0,78               |
| Bombas dosificadoras permanganato potásico (700 L/h a 2 bar)        | 1        | 1          | 1                       | 1          | 460            | 365,00                | 24,00                      | 0,30           | 0,37           | 72,40                 | 0,50                         | 0,16            | 0,53           | 0,95               |
| Equipo compacto preparación polielectrolito floculación (1.200 L)   | 1        | 1          |                         |            | 460            | 365,00                | 24,00                      | 0,74           | 0,92           | 83,70                 | 0,88                         | 0,71            | 1,13           | 0,78               |
| Bombas dosificadoras polielectrolito (floculación) (40 L/h a 2 bar) | 1        | 1          | 1                       | 1          | 460            | 365,00                | 16,00                      | 0,19           | 0,24           | 68,30                 | 0,37                         | 0,12            | 0,39           | 0,95               |
| Agitador eje vertical mezcla lenta                                  | 3        |            |                         |            | 460            | 365,00                | 24,00                      | 4,33           | 5,20           | 89,00                 | 14,61                        | 10,96           | 18,26          | 0,80               |
|                                                                     |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>DECANTADOR LAMELAR CON RECIRCULACIÓN DE FANGOS</b>               |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Válvulas motorizadas DN400 (fangos)                                 | 14       |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 40,32                        | 31,29           | 51,04          | 0,79               |
| Válvulas motorizadas DN1200 (caudalímetros)                         | 6        |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 17,28                        | 13,41           | 21,87          | 0,79               |
| Polipasto 1.500 Kg                                                  | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 1,98           | 2,37           | 86,80                 | 2,28                         | 1,77            | 2,88           | 0,79               |
| Bombas vaciado (500 m³/h a 10 mca)                                  | 1        | 1          |                         |            | 460            | 1,00                  | 8,00                       | 16,03          | 22,00          | 93,30                 | 17,18                        | 11,99           | 20,95          | 0,82               |
| Motor arrastre espesador                                            | 3        |            |                         |            | 460            | 365,00                | 24,00                      | 6,25           | 7,50           | 89,30                 | 21,00                        | 15,20           | 25,92          | 0,81               |
| Bombas recirculación fangos (200 m³/h a 8 mca)                      | 3        | 1          | 3                       | 1          | 460            | 365,00                | 12,00                      | 7,27           | 7,85           | 92,30                 | 24,74                        | 8,13            | 26,05          | 0,95               |
| Bombas purga fangos (150 m³/h a 8 mca)                              | 2        | 1          | 2                       | 1          | 460            | 365,00                | 4,00                       | 10,61          | 18,50          | 93,30                 | 23,83                        | 7,83            | 25,08          | 0,95               |
|                                                                     |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>FILTROS ABIERTOS</b>                                             |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |

| ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|-----------------------------------|------------------------------------|------------------------------------------|
|                                   |                                    |                                          |
| 13,33                             | 0,67                               | 0,00000202                               |
| 12.977,78                         | 35,56                              | 0,00010774                               |
| 3.693,82                          | 10,12                              | 0,00003067                               |
| 5.130,31                          | 14,06                              | 0,00004259                               |
| 26.344,59                         | 72,18                              | 0,00021872                               |
| 4.378,60                          | 12,00                              | 0,00003635                               |
| 7.702,94                          | 21,10                              | 0,00006395                               |
| 2.173,14                          | 5,95                               | 0,00001804                               |
| 85.303,37                         | 233,71                             | 0,00077903                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 80,65                             | 4,03                               | 0,00001222                               |
| 34,56                             | 1,73                               | 0,00000524                               |
| 4,55                              | 0,23                               | 0,00000069                               |
| 137,44                            | 137,44                             | 0,00041650                               |
| 183.930,57                        | 503,92                             | 0,00167973                               |
| 108.377,12                        | 296,92                             | 0,00098975                               |
| 34.785,72                         | 95,30                              | 0,00031768                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |

| EQUIPO                                                                  | UNIDADES |            | VARIABLES DE FRECUENCIA |            | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    |
|-------------------------------------------------------------------------|----------|------------|-------------------------|------------|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|
|                                                                         | ACTIVAS  | EN RESERVA | ACTIVOS                 | EN RESERVA |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVAr] | APARENTE [kVA] | FACTOR DE POTENCIA |
| Compuertas murales motorizadas (entrada agua) (600 x 600 mm)            | 16       |            |                         |            | 460            | 20,00                 | 0,10                       | 0,16           | 0,20           | 68,30                 | 3,75                         | 2,71            | 4,63           | 0,81               |
| Compuertas murales motorizadas (retrolavado filtros) (1100 x 1100 mm)   | 16       |            |                         |            | 460            | 20,00                 | 0,10                       | 0,16           | 0,20           | 68,30                 | 3,75                         | 2,71            | 4,63           | 0,81               |
| Polipasto 3.000 Kg                                                      | 2        |            |                         |            | 460            | 20,00                 | 0,10                       | 3,27           | 3,93           | 86,80                 | 7,54                         | 5,46            | 9,30           | 0,81               |
| Válvulas motorizadas DN400 (ingreso aire)                               | 16       |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 46,08                        | 35,76           | 58,33          | 0,79               |
| Válvulas motorizadas DN90 (vaciado)                                     | 16       |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 46,08                        | 35,76           | 58,33          | 0,79               |
| Válvulas motorizadas DN200 (salida agua)                                | 16       |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 46,08                        | 35,76           | 58,33          | 0,79               |
| Soplantes lavado de filtros (8.400 Nm³/h a 7 mca)                       | 2        | 1          | 2                       | 1          | 460            | 365,00                | 1,00                       | 190,00         | 202,00         | 96,60                 | 407,07                       | 133,80          | 428,50         | 0,95               |
| Bombas de lavado de filtros (5.300 m³/h a 10 mca)                       | 3        | 1          | 3                       | 1          | 460            | 365,00                | 8,00                       | 200,00         | 225,00         | 96,60                 | 641,67                       | 210,91          | 675,44         | 0,95               |
|                                                                         |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>TANQUE RETROLAVADO</b>                                               |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Compuertas murales motorizadas (entrada y salida agua) (1300 X 1300 mm) | 4        |            |                         |            | 460            | 20,00                 | 0,10                       | 0,32           | 0,40           | 74,50                 | 1,72                         | 1,61            | 2,35           | 0,73               |
| Válvulas motorizadas DN500 (sobrenadantes)                              | 3        |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 8,64                         | 6,71            | 10,94          | 0,79               |
| Válvulas motorizadas (caudalímetros sobrenadantes)                      | 3        |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 8,64                         | 6,71            | 10,94          | 0,79               |
| Bomba fangos (300 m³/h a 8 mca)                                         | 2        | 2          | 2                       | 2          | 460            | 365,00                | 16,06                      | 10,90          | 11,20          | 92,70                 | 24,49                        | 8,05            | 25,78          | 0,95               |
| Bomba sobrenadantes (1.600 m³/h a 8 mca)                                | 2        | 1          | 2                       | 1          | 460            | 365,00                | 8,00                       | 46,60          | 52,00          | 95,40                 | 100,09                       | 32,90           | 105,36         | 0,95               |
| Polipasto 1.600 Kg                                                      | 2        |            |                         |            | 460            | 20,00                 | 0,10                       | 1,98           | 2,37           | 86,80                 | 4,55                         | 3,53            | 5,76           | 0,79               |
|                                                                         |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>TANQUE ALMACENAMIENTO AGUA TRATADA</b>                               |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Agitadores sumergibles                                                  | 12       |            |                         |            | 460            | 365,00                | 24,00                      | 9,33           | 11,20          | 92,70                 | 120,82                       | 78,04           | 143,83         | 0,84               |
| Válvulas motorizadas DN2200/DN1800 (caudalímetros)                      | 3        |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 8,64                         | 6,71            | 10,94          | 0,79               |
| Válvulas motorizadas DN1600 (entrada y salida de agua)                  | 4        |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 11,52                        | 8,94            | 14,58          | 0,79               |

| ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|-----------------------------------|------------------------------------|------------------------------------------|
| 7,50                              | 0,37                               | 0,00000114                               |
| 7,50                              | 0,37                               | 0,00000114                               |
| 15,07                             | 0,75                               | 0,00000228                               |
| 92,17                             | 4,61                               | 0,00001396                               |
| 92,17                             | 4,61                               | 0,00001396                               |
| 92,17                             | 4,61                               | 0,00001396                               |
| 148.582,28                        | 407,07                             | 0,00135692                               |
| 1.873.670,60                      | 5.133,34                           | 0,01711115                               |
|                                   |                                    |                                          |
| 3,44                              | 0,17                               | 0,00000052                               |
| 17,28                             | 0,86                               | 0,00000262                               |
| 17,28                             | 0,86                               | 0,00000262                               |
| 143.551,83                        | 393,29                             | 0,00119180                               |
| 292.274,25                        | 800,75                             | 0,00242652                               |
| 9,10                              | 0,46                               | 0,00000138                               |
|                                   |                                    |                                          |
| 1.058.381,88                      | 2.899,68                           | 0,00878690                               |
| 17,28                             | 0,86                               | 0,00000262                               |
| 23,04                             | 1,15                               | 0,00000349                               |

| EQUIPO                                                                     | UNIDADES |            | VARIABLES DE FRECUENCIA |            | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    |
|----------------------------------------------------------------------------|----------|------------|-------------------------|------------|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|
|                                                                            | ACTIVAS  | EN RESERVA | ACTIVOS                 | EN RESERVA |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVAr] | APARENTE [kVA] | FACTOR DE POTENCIA |
| Polipasto 2.000 Kg                                                         | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 2,39           | 2,87           | 86,80                 | 2,76                         | 2,14            | 3,49           | 0,79               |
|                                                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>TANQUE CONCENTRADOS</b>                                                 |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Bombas sobrenadantes (380 m³/h a 10 mca)                                   | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 10,90          | 14,90          | 92,70                 | 23,52                        | 15,19           | 28,00          | 0,84               |
|                                                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>TANQUE HOMOGENEIZACIÓN FANGOS</b>                                       |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Agitadores sumergibles                                                     | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 2,50           | 3,00           | 86,80                 | 5,76                         | 4,47            | 7,29           | 0,79               |
| Bombas fangos homogeneizados (140 m³/h a 12 mca)                           | 3        | 1          | 3                       | 1          | 460            | 365,00                | 24,00                      | 10,61          | 18,50          | 93,30                 | 35,74                        | 11,75           | 37,62          | 0,95               |
|                                                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>ESPESAMIENTO FANGOS</b>                                                 |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Mesas espesadoras 1000 Kg/h                                                | 3        | 1          |                         |            | 460            | 365,00                | 24,00                      | 1,83           | 2,20           | 85,90                 | 6,40                         | 5,14            | 8,21           | 0,78               |
| Agitadores sumergibles tanque fangos espesados                             | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 2,50           | 3,00           | 86,80                 | 5,76                         | 4,47            | 7,29           | 0,79               |
| Bombas fangos espesados (30 m³/h a 8 mca)                                  | 3        | 1          | 3                       | 1          | 460            | 365,00                | 16,00                      | 0,79           | 5,50           | 89,00                 | 3,42                         | 1,13            | 3,60           | 0,95               |
| Polipasto 1.000 Kg                                                         | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 0,81           | 1,01           | 83,70                 | 0,97                         | 0,77            | 1,24           | 0,78               |
| Equipo compacto preparación polielectrolito espesamiento (6.000 L)         | 1        | 1          |                         |            | 460            | 365,00                | 24,00                      | 0,88           | 1,10           | 83,70                 | 1,05                         | 0,84            | 1,35           | 0,78               |
| Bombas dosificación polielectrolito (espesamiento) (1250-5000 L/h a 3 bar) | 3        | 1          | 3                       | 1          | 460            | 365,00                | 16,00                      | 0,64           | 0,80           | 83,70                 | 2,59                         | 0,85            | 2,73           | 0,95               |
|                                                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>DESHIDRATACIÓN DE FANGOS</b>                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Filtros banda 900 Kg/h                                                     | 3        | 1          |                         |            | 460            | 365,00                | 16,00                      | 4,29           | 5,15           | 89,00                 | 14,47                        | 10,85           | 18,08          | 0,80               |
| Puente grúa 10.000 Kg                                                      | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 10,42          | 12,50          | 92,70                 | 11,24                        | 7,26            | 13,38          | 0,84               |
| Tornillo transportador fangos deshidratados (20 m³/h)                      | 1        |            |                         |            | 460            | 365,00                | 16,00                      | 16,09          | 18,50          | 93,30                 | 17,24                        | 12,04           | 21,03          | 0,82               |

| ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|-----------------------------------|------------------------------------|------------------------------------------|
| 5,51                              | 0,28                               | 0,00000083                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 206.006,47                        | 564,40                             | 0,00171031                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 50.460,83                         | 138,25                             | 0,00041894                               |
| 313.071,50                        | 857,73                             | 0,00259918                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 56.088,47                         | 153,67                             | 0,00046566                               |
| 50.460,83                         | 138,25                             | 0,00041894                               |
| 19.995,70                         | 54,78                              | 0,00016601                               |
| 1,93                              | 0,10                               | 0,00000029                               |
| 9.210,04                          | 25,23                              | 0,00007646                               |
| 15.148,42                         | 41,50                              | 0,00012577                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 84.483,15                         | 231,46                             | 0,00070140                               |
| 22,47                             | 1,12                               | 0,00000341                               |
| 100.694,35                        | 275,87                             | 0,00083598                               |

| EQUIPO                                                                     | UNIDADES |            | VARIABLES DE FRECUENCIA |            | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    | ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|----------------------------------------------------------------------------|----------|------------|-------------------------|------------|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|-----------------------------------|------------------------------------|------------------------------------------|
|                                                                            | ACTIVAS  | EN RESERVA | ACTIVOS                 | EN RESERVA |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVar] | APARENTE [kVA] | FACTOR DE POTENCIA |                                   |                                    |                                          |
| Tornillo transportador fangos deshidratados (10 m³/h)                      | 2        |            |                         |            | 460            | 365,00                | 16,00                      | 4,58           | 5,50           | 89,00                 | 10,30                        | 7,72            | 12,87          | 0,80               | 60.149,81                         | 164,79                             | 0,00049938                               |
| Tornillo transportador fangos deshidratados (10 m³/h)                      | 2        |            |                         |            | 460            | 365,00                | 16,00                      | 2,50           | 3,00           | 86,80                 | 5,76                         | 4,47            | 7,29           | 0,79               | 33.640,55                         | 92,17                              | 0,00027929                               |
| Elevador de cangilones (10 m³/h)                                           | 2        |            |                         |            | 460            | 365,00                | 16,00                      | 4,58           | 5,50           | 89,00                 | 10,30                        | 7,72            | 12,87          | 0,80               | 60.149,81                         | 164,79                             | 0,00049938                               |
| Tornillo transportador fangos deshidratados (5 m³/h)                       | 4        |            |                         |            | 460            | 365,00                | 16,00                      | 1,20           | 1,50           | 84,30                 | 5,69                         | 3,83            | 6,86           | 0,83               | 33.252,67                         | 91,10                              | 0,00027607                               |
| Equipo compacto preparación polielectrolito espesamiento (6.000 L)         | 1        | 1          |                         |            | 460            | 365,00                | 24,00                      | 1,54           | 1,85           | 85,90                 | 1,79                         | 1,44            | 2,30           | 0,78               | 15.721,77                         | 43,07                              | 0,00013053                               |
| Bombas dosificación polielectrolito (espesamiento) (1250-5000 L/h a 3 bar) | 3        | 1          | 3                       | 1          | 460            | 365,00                | 16,00                      | 0,44           | 0,55           | 74,50                 | 2,11                         | 0,69            | 2,23           | 0,95               | 12.344,66                         | 33,82                              | 0,00010249                               |
| Compuerta descarga silos                                                   | 8        |            |                         |            | 460            | 365,00                | 2,00                       | 0,88           | 1,10           | 83,70                 | 8,41                         | 6,75            | 10,78          | 0,78               | 6.140,02                          | 16,82                              | 0,00005098                               |
| Báscula camiones                                                           | 1        |            |                         |            | 460            | 365,00                | 2,00                       | 0,20           | 0,25           | 68,30                 | 0,29                         | 0,21            | 0,36           | 0,81               | 213,76                            | 0,59                               | 0,00000177                               |
|                                                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| <b>EDIFICIO CLOROGAS</b>                                                   |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| Básculas 2000 Kg                                                           | 2        |            |                         |            | 460            | 365,00                | 1,00                       | 1,83           | 2,20           | 85,90                 | 4,27                         | 3,42            | 5,47           | 0,78               | 1.558,01                          | 4,27                               | 0,00001293                               |
| Vaporizadores 120 Kg/h                                                     | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 12,50          | 15,00          | 92,70                 | 26,97                        | 17,42           | 32,11          | 0,84               | 236.245,95                        | 647,25                             | 0,00196136                               |
| Reguladores de vacío                                                       | 6        |            |                         |            | 460            | 365,00                | 24,00                      | 0,02           | 0,03           | 68,30                 | 0,18                         | 0,13            | 0,22           | 0,81               | 1.539,09                          | 4,22                               | 0,00001278                               |
| Bombas circulación <i>Scrubber</i>                                         | 2        |            |                         |            | 460            | 12,00                 | 3,00                       | 4,58           | 5,50           | 9,00                  | 10,30                        | 7,72            | 12,87          | 0,80               | 370,79                            | 30,90                              | 0,00009363                               |
| Gas Fan                                                                    | 2        |            |                         |            | 460            | 12,00                 | 3,00                       | 3,33           | 4,00           | 86,80                 | 7,68                         | 5,56            | 9,48           | 0,81               | 276,50                            | 23,04                              | 0,00006982                               |
| Puente grúa 2.000 Kg                                                       | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 3,43           | 4,11           | 89,00                 | 3,85                         | 2,89            | 4,81           | 0,80               | 7,70                              | 0,38                               | 0,00000117                               |
|                                                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| <b>OTROS</b>                                                               |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| Grupo de agua a presión (agua filtrada para servicios) (50 m³/h a 70 mca)  | 2        | 2          |                         |            | 415            | 365,00                | 18,00                      | 16,09          | 18,50          | 93,30                 | 34,48                        | 24,07           | 42,05          | 0,82               | 226.562,28                        | 620,72                             | 0,00188097                               |
| Grupo de agua a presión (agua potable) (25 m³/h a 50 mca)                  | 1        | 1          | 1                       | 1          | 415            | 365,00                | 18,00                      | 4,58           | 5,50           | 89,00                 | 5,40                         | 1,77            | 5,68           | 0,95               | 35.476,77                         | 97,20                              | 0,00029454                               |
| Compresores aire de servicio (1000L/h a 10 bar)                            | 8        |            |                         |            | 415            | 365,00                | 8,00                       | 0,20           | 0,25           | 68,30                 | 2,34                         | 1,70            | 2,89           | 0,81               | 6.840,41                          | 18,74                              | 0,00005679                               |

| EQUIPO                 | UNIDADES |            | VARIABLES DE FRECUENCIA |            | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    | ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|------------------------|----------|------------|-------------------------|------------|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|-----------------------------------|------------------------------------|------------------------------------------|
|                        | ACTIVAS  | EN RESERVA | ACTIVOS                 | EN RESERVA |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVAr] | APARENTE [kVA] | FACTOR DE POTENCIA |                                   |                                    |                                          |
| Sistema HVAC (control) | 1        |            |                         |            | 415            | 365,00                | 14,00                      | 223,21         | 250,00         | 96,60                 | 231,07                       | 130,95          | 265,60         | 0,87               | 1.180.771,22                      | 3.234,99                           | 0,00980300                               |
| Sistema HVAC (otros)   | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 223,21         | 250,00         | 96,60                 | 231,07                       | 130,95          | 265,60         | 0,87               | 1.012.089,62                      | 2.772,85                           | 0,00840257                               |
| Iluminación exterior   | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 66,96          | 75,00          | 95,70                 | 69,97                        | 43,37           | 82,32          | 0,85               | 306.482,31                        | 839,68                             | 0,00254448                               |
| Iluminación interior   | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 47,83          | 55,00          | 95,40                 | 50,13                        | 31,07           | 58,98          | 0,85               | 219.578,89                        | 601,59                             | 0,00182299                               |
| Puente grúa 6.000 Kg   | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 4,56           | 5,47           | 89,00                 | 5,12                         | 3,84            | 6,40           | 0,80               | 10,24                             | 0,51                               | 0,00000155                               |
| UPS                    | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 0,12           | 0,15           | 68,30                 | 0,18                         | 0,13            | 0,22           | 0,81               | 769,55                            | 2,11                               | 0,00000639                               |
| A/C                    | 3        |            |                         |            | 415            | 365,00                | 12,00                      | 4,67           | 5,60           | 89,30                 | 15,68                        | 11,35           | 19,35          | 0,81               | 68.667,41                         | 188,13                             | 0,00057009                               |
| Operación laboratorio  | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 4,17           | 5,00           | 89,00                 | 4,68                         | 3,51            | 5,85           | 0,80               | 20.505,62                         | 56,18                              | 0,00017024                               |
| Bombas toma muestras   | 4        |            |                         |            | 415            | 365,00                | 12,00                      | 0,40           | 0,50           | 74,50                 | 2,15                         | 2,01            | 2,94           | 0,73               | 9.406,71                          | 25,77                              | 0,00007810                               |
| Oficinas SIO           | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 1,83           | 2,20           | 85,90                 | 2,13                         | 1,71            | 2,74           | 0,78               | 9.348,08                          | 25,61                              | 0,00007761                               |
| SUBTOTAL               |          |            |                         |            |                |                       |                            |                |                |                       | 3.071,91                     | 1529,38         | 3.467,80       | 0,89               | 11.320.967,58                     | 31.304,14                          | 0,104                                    |

Tabla 37. Consumo energético equipos mecánicos ETAP Bajo Consumo. (Fuente: Elaboración propia).

| EQUIPO                                                           | UNIDADES |   | VARIABLES DE FRECUENCIA |   | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    | ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|------------------------------------------------------------------|----------|---|-------------------------|---|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|-----------------------------------|------------------------------------|------------------------------------------|
|                                                                  |          |   |                         |   |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVar] | APARENTE [kVA] | FACTOR DE POTENCIA |                                   |                                    |                                          |
| <b>POZO BOMBEO DE ENTRADA</b>                                    |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| Clasificador de arenas                                           | 1        |   | 1                       |   | 460            | 365,00                | 24,00                      | 0,40           | 0,50           | 74,50                 | 0,65                         | 0,21            | 0,69           | 0,95               | 5.702,00                          | 15,62                              | 0,00004734                               |
| Bombas arenas (50 m³/h a 12 mca)                                 | 1        |   | 1                       |   | 460            | 365,00                | 24,00                      | 1,92           | 2,50           | 86,80                 | 2,39                         | 0,78            | 2,51           | 0,95               | 20.919,30                         | 57,31                              | 0,00017368                               |
| Bombas agua entrada (4.600 m³/h a 8 mca)                         | 3        | 1 | 3                       | 1 | 460            | 365,00                | 23,98                      | 86,98          | 150,00         | 96,40                 | 282,08                       | 92,71           | 296,92         | 0,95               | 2.469.030,75                      | 6.764,47                           | 0,02049839                               |
| Puente grúa 10.000 Kg                                            | 1        |   |                         |   | 460            | 20,00                 | 0,10                       | 9,38           | 11,25          | 92,70                 | 10,11                        | 6,53            | 12,04          | 0,84               | 20,23                             | 1,01                               | 0,00000306                               |
| Válvulas motorizadas DN1400 (entrada agua)                       | 2        |   |                         |   | 460            | 20,00                 | 0,10                       | 14,00          | 3,00           | 86,80                 | 32,26                        | 25,03           | 40,83          | 0,79               | 64,52                             | 3,23                               | 0,00000978                               |
| Válvulas motorizadas DN1000/DN800 (Bombeo agua)                  | 8        |   |                         |   | 460            | 20,00                 | 0,10                       | 14,00          | 3,00           | 86,80                 | 129,03                       | 100,14          | 163,33         | 0,79               | 258,06                            | 12,90                              | 0,00003910                               |
| Válvulas motorizadas DN1200/DN1400 (líneas a floculación)        | 5        |   |                         |   | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 14,40                        | 11,18           | 18,23          | 0,79               | 28,80                             | 1,44                               | 0,00000436                               |
| Bombas vaciado (150 m³/h a 12 mca)                               | 1        |   |                         |   | 460            | 2,00                  | 8,00                       | 5,77           | 7,50           | 89,30                 | 6,46                         | 4,68            | 7,98           | 0,81               | 103,39                            | 51,70                              | 0,00017232                               |
|                                                                  |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| <b>COAGULACIÓN</b>                                               |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| Bombas transferencia policloruro de aluminio (110 m³/h a 9 mca)  | 1        |   |                         |   | 460            | 12,00                 | 1,00                       | 2,50           | 3,00           | 86,80                 | 2,88                         | 2,24            | 3,65           | 0,79               | 34,56                             | 2,88                               | 0,00000873                               |
| Bombas dosificadoras policloruro de aluminio (2.500 L/h a 2 bar) | 2        | 1 | 2                       | 1 | 460            | 365,00                | 24,00                      | 1,83           | 2,20           | 85,90                 | 4,56                         | 1,50            | 4,80           | 0,95               | 39.985,28                         | 109,55                             | 0,00033197                               |
| Bombas dosificadoras sulfato de alúmina (2.500 L/h a 3 bar)      | 2        | 1 | 2                       | 1 | 460            | 365,00                | 24,00                      | 1,83           | 2,20           | 85,90                 | 4,56                         | 1,50            | 4,80           | 0,95               | 39.985,28                         | 109,55                             | 0,00033197                               |
| Bombas dosificadoras ácido sulfúrico (70 L/h a 2 bar)            | 1        | 1 | 1                       | 1 | 460            | 365,00                | 24,00                      | 0,19           | 0,24           | 68,30                 | 0,37                         | 0,12            | 0,39           | 0,95               | 3.259,71                          | 8,93                               | 0,00002706                               |
| Bombas dosificadoras hidróxido de sodio (50 L/h a 2 bar)         | 1        | 1 | 1                       | 1 | 460            | 365,00                | 24,00                      | 0,19           | 0,24           | 68,30                 | 0,37                         | 0,12            | 0,39           | 0,95               | 3.259,71                          | 8,93                               | 0,00002706                               |
|                                                                  |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| <b>FLOCULACIÓN</b>                                               |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| Compuerta murales motorizadas (1400 x 1400 mm)                   | 9        |   |                         |   | 460            | 20,00                 | 0,10                       | 0,60           | 0,75           | 81,00                 | 6,67                         | 6,24            | 9,13           | 0,73               | 13,33                             | 0,67                               | 0,00000202                               |

| EQUIPO                                                                | UNIDADES |            | VARIABLES DE FRECUENCIA |            | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    | ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|-----------------------------------------------------------------------|----------|------------|-------------------------|------------|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|-----------------------------------|------------------------------------|------------------------------------------|
|                                                                       | ACTIVAS  | EN RESERVA | ACTIVOS                 | EN RESERVA |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVAr] | APARENTE [kVA] | FACTOR DE POTENCIA |                                   |                                    |                                          |
| Rompe bóvedas dosificador permanganato potásico                       | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 0,60           | 0,75           | 81,00                 | 1,48                         | 1,39            | 2,03           | 0,73               | 12.977,78                         | 35,56                              | 0,00010774                               |
| Stand descargador de big-bag                                          | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 0,14           | 0,18           | 68,30                 | 0,42                         | 0,31            | 0,52           | 0,81               | 3.693,82                          | 10,12                              | 0,00003067                               |
| Sistema de calefacción permanganato potásico                          | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 0,20           | 0,25           | 68,30                 | 0,59                         | 0,42            | 0,72           | 0,81               | 5.130,31                          | 14,06                              | 0,00004259                               |
| Agitador vertical permanganato potásico                               | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 1,29           | 1,55           | 85,90                 | 3,01                         | 2,41            | 3,86           | 0,78               | 26.344,59                         | 72,18                              | 0,00021872                               |
| Bombas dosificadoras permanganato potásico (700 L/h a 2 bar)          | 1        | 1          | 1                       | 1          | 460            | 365,00                | 24,00                      | 0,30           | 0,37           | 72,40                 | 0,50                         | 0,16            | 0,53           | 0,95               | 4.378,60                          | 12,00                              | 0,00003635                               |
| Equipo compacto preparación polielectrolito floculación (1.200 L)     | 1        | 1          |                         |            | 460            | 365,00                | 24,00                      | 0,74           | 0,92           | 83,70                 | 0,88                         | 0,71            | 1,13           | 0,78               | 7.702,94                          | 21,10                              | 0,00006395                               |
| Bombas dosificadoras polielectrolito (floculación) (40 L/h a 2 bar)   | 1        | 1          | 1                       | 1          | 460            | 365,00                | 16,00                      | 0,19           | 0,24           | 68,30                 | 0,37                         | 0,12            | 0,39           | 0,95               | 2.173,14                          | 5,95                               | 0,00001804                               |
|                                                                       |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| <b>DECANTADOR LAMELAR ESTÁTICO</b>                                    |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| Rascadores                                                            | 6        |            |                         |            | 460            | 365,00                | 24,00                      | 0,30           | 0,37           | 72,40                 | 2,45                         | 1,65            | 2,96           | 0,83               | 21.488,62                         | 58,87                              | 0,00017840                               |
| Válvulas motorizadas DN400 (fangos)                                   | 14       |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 40,32                        | 31,29           | 51,04          | 0,79               | 80,65                             | 4,03                               | 0,00001222                               |
| Válvulas motorizadas DN1200 (caudalímetros)                           | 6        |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 17,28                        | 13,41           | 21,87          | 0,79               | 34,56                             | 1,73                               | 0,00000524                               |
| Polipasto 1.500 Kg                                                    | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 1,98           | 2,37           | 86,80                 | 2,28                         | 1,77            | 2,88           | 0,79               | 4,55                              | 0,23                               | 0,00000069                               |
| Bombas purga fangos (150 m³/h a 8 mca)                                | 2        | 1          | 2                       | 1          | 460            | 365,00                | 4,00                       | 10,61          | 18,50          | 93,30                 | 23,83                        | 7,83            | 25,08          | 0,95               | 34.785,72                         | 95,30                              | 0,00031768                               |
| Bombas vaciado (500 m³/h a 10 mca)                                    | 1        | 1          |                         |            | 460            | 1,00                  | 8,00                       | 16,03          | 22,00          | 93,30                 | 17,18                        | 11,99           | 20,95          | 0,82               | 137,44                            | 137,44                             | 0,00041650                               |
|                                                                       |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| <b>FILTROS ABIERTOS TASA DECLINANTE</b>                               |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |                                   |                                    |                                          |
| Compuertas murales motorizadas (entrada agua) (600 x 600 mm)          | 16       |            |                         |            | 460            | 20,00                 | 0,10                       | 0,16           | 0,20           | 68,30                 | 3,75                         | 2,71            | 4,63           | 0,81               | 7,50                              | 0,37                               | 0,00000114                               |
| Compuertas murales motorizadas (retrolavado filtros) (1100 x 1100 mm) | 16       |            |                         |            | 460            | 20,00                 | 0,10                       | 0,16           | 0,20           | 68,30                 | 3,75                         | 2,71            | 4,63           | 0,81               | 7,50                              | 0,37                               | 0,00000114                               |
| Polipasto 3.000 Kg                                                    | 2        |            |                         |            | 460            | 20,00                 | 0,10                       | 3,27           | 3,93           | 86,80                 | 7,54                         | 5,46            | 9,30           | 0,81               | 15,07                             | 0,75                               | 0,00000228                               |
| Válvulas motorizadas DN400 (ingreso aire)                             | 16       |            |                         |            | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 46,08                        | 35,76           | 58,33          | 0,79               | 92,17                             | 4,61                               | 0,00001396                               |



| EQUIPO                                                                  | UNIDADES |   | VARIABLES DE FRECUENCIA |   | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    |
|-------------------------------------------------------------------------|----------|---|-------------------------|---|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|
|                                                                         |          |   |                         |   |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVAr] | APARENTE [kVA] | FACTOR DE POTENCIA |
| Válvulas motorizadas DN90 (vaciado)                                     | 16       |   |                         |   | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 46,08                        | 35,76           | 58,33          | 0,79               |
| Válvulas motorizadas DN200 (salida agua)                                | 16       |   |                         |   | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 46,08                        | 35,76           | 58,33          | 0,79               |
| Soplantes lavado de filtros (5600 Nm³/h a 7 mca)                        | 1        | 1 | 1                       | 1 | 460            | 365,00                | 2,67                       | 160,00         | 165,00         | 96,50                 | 170,30                       | 55,98           | 179,27         | 0,95               |
|                                                                         |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>TANQUE RETROLAVADO</b>                                               |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Compuertas murales motorizadas (entrada y salida agua) (1300 X 1300 mm) | 4        |   |                         |   | 460            | 20,00                 | 0,10                       | 0,32           | 0,40           | 74,50                 | 1,72                         | 1,61            | 2,35           | 0,73               |
| Válvulas motorizadas DN500 (sobrenadantes)                              | 3        |   |                         |   | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 8,64                         | 6,71            | 10,94          | 0,79               |
| Válvulas motorizadas (caudalímetros sobrenadantes)                      | 3        |   |                         |   | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 8,64                         | 6,71            | 10,94          | 0,79               |
| Bomba fangos (300 m³/h a 8 mca)                                         | 2        | 2 | 2                       | 2 | 460            | 365,00                | 16,06                      | 10,90          | 11,20          | 92,70                 | 24,49                        | 8,05            | 25,78          | 0,95               |
| Bomba sobrenadantes (1.600 m³/h a 8 mca)                                | 2        | 1 | 2                       | 1 | 460            | 365,00                | 8,00                       | 46,60          | 52,00          | 95,40                 | 100,09                       | 32,90           | 105,36         | 0,95               |
| Polipasto 1.600 Kg                                                      | 2        |   |                         |   | 460            | 20,00                 | 0,10                       | 1,98           | 2,37           | 86,80                 | 4,55                         | 3,53            | 5,76           | 0,79               |
|                                                                         |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>TANQUE ALMACENAMIENTO AGUA TRATADA</b>                               |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Agitadores sumergibles                                                  | 12       |   |                         |   | 460            | 365,00                | 24,00                      | 9,33           | 11,20          | 92,70                 | 120,82                       | 78,04           | 143,83         | 0,84               |
| Válvulas motorizadas DN2200/DN1800 (caudalímetros)                      | 3        |   |                         |   | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 8,64                         | 6,71            | 10,94          | 0,79               |
| Válvulas motorizadas DN1600 (entrada y salida de agua)                  | 4        |   |                         |   | 460            | 20,00                 | 0,10                       | 2,50           | 3,00           | 86,80                 | 11,52                        | 8,94            | 14,58          | 0,79               |
| Polipasto 2.000 Kg                                                      | 1        |   |                         |   | 460            | 20,00                 | 0,10                       | 2,39           | 2,87           | 86,80                 | 2,76                         | 2,14            | 3,49           | 0,79               |
|                                                                         |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>TANQUE CONCENTRADOS</b>                                              |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Bombas sobrenadantes (380 m³/h a 10 mca)                                | 2        |   |                         |   | 460            | 365,00                | 24,00                      | 10,90          | 14,90          | 92,70                 | 23,52                        | 15,19           | 28,00          | 0,84               |
|                                                                         |          |   |                         |   |                |                       |                            |                |                |                       |                              |                 |                |                    |

| ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|-----------------------------------|------------------------------------|------------------------------------------|
| 92,17                             | 4,61                               | 0,00001396                               |
| 92,17                             | 4,61                               | 0,00001396                               |
| 165.761,69                        | 454,14                             | 0,00151381                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 3,44                              | 0,17                               | 0,00000052                               |
| 17,28                             | 0,86                               | 0,00000262                               |
| 17,28                             | 0,86                               | 0,00000262                               |
| 143.551,83                        | 393,29                             | 0,00119180                               |
| 292.274,25                        | 800,75                             | 0,00242652                               |
| 9,10                              | 0,46                               | 0,00000138                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 1.058.381,88                      | 2.899,68                           | 0,00878690                               |
| 17,28                             | 0,86                               | 0,00000262                               |
| 23,04                             | 1,15                               | 0,00000349                               |
| 5,51                              | 0,28                               | 0,00000083                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 206.006,47                        | 564,40                             | 0,00171031                               |
|                                   |                                    |                                          |

| EQUIPO                                                                     | UNIDADES |            | VARIABLES DE FRECUENCIA |            | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    |
|----------------------------------------------------------------------------|----------|------------|-------------------------|------------|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|
|                                                                            | ACTIVAS  | EN RESERVA | ACTIVOS                 | EN RESERVA |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVar] | APARENTE [kVA] | FACTOR DE POTENCIA |
| <b>TANQUE HOMOGENEIZACIÓN FANGOS</b>                                       |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Agitadores sumergibles                                                     | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 2,50           | 3,00           | 86,80                 | 5,76                         | 4,47            | 7,29           | 0,79               |
| Bombas fangos (140 m³/h a 12 mca)                                          | 3        | 1          | 3                       | 1          | 460            | 365,00                | 24,00                      | 10,61          | 18,50          | 93,30                 | 35,74                        | 11,75           | 37,62          | 0,95               |
|                                                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>ESPESAMIENTO FANGOS</b>                                                 |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Mesas espesadoras 1000 Kg/h                                                | 3        | 1          |                         |            | 460            | 365,00                | 24,00                      | 1,83           | 2,20           | 85,90                 | 6,40                         | 5,14            | 8,21           | 0,78               |
| Agitadores sumergibles tanque fangos espesados                             | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 2,50           | 3,00           | 86,80                 | 5,76                         | 4,47            | 7,29           | 0,79               |
| Bombas fangos homogeneizados (30 m³/h a 8 mca)                             | 3        | 1          | 3                       | 1          | 460            | 365,00                | 16,00                      | 0,79           | 5,50           | 89,00                 | 3,42                         | 1,13            | 3,60           | 0,95               |
| Polipasto 1.000 Kg                                                         | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 0,81           | 1,01           | 83,70                 | 0,97                         | 0,77            | 1,24           | 0,78               |
| Equipo compacto preparación polielectrolito espesamiento (6.000 L)         | 1        | 1          |                         |            | 460            | 365,00                | 24,00                      | 0,88           | 1,10           | 83,70                 | 1,05                         | 0,84            | 1,35           | 0,78               |
| Bombas dosificación polielectrolito (espesamiento) (1250-5000 L/h a 3 bar) | 3        | 1          | 3                       | 1          | 460            | 365,00                | 16,00                      | 0,64           | 0,80           | 83,70                 | 2,59                         | 0,85            | 2,73           | 0,95               |
|                                                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>DESHIDRATACIÓN DE FANGOS</b>                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Filtros banda 900 Kg/h                                                     | 3        | 1          |                         |            | 460            | 365,00                | 16,00                      | 4,29           | 5,15           | 89,00                 | 14,47                        | 10,85           | 18,08          | 0,80               |
| Puente grúa 10.000 Kg                                                      | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 10,42          | 12,50          | 92,70                 | 11,24                        | 7,26            | 13,38          | 0,84               |
| Tornillo transportador fangos deshidratados (20 m³/h)                      | 1        |            |                         |            | 460            | 365,00                | 16,00                      | 16,09          | 18,50          | 93,30                 | 17,24                        | 12,04           | 21,03          | 0,82               |
| Tornillo transportador fangos deshidratados (10 m³/h)                      | 2        |            |                         |            | 460            | 365,00                | 16,00                      | 4,58           | 5,50           | 89,00                 | 10,30                        | 7,72            | 12,87          | 0,80               |
| Tornillo transportador fangos deshidratados (10 m³/h)                      | 2        |            |                         |            | 460            | 365,00                | 16,00                      | 2,50           | 3,00           | 86,80                 | 5,76                         | 4,47            | 7,29           | 0,79               |
| Elevador de cangilones (10 m³/h)                                           | 2        |            |                         |            | 460            | 365,00                | 16,00                      | 4,58           | 5,50           | 89,00                 | 10,30                        | 7,72            | 12,87          | 0,80               |
| Tornillo transportador fangos deshidratados (5 m³/h)                       | 4        |            |                         |            | 460            | 365,00                | 16,00                      | 1,20           | 1,50           | 84,30                 | 5,69                         | 3,83            | 6,86           | 0,83               |
| Equipo compacto preparación polielectrolito espesamiento (6.000 L)         | 1        | 1          |                         |            | 460            | 365,00                | 24,00                      | 1,54           | 1,85           | 85,90                 | 1,79                         | 1,44            | 2,30           | 0,78               |

| ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|-----------------------------------|------------------------------------|------------------------------------------|
|                                   |                                    |                                          |
| 50.460,83                         | 138,25                             | 0,00041894                               |
| 313.071,50                        | 857,73                             | 0,00259918                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 56.088,47                         | 153,67                             | 0,00046566                               |
| 50.460,83                         | 138,25                             | 0,00041894                               |
| 19.995,70                         | 54,78                              | 0,00016601                               |
| 1,93                              | 0,10                               | 0,00000029                               |
| 9.210,04                          | 25,23                              | 0,00007646                               |
| 15.148,42                         | 41,50                              | 0,00012577                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 84.483,15                         | 231,46                             | 0,00070140                               |
| 22,47                             | 1,12                               | 0,00000341                               |
| 100.694,35                        | 275,87                             | 0,00083598                               |
| 60.149,81                         | 164,79                             | 0,00049938                               |
| 33.640,55                         | 92,17                              | 0,00027929                               |
| 60.149,81                         | 164,79                             | 0,00049938                               |
| 33.252,67                         | 91,10                              | 0,00027607                               |
| 15.721,77                         | 43,07                              | 0,00013053                               |

| EQUIPO                                                                     | UNIDADES |            | VARIABLES DE FRECUENCIA |            | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    |
|----------------------------------------------------------------------------|----------|------------|-------------------------|------------|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|
|                                                                            | ACTIVAS  | EN RESERVA | ACTIVOS                 | EN RESERVA |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVar] | APARENTE [kVA] | FACTOR DE POTENCIA |
| Bombas dosificación polielectrolito (espesamiento) (1250-5000 L/h a 3 bar) | 3        | 1          | 3                       | 1          | 460            | 365,00                | 16,00                      | 0,44           | 0,55           | 74,50                 | 2,11                         | 0,69            | 2,23           | 0,95               |
| Compuerta descarga silos                                                   | 8        |            |                         |            | 460            | 365,00                | 2,00                       | 0,88           | 1,10           | 83,70                 | 8,41                         | 6,75            | 10,78          | 0,78               |
| Báscula camiones                                                           | 1        |            |                         |            | 460            | 365,00                | 2,00                       | 0,20           | 0,25           | 68,30                 | 0,29                         | 0,21            | 0,36           | 0,81               |
|                                                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>EDIFICIO CLOROGAS</b>                                                   |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Básculas 2000 Kg                                                           | 2        |            |                         |            | 460            | 365,00                | 1,00                       | 1,83           | 2,20           | 85,90                 | 4,27                         | 3,42            | 5,47           | 0,78               |
| Vaporizadores 120 Kg/h                                                     | 2        |            |                         |            | 460            | 365,00                | 24,00                      | 12,50          | 15,00          | 92,70                 | 26,97                        | 17,42           | 32,11          | 0,84               |
| Reguladores de vacío                                                       | 6        |            |                         |            | 460            | 365,00                | 24,00                      | 0,02           | 0,03           | 68,30                 | 0,18                         | 0,13            | 0,22           | 0,81               |
| Bombas circulación <i>Scrubber</i>                                         | 2        |            |                         |            | 460            | 12,00                 | 3,00                       | 4,58           | 5,50           | 89,00                 | 10,30                        | 7,72            | 12,87          | 0,80               |
| Gas Fan                                                                    | 2        |            |                         |            | 460            | 12,00                 | 3,00                       | 3,33           | 4,00           | 86,80                 | 7,68                         | 5,56            | 9,48           | 0,81               |
| Puente grúa 2.000 Kg                                                       | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 3,43           | 4,11           | 89,00                 | 3,85                         | 2,89            | 4,81           | 0,80               |
|                                                                            |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| <b>OTROS</b>                                                               |          |            |                         |            |                |                       |                            |                |                |                       |                              |                 |                |                    |
| Grupo de agua a presión (agua filtrada para servicios) (50 m³/h a 70 mca)  | 2        | 2          |                         |            | 415            | 365,00                | 18,00                      | 16,09          | 18,50          | 93,30                 | 34,48                        | 24,07           | 42,05          | 0,82               |
| Grupo de agua a presión (agua potable) (25 m³/h a 50 mca)                  | 1        | 1          | 1                       | 1          | 415            | 365,00                | 18,00                      | 4,58           | 5,50           | 89,00                 | 5,40                         | 1,77            | 5,68           | 0,95               |
| Compresores aire de servicio (1000L/h a 10 bar)                            | 8        |            |                         |            | 415            | 365,00                | 8,00                       | 0,20           | 0,25           | 68,30                 | 2,34                         | 1,70            | 2,89           | 0,81               |
| Sistema HVAC (control)                                                     | 1        |            |                         |            | 415            | 365,00                | 14,00                      | 223,21         | 250,00         | 96,60                 | 231,07                       | 130,95          | 265,60         | 0,87               |
| Sistema HVAC (otros)                                                       | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 223,21         | 250,00         | 96,60                 | 231,07                       | 130,95          | 265,60         | 0,87               |
| Iluminación exterior                                                       | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 66,96          | 75,00          | 95,70                 | 69,97                        | 43,37           | 82,32          | 0,85               |
| Iluminación interior                                                       | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 47,83          | 55,00          | 95,40                 | 50,13                        | 31,07           | 58,98          | 0,85               |
| Puente grúa 6.000 Kg                                                       | 1        |            |                         |            | 460            | 20,00                 | 0,10                       | 4,56           | 5,47           | 89,00                 | 5,12                         | 3,84            | 6,40           | 0,80               |

| ENERGÍA CONSUMIDA ANUAL [kWh/año] | ENERGÍA CONSUMIDA DIARIA [kWh/día] | ENERGÍA ESPECÍFICA CONSUMIDA Ce [kWh/m³] |
|-----------------------------------|------------------------------------|------------------------------------------|
| 12.344,66                         | 33,82                              | 0,00010249                               |
| 6.140,02                          | 16,82                              | 0,00005098                               |
| 213,76                            | 0,59                               | 0,00000177                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 1.558,01                          | 4,27                               | 0,00001293                               |
| 236.245,95                        | 647,25                             | 0,00196136                               |
| 1.539,09                          | 4,22                               | 0,00001278                               |
| 370,79                            | 30,90                              | 0,00009363                               |
| 276,50                            | 23,04                              | 0,00006982                               |
| 7,70                              | 0,38                               | 0,00000117                               |
|                                   |                                    |                                          |
|                                   |                                    |                                          |
| 226.562,28                        | 620,72                             | 0,00188097                               |
| 35.476,77                         | 97,20                              | 0,00029454                               |
| 6.840,41                          | 18,74                              | 0,00005679                               |
| 1.180.771,22                      | 3.234,99                           | 0,00980300                               |
| 1.012.089,62                      | 2.772,85                           | 0,00840257                               |
| 306.482,31                        | 839,68                             | 0,00254448                               |
| 219.578,89                        | 601,59                             | 0,00182299                               |
| 10,24                             | 0,51                               | 0,00000155                               |

| EQUIPO                | UNIDADES |            | VARIABLES DE FRECUENCIA |            | TENSIÓN DE RED | DÍAS OPERACIÓN AL AÑO | HORAS DE OPERACIÓN DIARIAS | POTENCIA [kW]  |                | RENDIMIENTO MOTOR [%] | POTENCIA ABSORBIDA DE LA RED |                 |                |                    |           |        |            |
|-----------------------|----------|------------|-------------------------|------------|----------------|-----------------------|----------------------------|----------------|----------------|-----------------------|------------------------------|-----------------|----------------|--------------------|-----------|--------|------------|
|                       |          |            |                         |            |                |                       |                            | ABSORBIDA [kW] | INSTALADA [kW] |                       | ACTIVA [kW]                  | REACTIVA [kVar] | APARENTE [kVA] | FACTOR DE POTENCIA |           |        |            |
|                       | ACTIVAS  | EN RESERVA | ACTIVOS                 | EN RESERVA |                |                       |                            |                |                |                       |                              |                 |                |                    |           |        |            |
| UPS                   | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 0,12           | 0,15           | 68,30                 | 0,18                         | 0,13            | 0,22           | 0,81               | 769,55    | 2,11   | 0,00000639 |
| A/C                   | 3        |            |                         |            | 415            | 365,00                | 12,00                      | 4,67           | 5,60           | 89,30                 | 15,68                        | 11,35           | 19,35          | 0,81               | 68.667,41 | 188,13 | 0,00057009 |
| Operación laboratorio | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 4,17           | 5,00           | 89,00                 | 4,68                         | 3,51            | 5,85           | 0,80               | 20.505,62 | 56,18  | 0,00017024 |
| Bombas toma muestras  | 4        |            |                         |            | 415            | 365,00                | 12,00                      | 0,40           | 0,50           | 74,50                 | 2,15                         | 2,01            | 2,94           | 0,73               | 9.406,71  | 25,77  | 0,00007810 |
| Oficinas SIO          | 1        |            |                         |            | 415            | 365,00                | 12,00                      | 1,83           | 2,20           | 85,90                 | 2,13                         | 1,71            | 2,74           | 0,78               | 9.348,08  | 25,61  | 0,00007761 |

|                 |                 |                 |                 |             |
|-----------------|-----------------|-----------------|-----------------|-------------|
| <b>SUBTOTAL</b> | <b>2.103,32</b> | <b>1.187,12</b> | <b>2.437,44</b> | <b>0,86</b> |
|-----------------|-----------------|-----------------|-----------------|-------------|

|                     |                  |              |
|---------------------|------------------|--------------|
| <b>8.825.868,59</b> | <b>24.468,25</b> | <b>0,082</b> |
|---------------------|------------------|--------------|

**Tabla 38. Distribución del consumo energético por períodos horarios ETAP Convencional. (Fuente: Elaboración propia).**

Se indica en color rojo el período horario 1 (P1); en amarillo P2; en azul P3; en rosa P4, en naranja P5 y en verde P6.

| HORA          | LUNES A VIERNES |         |         |         |         |         |         |         |            |         |           |           | SÁBADOS<br>DOMINGOS Y<br>FESTIVOS<br>(9) |
|---------------|-----------------|---------|---------|---------|---------|---------|---------|---------|------------|---------|-----------|-----------|------------------------------------------|
|               | ENERO           | FEBRERO | MARZO   | ABRIL   | MAYO    | JUNIO   | JULIO   | AGOSTO  | SEPTIEMBRE | OCTUBRE | NOVIEMBRE | DICIEMBRE |                                          |
| 00:00 A 01:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                                        |
|               | 583,10          | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10     | 583,10  | 583,10    | 583,10    | 583,10                                   |
| 01:00 A 02:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                                        |
|               | 583,10          | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10     | 583,10  | 583,10    | 583,10    | 583,10                                   |
| 02:00 A 03:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                                        |
|               | 583,10          | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10     | 583,10  | 583,10    | 583,10    | 583,10                                   |
| 03:00 A 04:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                                        |
|               | 583,10          | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10     | 583,10  | 583,10    | 583,10    | 583,10                                   |
| 04:00 A 05:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                                        |
|               | 583,10          | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10     | 583,10  | 583,10    | 583,10    | 583,10                                   |
| 05:00 A 06:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                                        |
|               | 583,10          | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10  | 583,10     | 583,10  | 583,10    | 583,10    | 583,10                                   |
| 06:00 A 07:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                                        |
|               | 965,41          | 965,41  | 965,41  | 965,41  | 965,41  | 965,41  | 965,41  | 965,41  | 965,41     | 965,41  | 965,41    | 965,41    | 965,41                                   |
| 07:00 A 08:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                                        |
|               | 965,41          | 965,41  | 965,41  | 965,41  | 965,41  | 965,41  | 965,41  | 965,41  | 965,41     | 965,41  | 965,41    | 965,41    | 965,41                                   |
| 08:00 A 09:00 | 2               | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4          | 5       | 3         | 2         | 6                                        |
|               | 2133,90         | 2133,90 | 2133,90 | 2133,90 | 2133,90 | 2133,90 | 2133,90 | 2133,90 | 2133,90    | 2133,90 | 2133,90   | 2133,90   | 2133,90                                  |
| 09:00 A 10:00 | 1               | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3          | 4       | 2         | 1         | 6                                        |
|               | 2669,64         | 2648,78 | 2601,45 | 2554,13 | 2554,13 | 2554,13 | 2554,13 | 2554,13 | 2554,13    | 2554,13 | 2554,13   | 2554,13   | 2554,13                                  |
| 10:00 A 11:00 | 1               | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3          | 4       | 2         | 1         | 6                                        |
|               | 2690,40         | 2644,51 | 2597,19 | 2549,86 | 2549,86 | 2549,86 | 2549,86 | 2549,86 | 2549,86    | 2549,86 | 2549,86   | 2549,86   | 2549,86                                  |
| 11:00 A 12:00 | 1               | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3          | 4       | 2         | 1         | 6                                        |
|               | 2270,36         | 2228,73 | 2205,05 | 2157,72 | 2157,72 | 2157,72 | 2157,72 | 2157,72 | 2157,72    | 2157,72 | 2157,72   | 2157,72   | 2157,72                                  |
| 12:00 A 13:00 | 1               | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3          | 4       | 2         | 1         | 6                                        |
|               | 2252,38         | 2228,73 | 2181,41 | 2134,08 | 2134,08 | 2134,08 | 2134,08 | 2134,08 | 2134,08    | 2134,08 | 2134,08   | 2134,08   | 2134,08                                  |
| 13:00 A 14:00 | 1               | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3          | 4       | 2         | 1         | 6                                        |
|               | 2228,55         | 2204,91 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25    | 2110,25 | 2110,25   | 2110,25   | 2110,25                                  |
| 14:00 A 15:00 | 2               | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4          | 5       | 3         | 2         | 6                                        |

|               |         |         |         |         |         |         |         |         |         |         |         |         |         |
|---------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|               | 2133,90 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 |
| 15:00 A 16:00 | 2       | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4       | 5       | 3       | 2       | 6       |
|               | 2133,90 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 | 2110,25 |
| 16:00 A 17:00 | 2       | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4       | 5       | 3       | 2       | 6       |
|               | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 |
| 17:00 A 18:00 | 2       | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4       | 5       | 3       | 2       | 6       |
|               | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 |
| 18:00 A 19:00 | 1       | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3       | 4       | 2       | 1       | 6       |
|               | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 |
| 19:00 A 20:00 | 1       | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3       | 4       | 2       | 1       | 6       |
|               | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 | 1366,15 |
| 20:00 A 21:00 | 1       | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3       | 4       | 2       | 1       | 6       |
|               | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  |
| 21:00 A 22:00 | 1       | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3       | 4       | 2       | 1       | 6       |
|               | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  | 734,34  |
| 22:00 A 23:00 | 2       | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4       | 5       | 3       | 2       | 6       |
|               | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  |
| 23:00 A 24:00 | 2       | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4       | 5       | 3       | 2       | 6       |
|               | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  | 622,98  |
| Días al año   | 20      | 20      | 22      | 21      | 21      | 22      | 22      | 21      | 22      | 20      | 21      | 19      | 114     |

|                             |            |            |            |            |            |            |            |            |            |            |            |            |              |
|-----------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|
| <b>Potencia total [kWh]</b> | 642.433,81 | 638.374,93 | 696.485,38 | 660.851,48 | 660.851,48 | 692.320,60 | 692.320,60 | 660.851,48 | 692.320,60 | 629.382,36 | 660.851,48 | 597.913,24 | 3.587.479,46 |
| <b>P1 [kWh]</b>             | 326.246,28 | 323.133,09 |            |            |            |            | 345.554,58 |            |            |            |            | 298.433,50 |              |
| <b>P2 [kWh]</b>             | 207.599,11 | 206.653,41 | 349.719,36 |            |            |            | 227.318,75 |            |            |            | 329.847,55 | 196.320,74 |              |
| <b>P3 [kWh]</b>             |            |            | 227.318,75 |            |            | 345.554,58 |            | 329.847,55 | 345.554,58 |            | 216.986,08 |            |              |
| <b>P4 [kWh]</b>             |            |            |            | 329.847,55 | 329.847,55 | 227.318,75 |            | 216.986,08 | 227.318,75 | 314.140,53 |            |            |              |
| <b>P5 [kWh]</b>             |            |            |            | 216.986,08 | 216.986,08 |            |            |            |            | 206.653,41 |            |            |              |
| <b>P6 [kWh]</b>             | 108.588,42 | 108.588,42 | 119.447,26 | 114.017,84 | 114.017,84 | 119.447,26 | 119.447,26 | 114.017,84 | 119.447,26 | 108.588,42 | 114.017,84 | 103.159,00 | 3.587.479,46 |

**Tabla 39. Distribución del consumo energético por períodos horarios ETAP Bajo Consumo. (Fuente: Elaboración propia).**

Se indica en color rojo el período horario 1 (P1); en amarillo P2; en azul P3; en rosa P4, en naranja P5 y en verde P6.

| HORA          | LUNES A VIERNES |         |         |         |         |         |         |         |            |         |           |           | SÁBADOS DOMINGOS Y FESTIVOS (9) |
|---------------|-----------------|---------|---------|---------|---------|---------|---------|---------|------------|---------|-----------|-----------|---------------------------------|
|               | ENERO           | FEBRERO | MARZO   | ABRIL   | MAYO    | JUNIO   | JULIO   | AGOSTO  | SEPTIEMBRE | OCTUBRE | NOVIEMBRE | DICIEMBRE |                                 |
| 00:00 A 01:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                               |
|               | 532,31          | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31     | 532,31  | 532,31    | 532,31    | 532,31                          |
| 01:00 A 02:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                               |
|               | 532,31          | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31     | 532,31  | 532,31    | 532,31    | 532,31                          |
| 02:00 A 03:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                               |
|               | 532,31          | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31     | 532,31  | 532,31    | 532,31    | 532,31                          |
| 03:00 A 04:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                               |
|               | 532,31          | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31     | 532,31  | 532,31    | 532,31    | 532,31                          |
| 04:00 A 05:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                               |
|               | 532,31          | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31     | 532,31  | 532,31    | 532,31    | 532,31                          |
| 05:00 A 06:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                               |
|               | 532,31          | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31  | 532,31     | 532,31  | 532,31    | 532,31    | 532,31                          |
| 06:00 A 07:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                               |
|               | 900,02          | 900,02  | 900,02  | 900,02  | 900,02  | 900,02  | 900,02  | 900,02  | 900,02     | 900,02  | 900,02    | 900,02    | 900,02                          |
| 07:00 A 08:00 | 6               | 6       | 6       | 6       | 6       | 6       | 6       | 6       | 6          | 6       | 6         | 6         | 6                               |
|               | 900,02          | 900,02  | 900,02  | 900,02  | 900,02  | 900,02  | 900,02  | 900,02  | 900,02     | 900,02  | 900,02    | 900,02    | 900,02                          |
| 08:00 A 09:00 | 2               | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4          | 5       | 3         | 2         | 6                               |
|               | 1402,09         | 1402,09 | 1402,09 | 1402,09 | 1402,09 | 1402,09 | 1402,09 | 1402,09 | 1402,09    | 1402,09 | 1402,09   | 1402,09   | 1402,09                         |
| 09:00 A 10:00 | 1               | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3          | 4       | 2         | 1         | 6                               |
|               | 1701,06         | 1680,20 | 1632,87 | 1585,55 | 1585,55 | 1585,55 | 1585,55 | 1585,55 | 1585,55    | 1585,55 | 1585,55   | 1585,55   | 1585,55                         |
| 10:00 A 11:00 | 1               | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3          | 4       | 2         | 1         | 6                               |
|               | 1721,82         | 1675,93 | 1628,60 | 1581,28 | 1581,28 | 1581,28 | 1581,28 | 1581,28 | 1581,28    | 1581,28 | 1581,28   | 1581,28   | 1581,28                         |
| 11:00 A 12:00 | 1               | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3          | 4       | 2         | 1         | 6                               |
|               | 1538,55         | 1496,92 | 1473,24 | 1425,91 | 1425,91 | 1425,91 | 1425,91 | 1425,91 | 1425,91    | 1425,91 | 1425,91   | 1425,91   | 1425,91                         |
| 12:00 A 13:00 | 1               | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3          | 4       | 2         | 1         | 6                               |
|               | 1520,57         | 1496,92 | 1449,60 | 1402,27 | 1402,27 | 1402,27 | 1402,27 | 1402,27 | 1402,27    | 1402,27 | 1402,27   | 1402,27   | 1402,27                         |
| 13:00 A 14:00 | 1               | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3          | 4       | 2         | 1         | 6                               |
|               | 1496,74         | 1473,10 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44    | 1378,44 | 1378,44   | 1378,44   | 1378,44                         |
| 14:00 A 15:00 | 2               | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4          | 5       | 3         | 2         | 6                               |

|               |         |         |         |         |         |         |         |         |         |         |         |         |         |
|---------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|               | 1402,09 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 |
| 15:00 A 16:00 | 2       | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4       | 5       | 3       | 2       | 6       |
|               | 1402,09 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 | 1378,44 |
| 16:00 A 17:00 | 2       | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4       | 5       | 3       | 2       | 6       |
|               | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 |
| 17:00 A 18:00 | 2       | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4       | 5       | 3       | 2       | 6       |
|               | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 |
| 18:00 A 19:00 | 1       | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3       | 4       | 2       | 1       | 6       |
|               | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 |
| 19:00 A 20:00 | 1       | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3       | 4       | 2       | 1       | 6       |
|               | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 | 1276,01 |
| 20:00 A 21:00 | 1       | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3       | 4       | 2       | 1       | 6       |
|               | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  |
| 21:00 A 22:00 | 1       | 1       | 2       | 4       | 4       | 3       | 1       | 3       | 3       | 4       | 2       | 1       | 6       |
|               | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  | 668,94  |
| 22:00 A 23:00 | 2       | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4       | 5       | 3       | 2       | 6       |
|               | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  |
| 23:00 A 24:00 | 2       | 2       | 3       | 5       | 5       | 4       | 2       | 4       | 4       | 5       | 3       | 2       | 6       |
|               | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  | 572,19  |
| Días al año   | 20      | 20      | 22      | 21      | 21      | 22      | 22      | 21      | 22      | 20      | 21      | 19      | 114     |

|                             |            |            |            |            |            |            |            |            |            |            |            |            |              |
|-----------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|--------------|
| <b>Potencia total [kWh]</b> | 495.303,86 | 491.244,97 | 534.642,43 | 506.365,03 | 506.365,03 | 530.477,65 | 530.477,65 | 506.365,03 | 530.477,65 | 482.252,40 | 506.365,03 | 458.139,78 | 2.748.383,71 |
| <b>P1 [kWh]</b>             | 237.372,95 | 234.259,76 |            |            |            |            | 247.793,92 |            |            |            |            | 214.003,84 |              |
| <b>P2 [kWh]</b>             | 158.053,29 | 157.107,58 | 251.958,70 |            |            |            | 172.818,34 |            |            |            | 236.530,56 | 149.252,20 |              |
| <b>P3 [kWh]</b>             |            |            | 172.818,34 |            |            | 247.793,92 |            | 236.530,56 | 247.793,92 |            | 164.962,96 |            |              |
| <b>P4 [kWh]</b>             |            |            |            | 236.530,56 | 236.530,56 | 172.818,34 |            | 164.962,96 | 172.818,34 | 225.267,20 |            |            |              |
| <b>P5 [kWh]</b>             |            |            |            | 164.962,96 | 164.962,96 |            |            |            |            | 157.107,58 |            |            |              |
| <b>P6 [kWh]</b>             | 99.877,62  | 99.877,62  | 109.865,39 | 104.871,50 | 104.871,50 | 109.865,39 | 109.865,39 | 104.871,50 | 109.865,39 | 99.877,62  | 104.871,50 | 94.883,74  | 2.748.838,71 |



## 2.7. CÁLCULOS COSTES DE INVERSIÓN

Tabla 40. CAPEX ETAP Convencional. (Fuente: Elaboración propia).

Se indican en color naranja las diferencias respecto a la alternativa de bajo consumo

| Ítem     | Descripción                                             | Coste Total [EUR]        |
|----------|---------------------------------------------------------|--------------------------|
| <b>1</b> | <b>AJUSTE pH, COAGULACIÓN Y CÁMARA DE DISTRIBUCIÓN</b>  | <b>3.736.965,08 EUR</b>  |
|          | Obra Civil                                              | 1.721.216,08 EUR         |
|          | Cámara de mezcla                                        | 130.040,65 EUR           |
|          | Edificio reactivos                                      | 1.591.175,43 EUR         |
|          | Equipos Mecánicos                                       | 20.856,00 EUR            |
|          | Agitador eje vertical mezcla                            | 20.856,00 EUR            |
|          | Instrumentación                                         | 103.213,49 EUR           |
|          | Instrumentación                                         | 83.735,69 EUR            |
|          | Instrumentación sistemas de reactivos                   | 19.477,80 EUR            |
|          | Dosificación reactivos                                  | 170.463,43 EUR           |
|          | Sistema dosificación Policloruro de Aluminio            | 55.638,64 EUR            |
|          | Sistema dosificación Sulfato de Alúmina                 | 55.574,92 EUR            |
|          | Sistema dosificación Ácido Sulfúrico                    | 36.829,87 EUR            |
|          | Sistema dosificación Hidróxido de Sodio                 | 22.420,00 EUR            |
| <b>2</b> | <b>FLOCULACIÓN Y DECANTACIÓN</b>                        | <b>13.216.346,01 EUR</b> |
|          | Obra Civil                                              | 4.884.245,43 EUR         |
|          | Equipos Mecánicos                                       | 8.126.696,75 EUR         |
|          | Agitador eje vertical mezcla                            | 26.136,00 EUR            |
|          | Motor arrastre espesador                                | 19.360,00 EUR            |
|          | Bombas recirculación fangos 200 m³/h a 10 mca           | 21.824,00 EUR            |
|          | Bombas purga fangos 150 m³/h a 8 mca                    | 47.543,16 EUR            |
|          | Bombas drenaje 500 m³/h a 10 mca                        | 31.872,92 EUR            |
|          | Paquete lamelas                                         | 1.107.578,50 EUR         |
|          | Compuertas                                              | 111.144,72 EUR           |
|          | Polipasto eléctrico 1500 kg                             | 6.579,95 EUR             |
|          | Tuberías, válvulas y accesorios                         | 6.178.673,62 EUR         |
|          | Instrumentación                                         | 180.242,68 EUR           |
|          | Instrumentación                                         | 176.881,14 EUR           |
|          | Instrumentación sistemas de reactivos                   | 3.361,54 EUR             |
|          | Dosificación reactivos                                  | 25.161,15 EUR            |
|          | Sistema de dosificación Poly-DADMAC                     | 25.161,15 EUR            |
| <b>3</b> | <b>OXIDACIÓN, DESINFECCIÓN Y CÁMARA DE DISTRIBUCIÓN</b> | <b>1.645.510,03 EUR</b>  |
|          | Obra Civil                                              | 892.951,95 EUR           |
|          | Equipos Mecánicos                                       | 736.129,49 EUR           |
|          | Sistema dosificación Permanganato Potásico              | 153.100,08 EUR           |
|          | Sistema dosificación cloro gas                          | 583.029,41 EUR           |
|          | Instrumentación                                         | 16.428,59 EUR            |
| <b>4</b> | <b>FILTRACIÓN</b>                                       | <b>26.159.404,01 EUR</b> |
|          | Obra Civil                                              | 21.744.397,05 EUR        |
|          | Filtros                                                 | 12.832.758,91 EUR        |
|          | Tanque agua filtrada                                    | 8.911.638,13 EUR         |
|          | Equipos Mecánicos                                       | 4.246.443,70 EUR         |
|          | Bombas lavado de filtros                                | 957.440,00 EUR           |

| Ítem     | Descripción                                                 | Coste Total [EUR]       |
|----------|-------------------------------------------------------------|-------------------------|
|          | Compuertas motorizadas                                      | 250.209,01 EUR          |
|          | Falsos fondos                                               | 791.948,16 EUR          |
|          | Medio filtrante                                             | 809.006,80 EUR          |
|          | Polipasto eléctrico 2100 kg                                 | 23.686,85 EUR           |
|          | Soplantes 8.400 m <sup>3</sup> /h a 7 mca                   | 322.080,00 EUR          |
|          | Tuberías, válvulas y accesorios                             | 2.049.512,88 EUR        |
|          | Instrumentación                                             | 168.563,26 EUR          |
| <b>5</b> | <b>TANQUE RETROLAVADO</b>                                   | <b>1.013.043,80 EUR</b> |
|          | Obra Civil                                                  | 113.648,43 EUR          |
|          | Equipos Mecánicos                                           | 888.925,77 EUR          |
|          | Compuertas motorizadas                                      | 47.729,08 EUR           |
|          | Bombas fangos 300m <sup>3</sup> /h a 8 mca                  | 30.787,51 EUR           |
|          | Bombas sobrenadantes 1600 m <sup>3</sup> /h a 8 mca         | 67.751,85 EUR           |
|          | Polipasto eléctrico 1000 kg                                 | 8.695,65 EUR            |
|          | Polipasto eléctrico 1600 kg                                 | 7.513,49 EUR            |
|          | Tuberías, válvulas y accesorios                             | 726.448,19 EUR          |
|          | Instrumentación                                             | 10.469,60 EUR           |
| <b>6</b> | <b>RETORNOS SOBRENADANTES</b>                               | <b>191.985,87 EUR</b>   |
|          | Obra Civil                                                  | 113.648,43 EUR          |
|          | Equipos Mecánicos                                           | 71.377,73 EUR           |
|          | Tuberías, válvulas y accesorios                             | 71.377,73 EUR           |
|          | Instrumentación                                             | 6.959,71 EUR            |
| <b>7</b> | <b>TRATAMIENTO DE FANGOS</b>                                | <b>5.449.122,89 EUR</b> |
|          | Obra Civil                                                  | 2.624.694,26 EUR        |
|          | Equipos Mecánicos                                           | 2.678.812,17 EUR        |
|          | <b>Tanque homogeneización fangos</b>                        | <b>202.147,91 EUR</b>   |
|          | Agitador sumergible tanque homogeneización fangos           | 10.212,54 EUR           |
|          | Bombas fangos homogeneizados 140 m <sup>3</sup> /h a 12 mca | 65.060,00 EUR           |
|          | Tuberías, válvulas y accesorios                             | 191.935,37 EUR          |
|          | <b>Espesado mecánico de fangos</b>                          | <b>359.267,05 EUR</b>   |
|          | Mesas espesadoras 1000 kg/h                                 | 308.000,00 EUR          |
|          | Tuberías, válvulas y accesorios                             | 51.267,05 EUR           |
|          | <b>Tanque fangos espesados</b>                              | <b>148.633,58 EUR</b>   |
|          | Agitador sumergible tanque fangos espesados                 | 10.212,54 EUR           |
|          | Bombas fangos espesados 30 m <sup>3</sup> /h a 8 mca        | 24.920,00 EUR           |
|          | Sacos filtrantes                                            | 24.000,00 EUR           |
|          | Polipasto eléctrico 1000 kg                                 | 5.799,72 EUR            |
|          | Tuberías, válvulas y accesorios                             | 83.701,32 EUR           |
|          | <b>Deshidratación fangos</b>                                | <b>1.968.763,63 EUR</b> |
|          | Filtros banda 900 kg/h                                      | 739.900,00 EUR          |
|          | Tornillos transportadores de fangos                         | 295.893,42 EUR          |
|          | Silos fangos deshidratados                                  | 682.843,30 EUR          |
|          | Puente grúa 10 t                                            | 54.017,11 EUR           |
|          | Tuberías, válvulas y accesorios                             | 196.109,80 EUR          |
|          | Instrumentación                                             | 81.250,08 EUR           |
|          | Instrumentación tanque homogeneización fangos               | 49.858,67 EUR           |
|          | Instrumentación espesamiento fangos                         | 1.548,16 EUR            |
|          | Instrumentación tanque fangos espesados                     | 8.009,83 EUR            |
|          | Instrumentación deshidratación                              | 3.792,94 EUR            |

| Ítem      | Descripción                                              | Coste Total [EUR]        |
|-----------|----------------------------------------------------------|--------------------------|
|           | <i>Instrumentación sistemas de reactivos</i>             | 18.040,48 EUR            |
|           | Dosificación reactivos                                   | 64.366,38 EUR            |
|           | <i>Sistema de dosificación polielectrolito aniónico</i>  | 64.366,38 EUR            |
| <b>8</b>  | <b>TANQUE AGUA TRATADA</b>                               | <b>22.841.622,48 EUR</b> |
|           | Obra Civil                                               | 20.789.090,37 EUR        |
|           | Equipos Mecánicos                                        | 1.825.918,30 EUR         |
|           | <i>Agitadores sumergibles</i>                            | 123.185,47 EUR           |
|           | <i>Polipasto eléctrico 2100 kg</i>                       | 10.127,04 EUR            |
|           | <i>Tuberías, válvulas y accesorios</i>                   | 1.692.605,79 EUR         |
|           | Instrumentación                                          | 226.613,81 EUR           |
|           | <i>Instrumentación</i>                                   | 226.613,81 EUR           |
| <b>9</b>  | <b>EDIFICIOS (Laboratorio, Control y Administración)</b> | <b>2.704.015,34 EUR</b>  |
|           | Obra Civil                                               | 2.469.304,38 EUR         |
|           | Equipos Mecánicos                                        | 234.710,96 EUR           |
|           | <i>Laboratorio</i>                                       | 134.850,43 EUR           |
|           | <i>Administración</i>                                    | 99.860,53 EUR            |
| <b>10</b> | <b>OTROS</b>                                             | <b>1.217.403,54 EUR</b>  |
|           | Obra Civil                                               | 533.952,80 EUR           |
|           | Equipos Mecánicos                                        | 1.217.403,54 EUR         |
|           | <i>Aire de servicio</i>                                  | 65.763,75 EUR            |
|           | <i>Agua de servicio</i>                                  | 29.529,67 EUR            |
|           | <i>Agua potable</i>                                      | 15.025,73 EUR            |
|           | <i>Taller</i>                                            | 71.097,67 EUR            |
|           | <i>Báscula camiones 40 t</i>                             | 9.348,27 EUR             |
|           | <i>Repuestos</i>                                         | 615.298,78 EUR           |
|           | <i>Analíticas</i>                                        | 411.339,67 EUR           |
|           |                                                          |                          |
|           | <b>Total OC</b>                                          | <b>55.887.149,17 EUR</b> |
|           | <b>Total MEICA</b>                                       | <b>21.148.549,75 EUR</b> |
|           | <b>TOTAL</b>                                             | <b>77.035.698,92 EUR</b> |

**Tabla 41. CAPEX ETAP Bajo consumo. (Fuente: Elaboración propia).**

Se indican en color naranja las diferencias respecto a la alternativa convencional.

| Ítem     | Descripción                                             | Coste Total [EUR]        |
|----------|---------------------------------------------------------|--------------------------|
| <b>1</b> | <b>AJUSTE pH, COAGULACIÓN Y CÁMARA DE DISTRIBUCIÓN</b>  | <b>3.631.944,02 EUR</b>  |
|          | Obra Civil                                              | 1.645.759,15 EUR         |
|          | Instalación Static Mixers                               | 54.583,72 EUR            |
|          | Edificio reactivos                                      | 1.591.175,43 EUR         |
|          | Equipos Mecánicos                                       | 66.748,80 EUR            |
|          | Ajuste pH, coagulación (Static Mixers)                  | 66.748,80 EUR            |
|          | Instrumentación                                         | 103.213,49 EUR           |
|          | Instrumentación                                         | 83.735,69 EUR            |
|          | Instrumentación sistemas de reactivos                   | 19.477,80 EUR            |
|          | Dosificación reactivos                                  | 170.463,43 EUR           |
|          | Sistema dosificación Policloruro de Aluminio            | 55.638,64 EUR            |
|          | Sistema dosificación Sulfato de Alúmina                 | 55.574,92 EUR            |
|          | Sistema dosificación Ácido Sulfúrico                    | 36.829,87 EUR            |
|          | Sistema dosificación Hidróxido de Sodio                 | 22.420,00 EUR            |
| <b>2</b> | <b>FLOCULACIÓN Y DECANTACIÓN</b>                        | <b>21.842.777,51 EUR</b> |
|          | Obra Civil                                              | 13.551.860,93 EUR        |
|          | Equipos Mecánicos                                       | 8.085.512,75 EUR         |
|          | Pantallas deflectoras                                   | 2.538.877,51 EUR         |
|          | Bombas purga fangos 150 m³/h a 8 mca                    | 47.543,16 EUR            |
|          | Bombas drenaje 500 m³/h a 10 mca                        | 31.872,92 EUR            |
|          | Paquete lamelas                                         | 1.703.966,93 EUR         |
|          | Rascadores                                              | 558.467,04 EUR           |
|          | Compuertas                                              | 111.144,72 EUR           |
|          | Polipasto eléctrico 1500 kg                             | 6.579,95 EUR             |
|          | Tuberías, válvulas y accesorios                         | 3.069.543,68 EUR         |
|          | Instrumentación                                         | 180.242,68 EUR           |
|          | Instrumentación                                         | 176.881,14 EUR           |
|          | Instrumentación sistemas de reactivos                   | 3.361,54 EUR             |
|          | Dosificación reactivos                                  | 25.161,15 EUR            |
|          | Sistema de dosificación Poly-DADMAC                     | 25.161,15 EUR            |
| <b>3</b> | <b>OXIDACIÓN, DESINFECCIÓN Y CÁMARA DE DISTRIBUCIÓN</b> | <b>1.645.510,03 EUR</b>  |
|          | Obra Civil                                              | 892.951,95 EUR           |
|          | Equipos Mecánicos                                       | 736.129,49 EUR           |
|          | Sistema dosificación Permanganato Potásico              | 153.100,08 EUR           |
|          | Sistema dosificación cloro gas                          | 583.029,41 EUR           |
|          | Instrumentación                                         | 16.428,59 EUR            |
| <b>4</b> | <b>FILTRACIÓN</b>                                       | <b>14.348.512,93 EUR</b> |
|          | Obra Civil                                              | 9.933.505,97 EUR         |
|          | Filtros                                                 | 9.933.505,97 EUR         |
|          | Equipos Mecánicos                                       | 4.246.443,70 EUR         |
|          | Compuertas motorizadas                                  | 250.209,01 EUR           |
|          | Falsos fondos                                           | 791.948,16 EUR           |
|          | Medio filtrante                                         | 809.006,80 EUR           |
|          | Polipasto eléctrico 2100 kg                             | 23.686,85 EUR            |
|          | Soplantes 5600 m³/h a 7 mca                             | 201.075,94 EUR           |
|          | Tuberías, válvulas y accesorios                         | 2.170.516,94 EUR         |

| Ítem     | Descripción                                                      | Coste Total [EUR]        |
|----------|------------------------------------------------------------------|--------------------------|
|          | Instrumentación                                                  | 168.563,26 EUR           |
| <b>5</b> | <b>TANQUE RETROLAVADO</b>                                        | <b>1.013.043,80 EUR</b>  |
|          | Obra Civil                                                       | 113.648,43 EUR           |
|          | Equipos Mecánicos                                                | 888.925,77 EUR           |
|          | <i>Compuertas motorizadas</i>                                    | 47.729,08 EUR            |
|          | <i>Bombas fangos 300m<sup>3</sup>/h a 8 mca</i>                  | 30.787,51 EUR            |
|          | <i>Bombas sobrenadantes 1600 m<sup>3</sup>/h a 8 mca</i>         | 67.751,85 EUR            |
|          | <i>Polipasto eléctrico 1000 kg</i>                               | 8.695,65 EUR             |
|          | <i>Polipasto eléctrico 1600 kg</i>                               | 7.513,49 EUR             |
|          | <i>Tuberías, válvulas y accesorios</i>                           | 726.448,19 EUR           |
|          | Instrumentación                                                  | 10.469,60 EUR            |
| <b>6</b> | <b>RETORNOS SOBRENADANTES</b>                                    | <b>191.985,87 EUR</b>    |
|          | Obra Civil                                                       | 113.648,43 EUR           |
|          | Equipos Mecánicos                                                | 71.377,73 EUR            |
|          | <i>Tuberías, válvulas y accesorios</i>                           | 71.377,73 EUR            |
|          | Instrumentación                                                  | 6.959,71 EUR             |
| <b>7</b> | <b>TRATAMIENTO DE FANGOS</b>                                     | <b>5.449.122,89 EUR</b>  |
|          | Obra Civil                                                       | 2.624.694,26 EUR         |
|          | Equipos Mecánicos                                                | 2.678.812,17 EUR         |
|          | <b>Tanque homogeneización fangos</b>                             | 202.147,91 EUR           |
|          | <i>Agitador sumergible tanque homogeneización fangos</i>         | 10.212,54 EUR            |
|          | <i>Bombas fangos homogeneizados 140 m<sup>3</sup>/h a 12 mca</i> | 65.060,00 EUR            |
|          | <i>Tuberías, válvulas y accesorios</i>                           | 191.935,37 EUR           |
|          | <b>Espesado mecánico de fangos</b>                               | 359.267,05 EUR           |
|          | <i>Mesas espesadoras 1000 kg/h</i>                               | 308.000,00 EUR           |
|          | <i>Tuberías, válvulas y accesorios</i>                           | 51.267,05 EUR            |
|          | <b>Tanque fangos espesados</b>                                   | 148.633,58 EUR           |
|          | <i>Agitador sumergible tanque fangos espesados</i>               | 10.212,54 EUR            |
|          | <i>Bombas fangos espesados 30 m<sup>3</sup>/h a 8 mca</i>        | 24.920,00 EUR            |
|          | <i>Sacos filtrantes</i>                                          | 24.000,00 EUR            |
|          | <i>Polipasto eléctrico 1000 kg</i>                               | 5.799,72 EUR             |
|          | <i>Tuberías, válvulas y accesorios</i>                           | 83.701,32 EUR            |
|          | <b>Deshidratación fangos</b>                                     | 1.968.763,63 EUR         |
|          | <i>Filtros banda 900 kg/h</i>                                    | 739.900,00 EUR           |
|          | <i>Tornillos transportadores de fangos</i>                       | 295.893,42 EUR           |
|          | <i>Silos fangos deshidratados</i>                                | 682.843,30 EUR           |
|          | <i>Puente grúa 10 t</i>                                          | 54.017,11 EUR            |
|          | <i>Tuberías, válvulas y accesorios</i>                           | 196.109,80 EUR           |
|          | Instrumentación                                                  | 81.250,08 EUR            |
|          | <i>Instrumentación tanque homogeneización fangos</i>             | 49.858,67 EUR            |
|          | <i>Instrumentación espesamiento fangos</i>                       | 1.548,16 EUR             |
|          | <i>Instrumentación tanque fangos espesados</i>                   | 8.009,83 EUR             |
|          | <i>Instrumentación deshidratación</i>                            | 3.792,94 EUR             |
|          | <i>Instrumentación sistemas de reactivos</i>                     | 18.040,48 EUR            |
|          | Dosificación reactivos                                           | 64.366,38 EUR            |
|          | <i>Sistema de dosificación polielectrolito aniónico</i>          | 64.366,38 EUR            |
| <b>8</b> | <b>TANQUE AGUA TRATADA</b>                                       | <b>22.841.622,48 EUR</b> |
|          | Obra Civil                                                       | 20.789.090,37 EUR        |
|          | Equipos Mecánicos                                                | 1.825.918,30 EUR         |

| Ítem      | Descripción                                              | Coste Total [EUR]        |
|-----------|----------------------------------------------------------|--------------------------|
|           | <i>Agitadores sumergibles</i>                            | 123.185,47 EUR           |
|           | <i>Polipasto eléctrico 2100 kg</i>                       | 10.127,04 EUR            |
|           | <i>Tuberías, válvulas y accesorios</i>                   | 1.692.605,79 EUR         |
|           | Instrumentación                                          | 226.613,81 EUR           |
|           | <i>Instrumentación</i>                                   | 226.613,81 EUR           |
| <b>9</b>  | <b>EDIFICIOS (Laboratorio, Control y Administración)</b> | <b>2.704.015,34 EUR</b>  |
|           | Obra Civil                                               | 2.469.304,38 EUR         |
|           | Equipos Mecánicos                                        | 234.710,96 EUR           |
|           | <i>Laboratorio</i>                                       | 134.850,43 EUR           |
|           | <i>Administración</i>                                    | 99.860,53 EUR            |
| <b>10</b> | <b>OTROS</b>                                             | <b>1.217.403,54 EUR</b>  |
|           | Obra Civil                                               | 533.952,80 EUR           |
|           | <i>Taller</i>                                            | 106.732,11 EUR           |
|           | <i>Báscula</i>                                           | 280.500,56 EUR           |
|           | <i>Tanques combustible</i>                               | 146.720,12 EUR           |
|           | Equipos Mecánicos                                        | 1.217.403,54 EUR         |
|           | <i>Aire de servicio</i>                                  | 65.763,75 EUR            |
|           | <i>Agua de servicio</i>                                  | 29.529,67 EUR            |
|           | <i>Agua potable</i>                                      | 15.025,73 EUR            |
|           | <i>Taller</i>                                            | 71.097,67 EUR            |
|           | <i>Báscula camiones 40 t</i>                             | 9.348,27 EUR             |
|           | <i>Repuestos</i>                                         | 615.298,78 EUR           |
|           | <i>Analíticas</i>                                        | 411.339,67 EUR           |
|           |                                                          |                          |
|           | <b>Total OC</b>                                          | <b>52.668.416,67 EUR</b> |
|           | <b>Total MEICA</b>                                       | <b>21.153.258,55 EUR</b> |
|           | <b>TOTAL</b>                                             | <b>73.821.675,22 EUR</b> |

## 2.8. PLIEGO DE LICITACIÓN

Ver archivo externo “TFM-SanRomán\_MaríaJosé-Anexo1.pdf”

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## **1 Introduction and Overview**

### **1.1 Project Background**

Manila Water Company, Inc. (MWCI), is the exclusive concessionaire of the East Zone Service Area to deliver stable potable water supply since 1997. With efforts to expand coverage and improve services to the East Concessionaire Area, MWCI has planned a project to provide an alternative medium-water supply.

With the implementation of the Kaliwa Water Supply System Project (KWSSP) of the Metropolitan Waterworks and Sewerage Sysstem (MWSS), MWCI shall treat 300 Million Liters/Day (MLD) raw water from Kaliwa Low Dam to provide potable water to the Antipolo City and nearby municipalities. The project is also intended to lessen the load on the Angat dam water source.

The Works in this document are for the **Design and Construction of Kaliwa Raw Water Transmission Line (RWTL) and Stage 1 Water Treatment Plant (WTP)**. This project comprises of (i) conveyance of the raw water from MWSS Water portal to the WTP inlet, and (ii) process, control, mechanical, electrical, geotechnical and civil / structural works on the WTP.

The WTP shall be located in a 5.70-hectare raw land that is parallel to Pantay-Buhangin road and adjacent to Roman-Rojas road. The access to the WTP site is either Pantay-Buhangin road or Roman-Rojas road.

### **1.2 Scope of Works**

#### **1.2.1 Purpose**

- 1.2.1.1 Upon its completion, the 300 MLD Water Treatment Plant shall be capable to receive and treat incoming raw water from Kaliwa Low Dam and must produce potable water that is fully compliant with the treated water quality requirements described in this document, in accordance to the Philippine National Standards for Drinking Water (PNSDW) 2017.
- 1.2.1.2 The Raw Water Transmission Line shall interconnect with MWSS’ water portal and convey raw water to the WTP inlet.
- 1.2.1.3 The WTP shall be designed, constructed, tested and commissioned in accordance with the requirements and specifications stated in this Employer’s Requirements.
- 1.2.1.4 The WTP shall be comprised of all the process units described in this document, complying with all the necessary performance requirements.
- 1.2.1.5 Treatment of raw water shall be by conventional technology assisted by chemical treatment to meet the treated water quality limits. All proposed technologies for other parts of the Works shall be well proven for treatment of raw water and sludge.
- 1.2.1.6 Proposed technologies for other parts of the Works shall be matured and well proven for treatment of water and sludge.

- 1.2.1.7 It is the responsibility of the Contractor to supply all necessary materials and consumables, labor and supervision, plants and equipment, and associated engineering and specialty works which are deemed reasonably implicitly and explicitly included, required and appropriate by the Tender / Contract Documents.

1.2.2 General Obligation

- 1.2.2.1 It is the intent of this scope of works that the facilities to be designed and constructed by the Contractor shall be fit for the purpose in every way for the service required.
- 1.2.2.2 The Contractor, whether it is specifically referred to in the Conditions of Contract and/or these Employer's Requirements shall provide all equipment, construction plant, temporary works, labor, materials, tools, work, skills, expertise, services and transport necessary:
- 1 To perform all the design, engineering, procurement, construction, testing and commissioning of the Works; and
  - 2 For the safe, convenient, reliable, efficient and satisfactory completion and operation of the Works in accordance with the Employer's Requirements.
- 1.2.2.3 The Contractor is responsible for the overall functionality of the Works and all other interfaces arising from the Works. The Contractor must perform the work in a professional, timely, safe and environmentally responsible manner.
- 1.2.2.4 All design shall be in accordance with the best modern practice and shall facilitate safe access for inspection, cleaning, lubrication, repair, maintenance and replacement to ensure satisfactory operation under all service conditions. Design shall also consider constructability, potential disturbance to and interfacing with operation of existing facilities, neighboring community and industries, and general operation and maintenance requirements.
- 1.2.2.5 The design shall result in the lowest possible life cycle cost with due regard to reliability, minimum operating and maintenance cost. Design with highly automated treatment process system shall be adopted whenever possible.

1.2.3 The Scope of Works includes:

1.2.3.1 Design and construction of:

- 1 Raw Water Transmission Line from water portal to the intake structure and pumping station of WTP;
- 2 300 MLD capacity conventional WTP comprising of liquids and solids/sludge treatment technologies including all ancillaries and support facilities;
- 3 A 48ML treated water reservoir capacity within the Site;
- 4 A flow split/diverting structure in the RWTL to manage the following:  
(A) Supply of 300 MLD of raw water to Stage 1 WTP;

(B) Provision to convey additional 900MLD to the Stage 2 WTP at the surrounding area, and;

(C) Overflow provision

- 5 Design of suitable interface from the water portal to the RWTL connection;
- 6 Design of suitable interface from the RWTL to the inlet works of 300 MLD WTP;
- 7 Siltation protection provision in the RWTL flow diverting structure and other structure deem necessary in the design

#### 1.2.3.2 Design Provision

##### 1 Long Term East Source

Upon completion of the Long Term East Source, an additional 900MLD is expected to be conveyed from the water portal to the Stage 2 Water Treatment Plant. The flow diverting structure of the RWTL shall consider a block out for future interface connection to the Stage 2 WTP as specified in Section 12.2.

##### 2 Additional Process Units

Dichloromethane (DCM), a volatile organic compound, has been detected during the initial stages of the 12-month raw water sampling activities as shown in Appendix 4 Raw Water Sampling Data. Though its occurrence was considered an isolated case, the Employer finds it reasonable to prepare for such risk in case a more detailed study identify its necessity. The Contractor shall consider a space provision within the site to locate any future additional process units for VOC removal. Refer to Section 10.2 its general design requirements.

##### 3 Treated Water Transmission Lines

The reservoir shall be provided with discharge outlet provisions to connect with two (2) Treated Water Transmission Lines - Antipolo Line (AL) and Long Term East Line (LTEL). The battery limit of the RWTL and WTP scope shall be discharge outlet of the treated water reservoir as specified in Section 12.9.

##### 4. Treated Water Pumping Station

The Contractor shall include a space provision within the site to locate the Treated Water Pumping Station (scope by others). Refer to Section 10.2 its general design requirements. Further, the Contractor shall supply power to the Treated Water Pumping Station with a minimum rating of 10,000 KVA. The sizing of which shall be included in the electrical design. The Contractor shall coordinate with the Employer regarding any updates on the electrical demand load of the Treated Water Pumping Station.

1.2.3.3 The Scope of Works includes design, supply, construction, installation, testing and commissioning of the complete fully functional and operational RWTL and WTP and associated influent and effluent systems within the specified time for completion which shall include but not be limited to the following tasks:

- 1 Site mobilization, preparation, excavation, clearance, and provision of access and utilities and all temporary facilities as required by the Works;
- 2 Removal of trees on site, as specified in the tree cutting permit acquired by the Contractor;
- 3 Seismic assessment;
- 4 Collection, acquisition, review and analysis of needed data for the design, supply, construction, installation, testing, commissioning and process proving of the RWTL and WTP;
- 5 Protection or diversion of all affected existing services;
- 6 Public relationship and traffic management in all areas affected in any way by the Contract;
- 7 Acquisition of all licenses, permits and clearances required for the construction and operation of the RWTL and WTP;
- 8 Conducting two (2) Design for Safety reviews during design development of each discrete part of the Works;
- 9 Conducting one Hazard and Operability (HAZOP) review prior to design finalization of each discrete part of the Works;
- 10 Preparation and submission of all design, testing and commissioning (T&C), as-built and O&M documents;
- 11 Development, implementing and compliance with comprehensive health, safety and environmental programs
- 12 Development, implementing and compliance with quality management programs;
- 13 Interfacing with proposed and existing assets, as applicable;
- 14 Coordination and cooperation with other parties employed by the Employer on the Kaliwa Water Supply System Project, particularly the Engineer and other contractors of the associated networks;
- 15 Coordination and cooperation with adjacent developments, existing or under construction;
- 16 Training of Manila Water’s assigned O&M personnel;
- 17 One-year Process Proving Period (PPP) including operation and maintenance (O&M) of the WTP, as part of the Test on Completion to prove that the certified completed Works meet the specified performance requirements. The Contractor shall be responsible for regulatory compliance during the 1 year process proving period. All the works necessary for the satisfactory implementation of the PPP which includes but is not limited to resources, consumables, transportation, and logistics;
- 18 Appropriate disposal in accordance to RA 6969 of screenings, grit, and other waste products resulting from the operation of the RWTL and WTP during the commissioning and PPP;



- 19 Rectification of any defects during the 1 year Defects Notification Period (DNP) starting from the completion of process proving stage.

1.2.3.4 The RWTL shall include interface chamber to portal, intake screening system, flow diverting structure, interface chamber to WTP and pumping station. The WTP shall include, but not be limited to, the following facilities:

- 1 Coagulation and Flocculation tanks;
- 2 Sedimentation tanks with inclined settlers;
- 3 Filtration and backwash mechanisms;
- 4 Chlorination preparation and dosing for disinfection and suitable scrubber system;
- 5 Chlorine Contact tank and Treated Water Reservoir;
- 6 Sludge collection, thickening, dewatering and dewatered sludge handling and storage system;
- 7 Recovered water facility;
- 8 Chemical storage, dosing and disposal system;
- 9 Provision of land for any possible VOC treatment;
- 10 Algal control (as necessary);
- 11 All electrical including MV and LV installations, instrumentation, controls, automation, and supervisory control and data acquisition (SCADA) system;
- 12 All security and communication system;
- 13 All supporting facilities:
  - (A) Utilities including electricity, potable and service water, sewerage, telecommunications, internet; drainage, etc;
  - (B) Standby generator set, fuel storage tanks and associated piping works;
  - (C) Security equipment and office
  - (D) Fire detection, alarm and suppression system
  - (E) Hazardous waste storage;
  - (F) Lifting facilities and O&M vehicles;
  - (G) Administration operations, and office building(s);
  - (H) Laboratory facility;
  - (I) Equipment and spare parts storage area and shelves;
  - (J) Workshop(s);
  - (K) Roads and carparking;
  - (L) Landscaping;
  - (M) Perimeter fencing, gates and guard house;
  - (N) Lighting (plant and perimeter)
  - (O) All other ancillaries.

### **1.3 Applicable Codes and Standards**

All standards used in this specification are based on the Philippine, American and European Standards.

Work to be performed under these specifications shall be in accordance with the following codes and standards. Unless otherwise specified, the applicable governing editions and addenda to be used for all references or codes or standards specified herein shall be interpreted to be the jurisdictionally approved editions and addenda. If a code or standard is not jurisdictionally mandated, then the current edition and addendum in effect as of the Base Date shall apply. These references shall govern the works except where they conflict with Manila Water's (the Employer's) Standard Engineering Specifications (SES). When conflicts and disputes are evident in relation to the use and interpretation of the given Standards and Manila Water's SES, the Contractor shall comply with the applicable national Standards. Otherwise, the most applicable International standard shall be considered. The list of standards below indicates a selection of the most relevant national and international standards to be applied to this Works.

Where disputes arise in the interpretation of the standards, the more rigorous interpretation shall prevail.

Unless specified otherwise the design and drawings shall be in the international System of Units (SI Standards).

If the Contractor intends to utilize codes or references other than those listed below, one (1) full authorized English copy of such alternative codes and references adopted for the works or section of the works shall be submitted for review of the Engineer. Alternative standards shall be equal to or better than herein specified.

- 1.3.1 American Concrete Institute Manual of Concrete Practice (ACI)
- 1.3.2 American National Standards Institute (ANSI)
- 1.3.3 American Society for Testing of Materials (ASTM)
- 1.3.4 American Society of Civil Engineers (ASCE)
- 1.3.5 American Water Works Association (AWWA)
- 1.3.6 American Welding Society (AWS)
- 1.3.7 DENR Environmental Quality Standards for Noise and General Areas
- 1.3.8 DENR Administrative Order 2016-08 Water Quality Guidelines and General Effluent Standards of 2016
- 1.3.9 DENR Rules and Regulations for Toxic and Hazardous Wastes
- 1.3.10 Republic Act No. 8749, Philippine Clean Air Act of 1999
- 1.3.11 Department of Health (DOH)

- 1.3.12 Department of Public Works and Highways (DPWH)
- 1.3.13 Department of Labor and Employment (DOLE)
- 1.3.14 Fire Code of the Philippines
- 1.3.15 Institute of Electrical and Electronics Engineers (IEEE)
- 1.3.16 International Electro Technical Commission (IEC)
- 1.3.17 Japan Road Association (JRA)
- 1.3.18 National Pollution Control Commission (NPCC)
- 1.3.19 National Structural Code of the Philippines (NSCP)
- 1.3.20 National Building Code of the Philippines (NBC)
- 1.3.21 National Fire Protection Association (NFPA)
- 1.3.22 Occupational Health & Safety Advisory Services (OHSAS)
- 1.3.23 Philippine Drug Enforcement Agency (PDEA)
- 1.3.24 Philippine National Police (PNP)
- 1.3.25 Philippine Electrical Code (PEC)
- 1.3.26 Philippine National Standards for Drinking Water 2017 (PNSDW)
- 1.3.27 Philippine Mechanical Engineering (PME) Code
- 1.3.28 Revised National Plumbing Code of the Philippines (RNPCP)
- 1.3.29 Sanitation Code of the Philippines
- 1.3.30 Solid Waste Management Act
- 1.3.31 Steel Structures Painting
- 1.3.32 Uniform Plumbing Code (UPC)
- 1.3.33 Water Environment Federations (WEF)
- 1.3.34 Local Government Unit Ordinances

List of Abbreviation

|        |                                                                           |
|--------|---------------------------------------------------------------------------|
| AASHTO | American Association of State Highway and Transportation Officials        |
| ABS    | Acrylonitrile butadiene styrene                                           |
| AC     | Alternating Current                                                       |
| ACH    | Air Change per Hour                                                       |
| ACI    | American Concrete Institute                                               |
| ACMV   | Air Conditioning and Mechanical Ventilation                               |
| ADF    | Average Daily Flow                                                        |
| AEIC   | Association of Edison Illuminating Companies                              |
| AFBMA  | Anti-Friction Bearing Manufacturers Association                           |
| AGMA   | American Gear Manufacturers Association                                   |
| AIC    | Amperes Interrupting Circuit                                              |
| AISC   | American Institute of Steel Construction                                  |
| AISI   | American Iron and Steel Institute                                         |
| AL     | Antipolo Line                                                             |
| ANSI   | American National Standards Institute                                     |
| API    | American Petroleum Institute                                              |
| AS     | Australian Standard                                                       |
| ASCE   | American Society of Civil Engineers                                       |
| ASD    | Activated Sludge Diffusion                                                |
| ASHRAE | American Society of Heating, Refrigerating and Air-Conditioning Engineers |
| ASME   | American Society of Mechanical Engineers                                  |

|      |                                            |
|------|--------------------------------------------|
| ASTM | American Society for Testing and Materials |
| AWS  | American Welding Society                   |
| AWWA | American Water Works Association           |
| BIM  | Building Information Management            |
| BSI  | British Standard Institute                 |
| BWC  | Bureau of Working Conditions               |
| CAR  | Corrective Action Plan                     |
| CBR  | California Bearing Ratio                   |
| CCTV | Closed-circuit Television                  |
| CFD  | Computational Fluid Dynamics               |
| CHP  | Combined Heat and Power                    |
| CIP  | Cleaning-in-place                          |
| COSH | Construction Occupational Safety & Health  |
| CPE  | Chlorinated Polyethylene                   |
| CPVC | Chlorinated Polyvinyl Chloride             |
| CRD  | Component Resolved Diagnostic Testing      |
| CRSI | Concrete Reinforcing Steel Institute       |
| CT   | Constant Torque                            |
| dB   | Decibel                                    |
| DC   | Direct Current                             |
| DCM  | Dichloromethane                            |
| DCS  | Distributed Control System                 |

|        |                                                                            |
|--------|----------------------------------------------------------------------------|
| DIN    | Deutsches Institut für Normung e.V. (German Institute for Standardization) |
| DMP    | Design Management Plan                                                     |
| DN     | Nominal Diameter                                                           |
| DNP    | Defects Notification Period                                                |
| DO     | Dissolved Oxygen                                                           |
| DOH    | Department of Health                                                       |
| DOLE   | Department of Labor and Employment                                         |
| DOM    | Drawn Over Mandrel                                                         |
| DPWH   | Department of Public Works and Highways                                    |
| DSLCC  | Digital Synchronizer and Load Control                                      |
| ECC    | Environmental Compliance Certificate                                       |
| EDI    | Energy Dissipating                                                         |
| EEPROM | Electrically Erasable Programmable Read-Only Memory                        |
| EIC    | Electrical Interface Cabinet                                               |
| EISA   | Energy Independence and Security Act                                       |
| EMT    | Electrical Metallic Tubing                                                 |
| EN     | European Norm                                                              |
| EOT    | Electric Overhead Travelling                                               |
| EPDM   | Ethylene Propylene Diene Monomer                                           |
| EPPM   | Enterprise Primavera Project Management                                    |
| EPR    | Ethylene Propylene Rubber                                                  |
| EREP   | Emergency Response and Evacuation Plan                                     |

|        |                                                   |
|--------|---------------------------------------------------|
| FAT    | Factory Acceptance Test                           |
| FDAS   | Fire Detection and Alarm System                   |
| FEMA   | Failure Modes and Effects Analysis                |
| FGL    | Finish Ground Level                               |
| FLHA   | Field Level Hazard Analysis                       |
| FREPR  | Fire Retardant Ethylene Propylene Rubber          |
| FRXLPE | Flame Retardant Cross-Linked Polyethylene         |
| GCC    | General Conditions of Contract                    |
| GRP    | Glass reinforced Plastics                         |
| GSI    | Geological Strength Index                         |
| GUI    | Graphical User Interface                          |
| HAC    | High Alumina Cement                               |
| HAZCOM | Hazard Communication                              |
| HAZOP  | Hazard and Operability Analysis                   |
| HDPE   | High-density Polyethylene                         |
| HMI    | Human Machine Interface                           |
| HPC    | Heterotrophic Plate Count                         |
| HV     | High Voltage                                      |
| ICEA   | Insulated Cable Engineers Association             |
| IEC    | International Electro-Mechanical Commission       |
| IEEE   | Institute of Electrical and Electronics Engineers |
| IFAS   | Integrated Fixed Film Activated Sludge            |

|       |                                                |
|-------|------------------------------------------------|
| IGBT  | Insulated Gate Bipolar Transistors             |
| IP    | Indigenous people                              |
| ISO   | International Organization for Standardization |
| ITP   | Inspection and Test Plan                       |
| JHA   | Job Hazard Analysis (task specific)            |
| kPa   | KiloPascal                                     |
| kW    | Kilowatt                                       |
| kWh   | Kilowatt hour                                  |
| KWSSP | Kaliwa Water Supply System Project             |
| LCD   | Liquid Crystal Display                         |
| LCS   | Local Control Station                          |
| LLC   | Life Cycle Cost                                |
| LOPA  | Layer of Protection Analysis                   |
| LRFD  | Load Resistance Factor Design                  |
| LTEL  | Long Term East Line                            |
| LV    | Low voltage                                    |
| m3    | Cubic metre                                    |
| MC    | Maintenance Cleaning                           |
| MCCB  | Molded Case Circuit Breakers                   |
| MCCs  | Motor control centers                          |
| MCE   | Maximum Considered Earthquake                  |
| MCT   | Multi Cable Transit                            |



|        |                                                     |
|--------|-----------------------------------------------------|
| MDD    | Maximum Dry Density                                 |
| mg/L   | Milligram per liter                                 |
| MLD    | Million Liters per Day                              |
| mm     | Millimeter                                          |
| Mpa    | Mega pascal                                         |
| MSS    | Manufacturers Standardization Society               |
| MTBM   | Microtunnel boring machine                          |
| MV     | Medium Voltage                                      |
| MVA    | Megavolt Ampere                                     |
| MVAC   | Mechanical ventilation and air conditioning         |
| MWCI   | Manila Water Company Inc.                           |
| MWLS   | Manila Water Laboratory Services                    |
| MWSS   | Metropolitan Waterworks and Sewerage System         |
| NAMRIA | National Mapping and Resource Information Authority |
| NBC    | National Building Code of the Philippines           |
| NCIP   | National Commission on Indigenous Peoples           |
| NDE    | Nondestructive Examination                          |
| NEC    | National Electrical Code                            |
| NEMA   | National Electrical Manufacturers Association       |
| NFPA   | National Fire Protection Association                |
| NOAH   | Nationwide Operational Assessment of Hazard         |
| NPCC   | National Pollution Control Commission               |

|       |                                                           |
|-------|-----------------------------------------------------------|
| NPSH  | Net Positive Suction Head Available                       |
| NPT   | National Pipe Thread                                      |
| NSCP  | National Structural Code of the Philippines               |
| NTU   | Nephelometric Turbidity Unit                              |
| O&M   | Operation and Maintenance                                 |
| OEM   | Original Equipment Manufacturer                           |
| OHSAS | Occupational Health & Safety Advisory Services            |
| OHNAP | Occupational Health Nurses Association of the Philippines |
| OSHA  | Occupational Safety and Health Administration             |
| OSHS  | Occupational Safety and Health Standard                   |
| P&ID  | Piping and Instrumentation Diagram                        |
| PACl  | Polyaluminum Chloride                                     |
| PCA   | Plumbing Code of Australia                                |
| PCAB  | Philippine Contractors Accreditation Board                |
| PCC   | Point of Common Coupling                                  |
| PCI   | Precast Concrete Institute                                |
| PE    | Polyethylene                                              |
| PEC   | Philippine Electrical Code                                |
| PEP   | Project Execution Plan                                    |
| PLC   | Programmable Logic Controller                             |
| PNSDW | Philippines National Standard for Drinking Water          |
| PNRI  | Philippine Nuclear Research Institute                     |

|            |                                            |
|------------|--------------------------------------------|
| PolyDADMAC | Polydiallyldimethylammonium chloride       |
| PP         | Polypropylene                              |
| PPP        | Process Proving Period                     |
| PPE        | Personal Protective Equipment              |
| PQP        | Project Quality Plan                       |
| PS         | Primary Sludge                             |
| psi        | Pound per square inch                      |
| PSME       | Philippine Society of Mechanical Engineers |
| PSME       | Process Safety Management Analysis         |
| PTFE       | Polytetrafluorethylene                     |
| PVC        | Polyvinyl Chloride                         |
| PVDF       | Polyvinylidene Fluorocarbon                |
| PWM        | Pulse-Width modulated                      |
| QA         | Quality Assurance                          |
| QAD        | Quality Assurance Division                 |
| QAP        | Quality Audit Plan                         |
| QC         | Quality Control                            |
| RAS        | Return Activated Sludge                    |
| RC         | Recovery Cleaning                          |
| RC PVCL    | Reinforced Concrete with PVC Lining        |
| RESS       | Required Excavation and Support Sheet      |
| RGS        | Rigid Galvanized Steel                     |

|       |                                          |
|-------|------------------------------------------|
| RH    | Relative Humidity                        |
| RIO   | Remote Input/Output                      |
| RMS   | Root Mean Square                         |
| RO    | Regulatory Office                        |
| RSA   | Response Spectrum Analysis               |
| RTD   | Resistance Temperature Detectors         |
| RWTL  | Raw Water Transmission Line              |
| SAT   | Site Acceptance Test                     |
| SBR   | Styrene Butadiene Rubber                 |
| SCADA | Supervisory Control And Data Acquisition |
| SCR   | Screenings Capture Ratio                 |
| SDER  | Shaft Design Engineer’s Representative   |
| SES   | Standard Engineering Specifications      |
| SET   | Source Emission Test                     |
| SIL   | Safety Integrity Level Analysis          |
| SLR   | Solid Loading Rate                       |
| SOR   | Surface Overflow Rate                    |
| SOTR  | Standard Oxygen Transfer Rates           |
| SPDT  | Single Pole Double Throw                 |
| spm   | Strokes per minute                       |
| SPT   | Standard Soil Testing                    |
| SS    | Stainless Steel                          |

|         |                                                      |
|---------|------------------------------------------------------|
| SSHA    | Site-specific Seismic Hazard Assessment              |
| SSPC-SP | Structural Steel Painting Council - Surface Painting |
| SSTDs   | Solid-State Trip Devices                             |
| SWA     | Steel wire armored                                   |
| SWL     | Safe Working Load                                    |
| T&C     | Testing and Commissioning                            |
| TCU     | True color units                                     |
| TDER    | Tunnel Design Engineer's Representative              |
| TDS     | Total dissolved solids                               |
| TEFC    | Totally Enclosed Fan Cooled                          |
| TOC     | Tests on Completion                                  |
| TSS     | Total Suspended Solids                               |
| UBC     | University of British Columbia                       |
| UHMWPE  | Ultra High Molecular Weight Polyethylene             |
| UL      | Underwriters Laboratories Inc                        |
| uPVC    | Unplasticized Polyvinyl Chloride                     |
| UTM     | Universal Transverse Mercator                        |
| VAC     | Voltage, Alternating Current                         |
| VC      | Vitrified Clay                                       |
| VDC     | Voltage, Direct Current                              |
| VFA     | Volatile Fatty Acids                                 |
| VFD     | Variable Frequency Drive                             |

|     |                               |
|-----|-------------------------------|
| VOC | Volatile Organic Compound     |
| VPI | Vacuum Pressure Impregnation  |
| VSS | Volatile Suspended Solids     |
| VT  | Variable Torque               |
| WEF | Water Environment Federations |
| WGS | World Geodetic System         |
| WTP | Water Treatment Plant         |

## **4 The Site**

### **4.1 Location of Site**

- 4.1.1 The WTP site is approximately 5.70-hectare plot of land situated along Roman Rojas Road and parallel to Pantay Buhangin Road in Antipolo City. This area shall be utilized for the development of the WTP, subsequently identified in this document as the Site. The Site is situated on the same side of the existing Unity village. The lower right corner of the WTP site adjacent to the Roman Rojas has specific coordinates of X = 311375.5957, Y = 1613440.50311 (based in WGS 1984 UTM Zone 51 N).
- 4.1.2 The WTP shall be designed to maximise the use of area within the Site. The Contractor shall construct all permanent works within the Site boundary.
- 4.1.3 The site has gentle slope from the most eastern area of the land going to the farthest west area. Any area of the site can be utilized for temporary works (i.e. laydown area, temporary facility / storage).
  - 1 It shall be the Contractor's responsibility to assess and verify the viability of utilizing its proposed area of the plot for this purpose
  - 2 The Contractor shall be responsible for providing any additional area they deem necessary as part of the temporary works.
- 4.1.4 The RWTL will convey raw water from the tapping point allotted by MWSS in the water portal (Appendix 5 Drawing sheet 45429S-05507-E01 Rev 00) up to the inlet structure of the WTP. Specific coordinates of the stub-out to be provided by the Employer.
- 4.1.5 The boundaries for the plot of land, the Site, is shown in Appendix 2 Topographical Survey.

### **4.2 Site Access**

- 4.2.1 Access to the site shall be along public roads and the Contractor shall arrange the necessary permissions with local government units. The main access to the WTP site is through Roman-Rojas road.
- 4.2.2 In case of restrictions in access along the Roman-Rojas road, the Contractor is allowed to explore utilizing the Pantay-Buhangin road as an alternative site entry, however, they shall do so at their own risk and expense. This route can also be used for transport of equipment and materials to the Site
  - 4.2.2.1 The Contractor shall notify the Engineer and Employer on the necessary procedure and provision of temporary access road.
  - 4.2.2.2 In utilizing this alternative route, the Contractor shall be responsible for performing all due diligence required, including all coordination works necessary.
  - 4.2.2.3 Securing all necessary permits and private owner permission shall be the responsibility of the Contractor.
  - 4.2.2.4 Traffic management plan shall be updated to include all necessary coordination in using this access route.

- 4.2.2.5 Any cost incurred in exploring this alternative route will be the responsibility of the Contractor.
- 4.2.3 The Contractor shall acquaint himself with the actual site conditions and allow for any contingency with regards to the means of access and any special site restrictions including making good of all works disturbed or damaged and reinstatement to the condition at the start of the works, or modification to match the existing.
- 4.2.4 The Site will be handed over to the Contractor in the existing condition by the Employer, with no modifications.
- 4.2.5 The Contractor shall apply and pay for any access approvals required for undertaking the construction activities on the site access from the public road as necessary.
- 4.2.6 The Employer will provide the Right of Way to the Site; which shall be used by the Contractor. This access shall be the permanent access to the Site. In addition, the Contractor shall provide temporary access to the Site during construction. The Contractor shall make their own arrangements with the land owners and bear the costs for the acquisition of such temporary access. The Employer shall not be liable for any consequences or liabilities arising out of the Contractor's use of the temporary access during the performance of the works.
- 4.2.7 The Contractor shall take all necessary steps to minimize disturbance and disruption to the public including traffic on public roads due to activities associated with the Works.
- 4.2.8 The Contractor shall maintain the original or an improved condition of the site access road, properties or lands which are impacted due to the construction activities. The Contractor shall prepare a detailed pre-condition survey report on the site access roads, properties or lands which are expected to be affected by the Contractor accessing the Site for the duration of this Contract. Photographic documentation complete with dates shall be submitted by the Contractor to the Engineer for review.
- 4.2.9 The Contractor shall keep the existing public access roads leading to and around the Site clean at all time to the satisfaction of the Engineer. The Contractor shall be responsible for timely reinstatement of any affected facilities, infrastructure or properties.
- 4.2.10 The Contractor shall keep and maintain a log of all personnel and visitors arriving at and departing from the Site. The log shall be made available for inspection by the Engineer and the Employer as required.

#### **4.3 Permits to be Obtained by the Employer**

The Employer shall obtain the following Permits:

- 4.3.1 Environmental Compliance Certificate
- 4.3.2 Zoning Clearance (if necessary)

#### **4.4 Site Possession and Working Areas**

Possession of the Site, or parts thereof, given by the Employer is not exclusive. The Contractor shall cooperate with the Employer and other contractors who may be working at or adjacent to the proposed site, to minimize interference between all parties.



Contractor's attention is particularly drawn to the requirements of the Republic Act 4566, otherwise known as the Contractor's Licensing Law, which requires Contractor to install a signboard or billboard at the Site showing the Contractor's name, Contractor's license number, and relevant license classification. Content and format of the signboard shall be aligned with the Employer's corporate branding and prior to installation shall be agreed with the Employer.

All Contractor work areas on the Site will be assigned by the Employer. The Contractor shall confine their operations to areas so assigned. Should contractor find it necessary or advantageous to use any additional offsite area for any purpose or what so ever, the contractor at their expense provide and make their own arrangement for the use of such additional offsite areas.

#### **4.5 Site Condition and Constraints**

4.5.1 The Contractor shall make themselves aware of all possible site constraints during the tender. Mitigation measures for these constraints shall be included in their proposal. The Employer has initially identified the following site constraints:

4.5.1.1 The raw water characteristics provided in this document were analyzed before the construction of the Kaliwa Low Dam. The Contractor shall conduct a Raw Water Verification Study under a provisional sum, once water from the dam is available for sampling.

4.5.1.2 An existing creek used for irrigation traverses the vicinity of the WTP site and water portal as shown in Appendix 13 - Flood Hazard Assessment Report. If found necessary, the Contractor shall divert the existing waterway so as to not interfere with the RWTL alignment. The necessary coordination, design, permits, and cost of the diverted waterway shall be handled by the Contractor. The design of the modified waterway shall be submitted to the Engineer.

4.5.1.3 The surrounding area between the WTP site and water portal has varying ground slope ranging from gentle to steep slopes. The Contractor shall provide the necessary slope protection design and methodology statement for any excavation works during the construction phase to the Engineer for review. All excavation works shall adhere to the safety requirements stipulated in Section 3.22. The Employer shall not be liable for the methodology statements. If the approach in the method statement fails to mitigate the risk in design and construction, the Contractor shall revise the method statement and implement this at his own expense. No additional cost shall be charged to the Employer for the revision and implementation of this method statement.

4.5.1.4 The RWTL alignment will utilize segment of the existing public road due to the location of the water portal and the WTP site. The Contractor shall provide Traffic Management Plan indicating the construction methodology, duration of work to be implemented in the area and necessary slope protection measures. The Contractor shall conduct the respective coordination and acquire the necessary permits from various local or national government offices. The reinstatement of the road after the completion of works shall be handled by the Contractor. All costs incurred on this activity shall be handled by the Contractor.

- 4.5.1.5 An identified private lot shall be avoided by the Contractor in designing the alignment and construction of the RWTL. Any temporary access or works shall not be allowed in the private lot. The corner coordinates of the private area (based on WGS 1984) are shown below:
- 1 Corner 1 – (Latitude: 14°35'11.67"N; Longitude: 121°14'35.08"E)
  - 2 Corner 2 – (Latitude: 14°35'8.57"N; Longitude: 121°14'35.96"E)
  - 3 Corner 3 – (Latitude: 14°35'8.09"N; Longitude: 121°14'55.28"E)
  - 4 Corner 4 – (Latitude: 14°35'15.12"N; Longitude: 121°14'56.81"E)
- 4.5.1.6 The tentative coordinates (based form WGS 1984) for the allocated outfall for Manila Water from the water portal of MWSS is: Latitude: 14°34'53.33"N; Longitude: 121°14'57.64"E. The coordinates provided shall be verified with the respective Contractor of the water portal. All coordination and correspondences shall be well documented by the Contractor and informed to the Employer and Engineer. Necessary assistance from the Employer shall be informed and raised by the Contractor ahead of time.
- 4.5.1.7 The WTP site is near residential and commercial facilities. Nuisance, such as noise and dust, during construction and during RWTL and WTP operation shall be addressed by the Contractor. They shall be responsible for identifying baseline conditions of these nuisance, addressing them during design, and implementation.
- 4.5.1.8 Seismic findings identified that the Site is near an unnamed fault. Refer to Appendix 3 Table and Graph of Response Spectra.
- 4.5.1.9 Significant number of trees are observed on site. Removal of all trees duly identified in the tree cutting permit (number and type) shall be the responsibility of the Contractor.
- 4.5.1.10 The site is not prone to fluvial flooding. However, the Contractor shall be responsible to identify, assess and mitigate potential flooding due to water impoundment and overflows from the RWTL and WTP.
- 4.5.1.11 The site is expected to have shallow hard strata. The Contractor shall consider this in their design and planning the construction timeline. A method statement of the proposed excavation approach shall be provided by the Contractor.
- 4.5.1.12 Other constraints leading to potential risks shall be identified and mitigated by the Contractor.

## **4.6 Site Facilities**

- 4.6.1 The Contractor shall provide all necessary site facilities and amenities for the Works including those for the Employer's supervision team. The location and construction of the Contractor's site facilities shall be subject to the "no-objection" certificate by the Engineer. Where the Contractor deems it necessary to have additional area off site for the temporary storage and other facilities, this shall be included in the Bid price.

- 4.6.2 The Contractor shall provide full time housekeeping and modern sanitary services necessary to keep the Site, working areas and all site facilities in a clean, neat, hygienic and functional condition. The Contractor shall ensure that waterborne wastes from toilets, bathing places, sinks, etc., installed at the sites are discharged into septic tanks. All matters of health and sanitation shall comply with the requirements of the relevant authorities.
- 4.6.3 The Contractor's site offices shall be of the construction outlined below:
- 4.6.3.1 Steel construction with reinforced concrete floor slabs. The area shall be cleared and backfilled with hardcore to be spread, leveled and compacted. The first story slab shall be provided with a damp proof membrane. The second story slab shall be a composite slab using steel sheet decking or similar. The floor of the second story shall have sufficient bracing and support to prevent any movement and vibration when in use. The staircases shall be steel with steel handrail. The roof shall be insulated with an approved insulating material.
  - 4.6.3.2 The building walls shall be of sandwich panel construction with minimum 42mm thick galvanized steel sheet on both sides with an infill of rockwool insulation.
  - 4.6.3.3 The building roof shall be minimum 0.37mm thick profiled galvanized steel sheet, Sundek or similar approved, with minimum 25mm thick mineral wool insulation.
  - 4.6.3.4 The building design including columns, beams, roof trusses and fasteners, drawings and calculations shall be approved and certified by a Licensed Engineer.
  - 4.6.3.5 Adequate drains shall be provided for the drainage of hard standing area. The layout shall comply with all codes and regulations of the relevant authorities, i.e. fire safety protection, ventilation, lightning protection and governing building regulations for temporary site offices/buildings.
  - 4.6.3.6 There shall be sufficient separate male and female toilet, washing and shower facilities for Contractor's and Manila Water's supervising personnel.
- 4.6.4 The Contractor shall make necessary coordination and connections to the existing potable water line for both Temporary and Permanent Works. All connections shall incorporate break tanks and backflow protection to prevent contamination of water supplies. Any temporary connections for construction accommodation shall also incorporate backflow protection.
- 4.6.5 The Contractor shall remove all site facilities and Temporary Works upon completion of the Works.

#### **4.7 Hours of Work**

The Contractor shall plan and manage the work to conform to the requirement of the programme. The Contractor shall be solely responsible for obtaining the necessary permits (whenever applicable), including but not limited to, the Third Party, in case the Contractor wishes to extend beyond the Normal Working Hours. The Employer assumes

no liability arising out of the Contractor's requirement of extending the working hours beyond the Normal Working Hours.

#### **4.8 Site Security**

- 4.8.1 The Contractor shall install temporary security fences to provide security around the perimeter of the Site. Such temporary fencing shall be dismantled upon completion of the Contract.
- 4.8.2 The Contractor shall be responsible for the site security of all the operations, site staff and subcontractors, storage of their own materials, tools and equipment, protection of completed works in place, site offices and the like. The Contractor shall provide at their own cost, such as additional security as they deem necessary for protection of the compound and areas of works.
- 4.8.3 The Contractor shall provide CCTV Cameras for continuous monitoring of key areas such as all entry and exit points and the perimeter. The CCTV cameras shall be of High-Definition type. The storage capacity of the CCTV footage shall be minimum of 28 days.

#### **4.9 Temporary Site Services**

The Contractor shall install, operate, maintain and subsequently remove temporary supplies of power, water, communication for the construction, testing and commissioning, Process Proving Period and maintenance of the Works. The Contractor shall pay for all the utilities.

##### **4.9.1 Temporary Power Supply**

The Contractor shall ensure that adequate electric power shall be made available at the Site 7 days before commencement of the Works on the Site. All materials and expenses that may be incurred in securing the electrical connection shall be on the Contractor's account.

The Contractor shall ensure that the generator set, including fuel and auxiliaries be available on the Site throughout the performance of the Works.

The Contractor shall promptly settle all electric bills that may be assessed by reason of the execution of the Works to ensure continuous supply of electricity. At no time shall a suspension of the Works be justifiable by reason of the Contractor's failure to settle the electric bills.

##### **4.9.2 Water Supply**

The Contractor shall ensure that adequate water supply shall be made available at the Site 7 days before commencement of the Works. All materials and expenses that may be incurred in securing the water connection shall be on the Contractor's account.

The Contractor shall promptly settle all water bills that may arise by reason of the execution of the Works to ensure continuous supply of water. At no time shall a suspension of the Works be justifiable by reason of the Contractor's failure to settle the water bills.

#### 4.9.3 Supply of Gas

The Contractor shall make available adequate fuel that may be needed to operate the machinery and equipment on the Site in the execution of the Works. The Contractor shall ensure safe storage of the fuel within the Site and shall be responsible for any damage that may occur on the Works or other neighboring areas that may be caused by improper or negligent storage of the gas on the Site.

At no time shall a suspension of the Works be justifiable by reason of the Contractor's failure to provide adequate fuel to operate the machinery and equipment on the Site.

#### 4.9.4 Sewage / Wastewater Management System

The Contractor shall provide full time housekeeping and modern sanitary services necessary to keep the Site, working areas and all site facilities in a clean, neat, hygienic and functional condition. The Contractor shall ensure that waterborne wastes from toilets, bathing places, sinks, etc., installed at the sites are discharged into septic tanks. All matters of health and sanitation shall comply with the requirements of the relevant authorities.

#### 4.9.5 Internet Connection

The Contractor shall secure at their own expense and maintain throughout the performance of the Works, an internet connection with at least 100 MBPS on Site. This internet connection shall be made available at all times for use by the Employer's Personnel and the Engineer and all persons working under their supervision.

### 4.10 Site Establishment, Mobilization and Demobilization

The Contractor shall be responsible for mobilization and site establishment within the agreed time schedule. The Contractor shall be responsible for effective site clearance throughout the Contract Period. Upon issuance of the Performance Certificate, the Contractor shall clear the Site.

4.10.1 Site Clearance during construction: During the Contract Period, the Contractor shall keep the Site free from all unnecessary obstruction, and shall store or remove any surplus materials, clear away any wreckage, rubbish or temporary works from the Site and remove any Contractor's equipment no longer required for Performance of the Works. Otherwise, they shall be stored on the Site in an orderly fashion and shall be properly and securely stored therein. The Contractor shall make safe and reinstate all areas affected by the temporary works.

4.10.2 The Contractor is required to seek their own dumping grounds at their own cost for the disposal of all unwanted materials excavated and all other construction waste materials, resulting from the site clearance, excavation and all works under this Contract. The Contractor is prohibited from dumping unwanted building debris, excavated materials, dredged material etc., on any vacant plot of land, roadside, water body or drains. In the event the Contractor fails to maintain the facilities in order, the Employer shall employ workers, machinery and all else necessary for the removal and proper disposal of such dumping and all costs incurred thereof shall be deducted from any monies due or to be due to the Contractor.

- 4.10.3 Site Clearance after completion: After completion of all parts of the RWTL and WTP, the Contractor shall clear away and remove all wreckage, rubbish and debris of any kind from the Site, and shall leave the Site and the RWTL and WTP in a clean and safe condition and to the entire satisfaction of the Engineer.
- 4.10.4 The Contractor shall touch up all paintwork and make good at their own expense any damage to the structures, fittings or decorations resulting from their operations to the complete satisfaction of the Engineer. On completion, huts, sheds, etc., shall be removed and the same area occupied by and used by the Contractor shall be left clean to the satisfaction of the Engineer. However, the Contractor may retain on Site, during the Defects Notification Period, such Goods as are required for the Contractor to fulfil their obligations under the Contract.

#### **4.11 Works by Others and Interfaces**

##### **4.11.1 Interfaces**

The Contractor shall be responsible for all interfacing and coordination with all his subcontractors and other contractors if employed by the Employer or others on or adjacent to the Site. The Contractor shall closely program and coordinate the works done by their subcontractors and shall endeavor to devise ways by which all persons on the Site will be able to perform their respective duties without any impediment or limitations.

##### **4.11.2 Works by others**

4.11.2.1 The interface arrangement from the water portal to the RWTL shall be designed and shall be the sole responsibility of the Contractor. The design and construction details of the water portal shall be under a different Contractor. The draft concept design of the water portal from MWSS is shown in Appendix 5 Water Portal Concept Design for Contractor's initial information and shall be verified with the MWSS Contractor.

4.11.2.2 The transmission line connecting the Stage 2 of Kaliwa Water Treatment inlet works from the RWTL shall be terminated in a flow split chamber.

4.11.2.3 The treated water distribution network for the Antipolo Area and Long Term East Line shall be terminated in the treated water reservoir of the WTP. The Contractor shall coordinate with other contractors and the Employer to identify at which elevation of the reservoir wall shall the interconnection (including gates and valves) will be placed and area of the block out to be considered. The Contractor shall provide the necessary gates and valves to be installed in the reservoir. The design of the interconnection of treated water distribution network to the WTP reservoir shall be beyond the Contractor's scope. Further, any design and construction of transmission line, appurtenances, or added structure adjacent to the reservoir for the distribution network shall be excluded from scope of the Contractor.

##### **4.11.3 Employer free issue material**

The Employer will not provide any free material to the Contractor.

#### **4.12 Right of Way**

The Employer shall acquire the needed Right of Way to access the RWTL and WTP Site. At least 5m on each side of the pipe centerline shall be allotted for Right of Way. Refer to Appendix 9 Conceptual Raw Water Transmission Line Alignment.

#### **4.13 Site Benchmark References**

The reference benchmark is located along Magsaysay avenue in Teresa, Rizal. The elevation is referred from NAMRIA Benchmark RZ-100 (Y2011) with 45.4237m +/- 0.01875m Mean sea level (MSL). The datum used by the Water Portal Concept design is 10.472m above MSL which shall be the elevation reference for the WTP and RWTL design.

## **5 Collection and Acquisition of Data**

The Contractor is responsible to obtain all the necessary information to ensure the satisfactory completion of the Works. No claim for extra as a result of any alleged ignorance in any aspect will be entertained by the Employer.

### **5.1 Site Investigation and Surveys**

#### **5.1.1 Setting Out**

- 5.1.1.1 The Contractor shall submit to the Employer for review in advance any setting-out work, a description of the methods and procedures it intends to use.
- 5.1.1.2 The Contractor shall be responsible for the true and proper setting out of the WTP in relation to bench marks, reference marks and lines provided to the Contractor in writing by or on behalf of the Employer. The Contractor shall set out the Works in relation to original points, lines and levels of reference specified in the Contract or as notified by the Engineer and shall use reasonable efforts to verify their accuracy before they are used.
- 5.1.1.3 If the Contractor chooses to use triangulation points or bench marks other than those furnished by the Employer, he shall do so at his own expense and risk.
- 5.1.1.4 The Contractor shall be responsible for the correct positioning of all parts of the Works, and shall rectify any error in the positions, levels, dimensions or alignment. If at any time during the Contract, any error shall appear on the position, level or alignment of the facility, the Contractor shall forthwith notify the Engineer of such error and, at their own expense, immediately rectify such error to the satisfaction of the Employer.
- 5.1.1.5 Surveying works shall only be carried out by qualified and competent persons to ensure proper fulfilment of the survey tasks assigned to them. For the performance of the survey works, the Contractor shall provide reliable, calibrated and accurate instruments. The Contractor shall provide to the Engineer a copy of the documents stating that the surveyors are qualified to conduct the works and calibration certificates of the surveying instruments to be utilized in the survey works.
- 5.1.1.6 Where necessary, the Contractor shall carry out surveys to locate, maintain or reinstate any boundary pegs as will be required for setting out. The Contractor shall maintain and reinstate any permanent survey marks and boundary pegs which may have been disturbed, damaged or rendered inaccurate at their own expense.

#### **5.1.2 Site Development**

- 5.1.2.1 The Contractor shall, together with the Engineer, conduct a site survey and inspection prior to commencement of any works at the Site. The Contractor shall be responsible for the Site clearing, grubbing, and demolition and hauling of unsuitable or dismantled unnecessary vegetation or structures at Site.



5.1.2.2 The Contractor shall remove massive rock boulders and peaty soil as may be present at the Site. A drainage system with a suitable capacity to be connected to an existing drainage line shall be constructed.

5.1.2.3 The Contractor shall build up the Site by filling to the elevation stated in these Employer's Requirements.

## **5.2 Topographic Survey**

5.2.1 The topographical survey of the existing site has been undertaken and is attached for reference only (refer to in Appendix 2 Topographical Survey). The Contractor shall be responsible to verify this information. The Contractor acknowledges that any failure to acquaint himself with all such data and information shall not relieve their responsibility for properly estimating the difficulty or cost to successfully complete the Works.

5.2.2 The Employer does not represent the information made available to completely indicate actual conditions and does not warrant the correctness of the information provided. The Contractor shall be responsible to verify the completeness and accuracy of the data and information provided by the Employer.

5.2.3 The Contractor shall undertake further topographic survey necessary to ascertain the contour of the site and design parameters that shall serve as the basis of their design and construction of Works. The cost of acquiring any additional topographical information shall be included in the tender amount.

5.2.4 The topography of the site has gentle slope from farthest east of the area going to the western side. It shall be the Contractor's responsibility to identify a suitable ground level and to bring the entire site to ground level.

## **5.3 Geotechnical Investigation and Geological Survey**

5.3.1 The Contractor shall be responsible to verify the Geotechnical Investigation, including the Shear Wave Velocity Profile, Borehole information and Appendix 3 - Table and Graph of Response Spectra provided in the Bidding Documents. The Contractor shall acknowledge that any failure to acquaint himself with all such data and information shall not relieve their responsibility for properly estimating the difficulty or cost to successfully complete the Works.

5.3.2 The Employer does not represent that information made available indicates completely the actual condition and does not warrant the correctness of the information provided. The Contractor shall be responsible to verify the completeness and accuracy of the data and information provided by the Employer. The Contractor shall acknowledge that any failure to acquaint himself with all such data and information shall not relieve their responsibility for properly estimating the difficulty or cost to successfully complete the Works.

5.3.3 The Contractor shall undertake further geotechnical investigations and geological survey necessary to ascertain the ground conditions and design parameters that shall serve as the basis of their design and construction of Works.

- 5.3.4 The Contractor shall assess any potential hazard including liquefaction, slope stability during construction, lateral spreading rock sliding, increase in pore water pressure, and settlement to consider its impact to the design and/or provision of any mitigation measures. The cost of acquiring additional geotechnical information shall be included in the tender amount.
- 5.3.5 The Contractor shall classify the soil site class in accordance with Chapter 20 of ASCE/SEI 7-10. Classification shall be as based from standard soil testing (i.e. SPT) and shear wave velocity measurements.
- 5.3.6 The geotechnical specialist that will be engaged by the Contractor shall not be the same specialist that was previously commissioned to perform geotechnical investigation for the site by the Employer.
- 5.3.7 The Contractor shall provide the Engineer or the Employer a draft geotechnical and geological survey report formulated by the geotechnical specialist. The draft geotechnical and geologic report shall reflect the assumptions considered and respective explanation of the results and recommendations.
- 5.3.8 Whenever required by the Engineer or the Employer, the Contractor shall make the geotechnical specialist available in site coordination meetings.
- 5.3.9 After excavation is completed down to required foundation elevations, the Contractor's geotechnical engineer and geologist shall inspect the actual soil conditions and:
  - 5.3.9.1 Supplement the final geotechnical and geological survey report with a certification that actual site conditions are consistent with the assumptions, results and recommendations in the geotechnical and geological survey report, or
  - 5.3.9.2 Amend the geotechnical and geological survey report to reflect actual site conditions.
- 5.3.10 In either case, the Contractor shall not be allowed to perform any concreting or preparatory works until the certification or amendment to the geotechnical report is issued.

#### **5.4 Flood Levels**

- 5.4.1 There is no history of drainage or fluvial flooding on this site based on the data found in Project NOAH. Risks of a flood path being available are very limited. An existing Yapak creek is identified on the site boundary of the WTP Site. Part of the mentioned creek is also located between the WTP and water portal land areas. Flooding would only be expected from plant and RWTL overflows. It shall be the Contractor's responsibility to assess, analyze and mitigate any flooding potential.
- 5.4.2 The Flood Hazard Assessment Report is found in Appendix 13. For the purpose of setting elevations of the mechanical and electrical equipment, an additional of at least 300mm shall be considered on proposed FGL.
- 5.4.3 All buildings or structures to be constructed shall be designed to prevent damage from ingress of water. A suitable drainage system within and surrounding the Site shall be provided by the Contractor.

- 5.4.4 New roads shall comprise soakaways and sustainable drainage systems.
- 5.4.5 Thresholds shall be designed and provided to stop water entering the WTP.
- 5.4.6 Plant and equipment shall be located so as not to be in the path of any water which may enter a structure from flows coming through doors or other surface drainage routes.
- 5.4.7 All tanks, vessels, chambers and manholes shall have coping levels above the design flood level and should be suitably protected to prevent water ingress.
- 5.4.8 Any new buildings that are within the site shall be flood-proofed by raising the threshold of flooring to above the design flood level.
- 5.4.9 Roadways and other hardstanding areas shall be designed not to be flooded in the event of floodwaters reaching the design flood level.
- 5.4.10 The Contractor shall ensure that the design allows free drainage of all waters away from key equipment and off the site following a flood event and red rainfall advisory.

## **5.5 Existing Services**

- 5.5.1 The Contractor shall undertake a comprehensive survey of the site to determine the location of existing services that are affected by the scope of works. The Contractor shall take every precaution, to protect from damage all existing services wherever encountered or which are adjacent to the Works. The Contractor shall be responsible at their own cost for timely making good any damage made to existing services to minimize nuisance to users.
- 5.5.2 The Contractor shall not interfere with the operation of any existing mains, services and plant and equipment. Where permanent or temporary relocation or diversion of any services is required, the Contractor shall submit their proposal to the Engineer and the relevant authorities for prior approval.
- 5.5.3 The Contractor shall give ample warning to the Engineer if services diversion or relocation is required. The Contractor shall submit the method of works, risk assessment, protective measures and any supporting documents for approval prior to commencement of the relocation or diversion works.

## **5.6 Interfaces with adjacent landowners**

The Contractor shall be responsible for any liaison and coordination with the adjacent landowners which is required for Performance of the Works, at own cost. The Employer shall not be liable for any consequences or liabilities arising out of the Contractor's liaison and coordination with the adjacent landowners.

## **5.7 Photographic Survey**

The Contractor shall carry-out the photographic and video survey of the Site conforming to Appendix 22 MWCI Project Photo / Video Documentation Program.

## **5.8 Pre-Construction condition survey**

The Contractor shall carry out a pre-construction survey to record photographic evidence including description of all existing cracks, defects, etc on all structures which may be affected by the Contractor's activities commencing from pre-works before commencement of any demolition, excavation, piling or construction works. "All structures" shall include, but not be limited to roads, pavements, buildings, bridges, all types of utilities, foundations and piers of any type, large sign gantries, water or earth retaining structures, culverts or drains, etc. The Contractor shall endeavour to survey all premises and structures that may be affected by their works including delivery or storage of goods relating to the Works. The Contractor shall be responsible for the repair of any damages arising from the Works irrespective of whether pre-construction survey has been carried out at the damaged premises.

If any defect is found during the pre-construction survey, the Contractor shall submit a copy of the survey report to the owner of the affected structure and arrange for joint inspection with the owner and the Engineer.

The Contractor shall submit to the Engineer within one month from the date of contract award, a well-documented record complete with dimensioned survey plans and suitably captioned photographs with date imprint to illustrate the existing condition of the site and its adjacent areas.

## 10 General Design Requirements

### 10.1 General Design Principles

- 10.1.1 The Contractor shall be responsible for the design of the project, including all associated elements and components. This shall be done in such manner that all permanent structures are located within the Site, except for sections of pipelines and services which need to be connected to facilities being constructed by others.
- 10.1.2 The design of RWTL and WTP shall be fit for its intended purpose; and shall be based on international best practices and shall utilize well proven technologies to comply with the specified requirements.
- 10.1.3 Safety during all aspects and all stages of design shall be considered.
- 10.1.4 The RWTL and WTP shall be designed to minimize operating costs.
- 10.1.5 The process units shall be designed in modules to allow sufficient turn-down of the works’ throughput during low flows. The control arrangement shall be capable of efficiently treating the full range of the flows.

### 10.2 Process Plant Configuration

- 10.2.1 The following process components and treatment technologies shall be required for the RWTL and WTP. Performance and specific requirements for each component are discussed in the following sections. Should the Contractor deem to adopt a different approach, the Contractor must demonstrate that their proposed design will create a greater value for the Employer and that such scheme is properly backed up with supporting calculations, simulations, documentations or other submittals.

| AREA                           | PROCESSES                                                                                                                                                                                                                                                       |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Raw Water Transmission         | <ul style="list-style-type: none"><li>■ Intake Screening System</li><li>■ Flow Diversion with overflow provision to Yapak creek (same waterway of water portal overflow)</li><li>■ Reception Point at Plant Inlet</li><li>■ Raw Water Pumping Station</li></ul> |
| Coagulation                    | <ul style="list-style-type: none"><li>■ Coagulant Dosing</li><li>■ Hydraulic Mixing</li></ul>                                                                                                                                                                   |
| Flocculation and Sedimentation | <ul style="list-style-type: none"><li>■ Flocculant Dosing</li><li>■ Hydraulic Mixing</li><li>■ Sedimentation</li></ul>                                                                                                                                          |
| Filtration                     | <ul style="list-style-type: none"><li>■ Filtration</li><li>■ Backwash (water, air scour, or combined)</li></ul>                                                                                                                                                 |
| Chlorination                   | <ul style="list-style-type: none"><li>■ Pre-chlorination</li><li>■ Intermediate chlorination</li><li>■ Post-chlorination</li><li>■ Gas chlorinator and dosing</li><li>■ Scrubber</li></ul>                                                                      |

| AREA                          | PROCESSES                                                                                                                                                                                                                      |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Storage                       | ■ Contact tank and treated water reservoir                                                                                                                                                                                     |
| Sludge Treatment and Disposal | <ul style="list-style-type: none"> <li>■ Sludge pumping and conveyance</li> <li>■ Dewatering polymer preparation and dosing</li> <li>■ Sludge thickening and dewatering</li> <li>■ Sludge cake handling and storage</li> </ul> |
| Recovered Water System        | ■ Recovered water pumping, conveyance and overflow provision                                                                                                                                                                   |
| Chemical Dosing               | <ul style="list-style-type: none"> <li>■ pH adjustment</li> <li>■ Oxidation</li> </ul>                                                                                                                                         |

10.2.2 The Contractor shall incorporate all necessary design features into the mechanical, electrical, instrumentation and control systems for a holistic design to ensure a complete, safe and swift operation of the RWTL and WTP for speedy recovery upon either a total power failure or fluctuation of the quality of the supply power. This shall avoid the possibility of supplying untreated water from the WTP.

10.2.3 The Contractor shall provide a complete system of the mechanical and electrical works for the RWTL and WTP for complete, safe, reliable and satisfactory operation and maintenance of the specified facilities.

10.2.4 The Contractor shall provide an appropriate level of redundancy in the design and duty/standby arrangements of all process tanks and equipment.

10.2.5 The WTP shall be capable of treating flows as described in Section 11.3 at any time during its operational lifetime, under all anticipated treated water quality standards given in the specification. The design shall allow for at least one (1) process unit of each type to be turned off for maintenance without turning down capacities and failure of the treated water standards.

10.2.6 All duty units and standby units of individual mechanical and electrical equipment to be provided under this Contract shall have identical capacity, components and performance. In general, the required minimum level of redundancy for the plant is N+1. Unless otherwise specified, for each type of equipment, at least one (1) standby unit shall be provided.

#### 10.2.7 Space Provision

##### 10.2.7.1 Additional Process Units (VOC Removal)

- 1 The proposed WTP process configuration and design shall consider a minimum of 1,900-square meter space provision within the site for any future developments for VOC removal facilities.
- 2 The Contractor shall ensure tapping points complete with stub outs, blinds and isolation, are made available after the sedimentation process for the extraction and return of the treated water back to the main treatment process. The water portal Contractor shall provide the stainless steel pipe stub out with a minimum length of 2m. The tapping points shall allow future connections to be done with no interruptions to the operations of the WTP.

#### 10.2.7.2 Treated Water Pumping Station

The WTP shall consider a minimum of 1,600-square meter space provision within the site layout for the Treated Water Pumping Station that will supply treated water to Antipolo Line (AL). This area shall be fixed and included in the site development works of the Contractor. The space provision shall remain clear and free from any structures. The actual Treated Water Pumping Station (scope by others) shall be located at the same FGL as the treated water reservoir at FGL 98.5m, based on Water Portal Concept Design datum in Section 4.13.

### 10.3 Design Life

The components of the RWTL and WTP shall have a design life in accordance with the details below. On reaching the design life, it is anticipated that the structure and plant will require either major overhaul or renewal.

| Project Component/Structure/Plant Item | Design Life (years) |
|----------------------------------------|---------------------|
| Civil and structural works             | 50                  |
| Mechanical works                       | 20                  |
| Steel works                            | 30                  |
| Plastic works                          | 50                  |
| Pipe work                              | 50                  |
| Transformers                           | 25                  |
| Switch gears                           | 20                  |
| MCCs                                   | 15                  |
| Motors                                 | 20                  |
| PLC/SCADA/Instruments                  | 10                  |
| Diffusers (in aeration equipment)      | 5                   |
| Blowers                                | 10                  |
| Submersible Pumps                      | 10                  |

#### **10.4 Physical Design Requirements**

- 10.4.1 The Works shall include building(s) for equipment and electrical substation. The external form and finishes shall comply with the Manila Water's Standard Engineering Specifications (SES) in Appendix 15.
- 10.4.2 The design of the RWTL and WTP shall provide reasonable access to carry out O&M work. Walkways shall be provided to give adequate personnel access to various parts of the RWTL and WTP for O&M purposes.
- 10.4.3 Unless otherwise required, all structural walls, slabs, beams, columns and members, particularly the water retaining parts of the RWTL and WTP shall, in general, be in reinforced concrete, and designed in accordance with the relevant codes and standards.
- 10.4.4 Materials shall be selected for their compatibility and proven application on potable water facilities.
- 10.4.5 A full complement of tools, accessories and spare parts necessary for not less than 5 years operation from successful commissioning by the RWTL and WTP operators shall be provided, and appropriately labelled and stored.
- 10.4.6 All finished ground levels shall be suitably graded to a system of surface drainage that connects to an adequate drainage outlet system. The profile of the Works shall be finished to blend with the adjacent grounds. All slopes shall be designed with a gradient that is stable under the expected weather conditions and will not promote surface water scouring. Retaining walls and landscaping shall be provided, as necessary, complete with proper drainage.
- 10.4.7 General Design Requirements
  - 10.4.7.1 Any covers installed shall include removable hatches or other suitable openings to enable access to any replaceable or maintainable unit or instrument. Hinged-type removable hatches shall be able to open fully without hindering maintenance operation.
  - 10.4.7.2 Properly located and arranged isolation structures and piping shall be provided such that each unit of the plant can be removed for servicing independently. The isolation design shall facilitate plant operation during unit maintenance and emergency repair to minimize deterioration of treated water quality and ensure rapid process recovery upon return to normal operational mode.
  - 10.4.7.3 Appropriate means shall be provided to dewater each unit to an appropriate point in the process in consultation with the Engineer. The pipe lines that are prone to clogging shall be provided with means for cleaning or flushing.
  - 10.4.7.4 All tanks shall be provided with an easy-connect coupling which shall be easily accessible by road tanker to allow removal of sludge or sewage during maintenance or for emergency reasons. In particular, all sludge tanks shall have easy-connect couplings to allow sludge removal for seeding of other plants.



- 10.4.7.5 Associated operational and health and safety concerns resulting from any enclosure of the treatment process and operational site shall be incorporated into the design, including odor, noise, lighting, ventilation and confined space requirements.
- 10.4.7.6 All critical, non-submersible process equipment including control systems, blowers, sludge dewatering equipment, MCCs and switchgear and other long lead, high value process critical items shall be installed at a minimum of 300mm shall be added on top of the proposed FGL. All the critical electrical, mechanical, instrumentation installations shall be at a minimum of 300mm on top of the proposed FGL. The elevations provided in this clause is in reference to Appendix 2 Topographical Survey.
- 10.4.7.7 Mechanical and electrical plant located below the finished grade line shall be submersible to IP68, as a minimum. This shall include pumps, instruments, valve and penstock actuators, such that after major flooding, the WTP can be re-commissioned to operate in manual mode within a minimum length of time.
- 10.4.7.8 All process units shall be designed with minimum 0.5m freeboard above the maximum operating water level and with accordance to MWCI SES 11.
- 10.4.7.9 Wash down point complete with flexible hose shall be located at suitable locations for the general cleaning and maintenance of the WTP. Washwater connections shall be provided adjacent to each process train basin and fittings shall be supplied to allow hose connections for cleaning and washing purposes. Location of connections shall be such that not more than 10 m of hose is needed to reach the edge of a tank. Washwater shall be of sufficient pressure to reach all areas of a tank. Washwater shall be recycled/reuse water.

## **10.5 Design Reports**

- 10.5.1 The Contractor shall submit Outline Design and Detailed Design Reports.
- 10.5.2 The Outline Design Report is a pre-requisite to the Outline Design Certificate and shall include a comprehensive description of the design philosophy, drawings and preliminary engineering details of the Works such as:
  - 10.5.2.1 Proposed site plan and functional layout plans and sections of the RWTL and WTP complete with survey and setting out details and other dimensioned details to confirm construction feasibility.
  - 10.5.2.2 Design references such as topographic surveys, geotechnical investigation, raw water characteristics, rainfall and flood data, etc.
  - 10.5.2.3 Design criteria of the process units and process flow and control schematic diagram.
  - 10.5.2.4 Mass balance for WTP including all streams (liquid stream, sludge stream, chemical dosing, site returns and other flows entering/leaving into the WTP) and all associated process calculation such as process related structures and devices, main equipment, odor control system, chemical dosing rates and consumption, and utilities consumption rates.

10.5.2.5 Process and Instrumentation Diagrams (P&IDs)

10.5.2.6 Hydraulic design criteria complete with hydraulic calculations and a hydraulic profile of the RWTL and through the WTP, under the conditions of minimum, average and peak flows for the situations when all treatment modules are in operation at the design treatment capacity and when any one treatment module is shutdown.

10.5.2.7 Structural, mechanical and electrical design calculations.

10.5.2.8 Electrical single line diagrams and switchboard layouts.

10.5.2.9 Process control philosophy for the WTP.

10.5.2.10 List of mechanical and electrical equipment with complete description of parameters including capacity, motor rating, quantity of duty and standby, material of construction, brand, efficiency, etc.

10.5.3 The Detailed Design Report is a pre-requisite to the End of Design Certificate and shall include a comprehensive description of the design philosophy, construction drawings and engineering details of the works.

10.5.4 The Detailed Design Report shall also include the detailed electrical calculations such as load flow analysis, short circuit analysis, protecting coordination study, arc flash analysis.

10.5.5 Headroom inside buildings shall be minimum 2.7 m except where otherwise specified. Headroom shall be measured at the point of lowest clearance, e.g. in areas with pipes suspended from ceilings, headroom shall be measured from the bottom of the pipe or hanger, whichever is lowest. Headroom inside areas with suspended ceilings shall be minimum of 2.4 m.

## **10.6 Computational Fluid Dynamics Modelling**

10.6.1 As minimum, the Contractor shall conduct Computational Fluid Dynamics Modelling of the elements of the plant specified in Section 12. Additional CFD modelling shall be performed as needed to verify the performance of relevant systems.

10.6.2 The simulation shall be developed by a competent specialist with at least 5 years of experience in water projects, and shall be approved by the Employer.

10.6.3 CFD Code - The simulation will be performed with the commercial code Fluent 14.5 from ANSYS Inc. and for the open channel flows, Flow 3D. Fluent has had the most verification testing (That is, CFD results compared with data from physical tests.) in the water industry.

10.6.4 Turbulence Modeling – Turbulent effects will be simulated using the Two Equation Realizable K-Epsilon model. This model is considered an industry standard for internal flow models involving motion of fluids at the velocity ranges anticipated.

10.6.5 CFD modelling shall be carried out with the outline design documentation prepared as a reference, as a minimum.

10.6.6 All recommendations from the CFD model shall be incorporated in the Detailed Design Documents. All recommendations shall be provided by the Contractor without additional cost to the Employer.

#### 10.6.6.1 Model Domain

- 1 Mesh - The computational mesh will be created in Gambit 2.4. The mesh used will be a hybrid of structured and unstructured cell types. Where possible, the model will be meshed with a structured mesh consisting of six sided hexahedral cells. In CFD models of the type undertaken here (internal flow of an incompressible fluid) the results obtained for structured and unstructured meshes are essentially identical, however, hexahedral meshing is used wherever possible to obtain the best computational efficiency. When comparing structured and unstructured meshes of equal resolution, the structured mesh will require as much as 75% fewer cells thus requiring less computation time.
- 2 Water Surface – Where possible a simplified treatment of the water surface will be used. The water surface will be modeled with a symmetry plane or rigid lid boundary. A rigid lid boundary can be used to represent a water surface when the water surface is assumed nearly flat with no significant wave action or other vertical displacements. The rigid lid boundary acts like a wall in that no mass may pass through it, but it is frictionless and has no boundary layers forming on it. In areas of free surface flow, typically the outlet weirs arrangement, the Flow 3D software would be used.

#### 10.6.6.2 Output

- 1 The Contractor shall submit a methodology of the model development, clearly indicating the assumptions and limitations.
- 2 The results of the analysis will be presented in a technical report complete with relevant screen shots and drawings of any modifications.
  - Contours of velocity magnitude taken at appropriate time intervals
  - Streakline plots showing bulk flow patterns
  - Tracers introduced to show both well mixed and potential dead zones
  - Graphs of volume averaged velocity versus time
- 3 The Contractor shall undertake a suitable number of model runs to test their design and to demonstrate optimization of their design. A single model run of a proposed design shall not be considered sufficient to satisfy these criteria and there shall be objective evidence that the selection and positioning of elements of the work delivers the most effective performance, when balanced amongst all competing design criteria.
- 4 As minimum, the Contractor shall show performance of each element of the plant at the following conditions;
  - 100 MLD – 6 NTU, 65 NTU, 125 NTU
  - 300 MLD – 6 NTU, 65 NTU, 125 NTU
- 5 Suitable model runs shall be undertaken to prove performance at all of these levels, including recovered water flows.

- 6 Any modifications suggested by the modelling, to arrangements of elements such as lamellas, baffles or other equipment, shall be tested.
- 7 The Contractor shall assume that they need to present the model runs to the Employer's team at the Employers offices at least twice during the testing and development of the solution. Suitable provision shall be made for the modelling specialist to visit Manila to do at least two one-day workshops for this. Other meetings may be held but may be undertaken via electronic or other means.

## **10.7 Chlorine Decay Analysis**

- 10.7.1 The aim of the chlorine decay analysis is to determine the optimum chlorine dosing rate at the WTP in order to maintain residual chlorine levels at the downstream reservoir within MWCI limits.
- 10.7.2 The Contractor shall conduct chlorine decay analysis on the Antipolo treated water transmission line until the Boso-Boso reservoir outlet, based on the treated water quality limits defined in Section 11.4. The coordinates, preliminary alignment, pipe diameter and elevations are found in Appendix 10 Concept Design Details of Antipolo Treated Water Transmission Line.
- 10.7.3 The analysis shall be developed by a competent specialist with at least 5 years of experience in potable water supply network projects, and shall be approved by the Employer.
- 10.7.4 Hydraulic modelling softwares such as WaterGEMS or EPANET, shall be used for the simulation. Should the Contractor opt to use other programs for the modelling, the Contractor's bid shall include the provision of providing the Employer an authorized stand-alone copy of the said program.
- 10.7.5 First-order reaction shall be used to develop the model for its known application in predicting chlorine decay in water distribution systems. The Contractor shall calculate for water age. Decay models shall run over a 24-hour period as minimum, and parameter readings taken at 30-minute intervals.
- 10.7.6 Chlorine decay analysis shall be submitted together with outline design deliverables. All recommendations from the analysis shall be provided by the Contractor without additional cost to the Employer and shall already be incorporated in the outline design.
- 10.7.7 Output
  - 1 The Contractor shall submit a methodology of the model development, clearly indicating assumptions and limitations.
  - 2 The results of the analysis will be presented in a technical report complete with relevant screen shots and drawings.
    - Schematic diagram of the water system
    - Graphs of flow rate and concentration versus time
    - Recommendations
    - Raw simulation files shall be submitted as an attachment

- 3 The Contractor shall undertake a suitable number of model runs to test optimum dosing. As minimum, The Contractor shall run the model under the following conditions:

Residual chlorine concentration at the WTP

100 MLD – 0.6 mg/L, 0.9 mg/L, 1.2 mg/L, 1.5 mg/L

300 MLD – 0.6 mg/L, 0.9 mg/L, 1.2 mg/L, 1.5 mg/L

- 4 The Contractor is not limited to the above conditions and must add suitable model runs to properly demonstrate residual chlorine levels at the Boso-Boso reservoir outlet.

### 10.8 Documentation for Permits

The Contractor shall prepare all the design and documents required for the purpose of obtaining the permits from various agencies as stated below. The Contractor shall give all notices, pay all taxes, duties and fees and shall be responsible for the preparation of all documents that will be necessary to obtain all the permits that may be required by the national government, all relevant government agencies and all local government units affected by the Works, including but not limited to the following:

| Agency          | Approval / Permit                                                                                              |
|-----------------|----------------------------------------------------------------------------------------------------------------|
| LLDA            | LLDA Clearance<br><br>Discharge Permit<br><br>Designation and appointment of a Pollution Control Officer (PCO) |
| CAAP            | Permit to Operate (Heliports)                                                                                  |
| DPWH            | Construction / Excavation Permit                                                                               |
| LGU (Municipal) | Locational Clearance                                                                                           |
|                 | Building Permit                                                                                                |
|                 | Occupancy Permit                                                                                               |
|                 | Electrical Permit                                                                                              |
|                 | Sanitary Inspection/Health Certificate                                                                         |
|                 | Fire Safety Inspection Certificate                                                                             |
|                 | Certificate of Potability                                                                                      |

| Agency    | Approval / Permit                                                                                                       |
|-----------|-------------------------------------------------------------------------------------------------------------------------|
|           | Drinking Water Site Clearance                                                                                           |
| LGU       | Barangay Clearance                                                                                                      |
| DENR      | Tree Cutting Permit                                                                                                     |
|           | Permit to Operate of Air Pollution Source Equipment/Control Facility                                                    |
|           | Registration as Hazardous Waste Generator (DENR ID)                                                                     |
|           | Permit to Transport (PTT)                                                                                               |
|           | Various Chemical Permits                                                                                                |
|           | PICCS Certification                                                                                                     |
|           | PMPIN Certificate or SQI Clearance                                                                                      |
|           | Chemical Control Order (CCO)                                                                                            |
|           | Priority Chemical List (PCL)                                                                                            |
| PDEA, PNP | Permit/License to Purchase and Move Restricted Chemicals                                                                |
| DOH       | Certificate of Potability<br><br>Other necessary permits as may be required prior to distribution of water to consumers |

## 10.9 Works by Sub-Contractors

The Contractor shall obtain the Engineer’s prior consent if the Contractor intends to appoint a Sub-contractor for the design of the works. The Contractor shall provide a document or technical note proving the competence and capability of the sub-contractor to perform and deliver the appointed design works.

## 10.10 Hazard Identification / Analysis and Assessment Workshops

10.10.1 The Contractor shall arrange for workshops during the Design period prior to approval of any final design drawings and final design documents.

10.10.2 The Contractor shall arrange, as a minimum three workshops at each of the stages of the design development, with minimum expectations as stated below:

- 10.10.2.1 Outline Design – the purpose of the workshop at this stage is to identify the hazards considering the scope of the work; and identify the mitigations measures
- 10.10.2.2 Upon 50% completion of the Detailed Design – the purpose of the workshop at this stage is to identify the hazards considering the scope of the work; and identify the mitigations measures
- 10.10.2.3 Upon 90% completion of the Detailed Design– the purpose of the workshop at this stage is to review the earlier hazards, identify any new hazards, review the progress of mitigation measures and identify new mitigation measures
- 10.10.3 The Contractor shall arrange the workshops with the participation from the following, as a minimum:
  - 10.10.3.1 The Contractor's key design and construction staff
  - 10.10.3.2 The representatives of the Engineer
  - 10.10.3.3 The representatives of the Employer

#### **10.11 HAZOP**

- 10.11.1 The Contractor shall undertake a HAZOP for the plant design when outline design has been broadly completed and scheme is fully understood and documented. The Contractor shall propose the schedule for the HAZOP workshop and shall notify the Engineer at least thirty (30) days before the intended schedule.
- 10.11.2 This shall be accepted by the Employer before any procurement of process plant and equipment takes place. The HAZOP shall be updated as design progresses and if changes occur.
- 10.11.3 As a minimum, each HAZOP study shall:
  - 10.11.3.1 Identify a list of risks and hazards associated with O&M of each discrete part of the WTP. The assessment of risks and hazards shall consider impact to human health and safety, process and performance of WTP, equipment failure or damage and environmental impacts. All findings and recommendations shall be incorporated in the Outline Design Documents, prior to proceeding with the Detailed Design.
  - 10.11.3.2 Identify, evaluate and recommend cost effective additional risk reduction measures that shall be implemented to reduce and mitigate risks of O&M of the WTP.
  - 10.11.3.3 The Contractor may use the HAZOP hazard analysis technique, in accordance with the recommendations of BS IEC 61882 Hazard and operability studies (HAZOP studies) application guide.
- 10.11.4 The HAZOP shall be led by an independent facilitator who is not part of the Contractor, or their partner/sub-contractor, organizations. The HAZOP facilitator shall have at least 5 years of experience in facilitating HAZOP for WTP and be approved by the Employer.

- 10.11.5 The HAZOP shall be run in Manila, in a location that is neutral among all parties. Attendance of the Employer and Engineer shall be required. The Project Manager, Design Manager, Designers/reviewers of each disciplines of the Employer, Contractor and the Engineer shall be present. The minimum number of attendees shall be 20.
- 10.11.6 The Contractor shall be responsible for all cost associated with the HAZOP including the facilitator, their accommodation, all documentation, and venue.
- 10.11.7 The HAZOP shall be carried out with the outline design documentation prepared as a reference, as a minimum.
- 10.11.8 All recommendations from the HAZOP shall be incorporated in the Detailed Design Documents. All recommendations shall be provided by the Contractor without additional cost to the Employer.

## 10.12 Design Documents

The Contractor shall prepare a detailed programme of work for the review of design deliverables; and submit to the Engineer for review within 28 days from the Notice to Proceed. The Contractor shall provide the deliverables in minimum two stages – outline design stage and developed design stage. The Contractor shall include the appropriate design deliverables for Permits to be obtained by the Contractor. The programme of the Contractors design deliverables shall include appropriate logic of workflow; including but not limited to the time for the review by the Engineer (conforming to GCC), Permitting requirements, and other interfaces for the execution of the Works.

The design deliverables for the RWTL and WTP shall include the following, as a minimum:

| Stage of Design Deliverables | Minimum Requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Outline Design               | <ul style="list-style-type: none"><li>■ Process Flow Diagrams including detailed mass balance which shall cover all liquid, recycle and sludge streams at design flows</li><li>■ Process Description which completely describes the processes and sub-process involved in the Treatment Plant</li><li>■ Mass Balance Diagram</li><li>■ Piping and Instrumentation Diagram</li><li>■ Hydraulic Profile including the headloss calculations</li><li>■ Process Design Computations including design criteria, basis, and percent removal rates per equipment or process</li><li>■ Simulations and modelling (process, CFD and chlorine decay)</li><li>■ General arrangement, equipment layout and main pipe routings</li><li>■ Equipment List</li></ul> |



| Stage of Design Deliverables | Minimum Requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                              | <ul style="list-style-type: none"> <li>■ Process unit / equipment datasheets ensuring local support in the Philippines</li> <li>■ Chemical and Utilities Consumption List</li> <li>■ Process Control Philosophy</li> <li>■ Risk Log</li> <li>■ Single Line Diagram</li> <li>■ Draft Commissioning Plan – outlining basic approach, dependencies, and timing so commissioning approach is considered in design;</li> <li>■ Lifting and Handling Strategy – covering access and maintenance of all plant and equipment, shall ensure that operational issues are properly understood and actions identified.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Detailed Design              | <ul style="list-style-type: none"> <li>■ Fully developed and dimensioned drawings showing plans, elevations, sections</li> <li>■ All supporting design computations</li> <li>■ BIM Models</li> <li>■ Material datasheets (i.e. pipes,others) including storage manuals</li> <li>■ Updated mechanical and electrical equipment datasheets including O&amp;M and storage manuals</li> <li>■ HAZOP study report</li> <li>■ Updated CFD / sump model test report</li> <li>■ Detailed drawings with sufficient details for construction</li> <li>■ “Issue for Construction (IFC)” drawings</li> <li>■ Traffic control manual</li> <li>■ General <ul style="list-style-type: none"> <li>● Updated PID's</li> <li>● Finalized site development plan</li> <li>● Updated risk log</li> <li>● Updated interface plan showing items addressed</li> <li>● Updated lifting and handling strategy</li> <li>● Access and maintenance strategy</li> <li>● Updated OPEX assessment</li> <li>● List of deviations from specification, with capital and operational impacts identified</li> </ul> </li> <li>■ Structural calculations shall include, as a minimum, the items stated below –</li> <li>■ Civil/Structural <ul style="list-style-type: none"> <li>● Geotechnical design calculations</li> <li>● Structural design calculations</li> <li>● Reinforcement drawings</li> <li>● Seismic assessment/analysis</li> <li>● Foundation design</li> </ul> </li> </ul> |

| Stage of Design Deliverables | Minimum Requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                              | <ul style="list-style-type: none"> <li>● Hydraulic design</li> <li>● Detailed underground pipeline design calculations - below ground (pipework and support)</li> <li>● Detailed plant location drawings</li> <li>● Detailed pipework arrangements and support arrangements</li> <li>● Drainage design calculations and drawings (stormwater and domestic wastes)</li> <li>● Design calculations for roads and pavements</li> <li>● Design drawings and profiles for roads and pavements</li> <li>● Swept Path Analysis</li> </ul> <p>■ Mechanical</p> <ul style="list-style-type: none"> <li>● Updated process unit/equipment datasheets - equipment selection and performance curves, all motorized equipment, and major equipment;</li> <li>● Equipment layout</li> <li>● Equipment schedules</li> <li>● Pipe size calculations</li> <li>● Piping layouts/isometrics</li> <li>● Pump sizing and calculations</li> <li>● Plant sizing and calculations</li> <li>● Procurement datasheets</li> <li>● Mechanical calculations including equipment selection and performance curves, all motorized equipment, and major equipment; pump, blower, mixer and pipe sizing calculations</li> </ul> <p>■ Electrical/Control</p> <ul style="list-style-type: none"> <li>● Electrical design calculations - equipment selection, load schedule, load flow analysis, short circuit calculations, protective coordination studies, and arc flash analysis</li> <li>● Electrical/Instrumentation layouts</li> <li>● Finalized Single Line Diagram</li> <li>● Developed Functional Design Specification</li> <li>● Procurement datasheets</li> <li>● Communications hierarchy</li> <li>● SCADA system architecture - showing key screens/level of control etc.</li> <li>● Finalized electrical layouts</li> <li>● MCC layouts</li> <li>● Signals list</li> <li>● SCADA screens layout/content/reports</li> <li>● Communications list - showing all alarms received/transmitted</li> </ul> |

| Stage of Design Deliverables      | Minimum Requirements                                                               |
|-----------------------------------|------------------------------------------------------------------------------------|
|                                   | <ul style="list-style-type: none"> <li>• User requirement specification</li> </ul> |
| The Contractor to develop details | The Contractor to provide details                                                  |

Design calculations for review shall be submitted with raw calculation files in excel format for verification. All accompanying process modelling files shall be provided. In case of proprietary technology in which calculation software file cannot be provided, design calculation document shall at least indicate the working formula or equation used for the calculation.

### 10.13 Design Documents Tracking

10.13.1 The Contractor shall prepare a deliverables tracking system, which shall include as a minimum the following items. The Contractor shall submit the tracking list to the Engineer for review on a weekly basis.

The tracking system shall include as a minimum:

- 1 Detailed list of deliverables;
- 2 Submission date of the deliverables to the Engineer for review;
- 3 The date when the Engineer’s review comments are expected (conforming to GCC);
- 4 Current physical progress of the deliverables (the rules of the progress shall be agreed with the Engineer);
- 5 Summary of the previous comments from the Engineer; and
- 6 Status of compliance with the previous comments

### 10.14 Submission Process

10.14.1 Every drawing submitted by the Contractor to the Engineer for review and issuance of no objection certificate shall be:

10.14.1.1 Based on previous designs or documents, with no objection stamp. Interrelated drawings shall be submitted at the same time in a complete and self-sufficient set. Copies shall be collated into ordered bundles each with a list of contents.

10.14.1.2 Accompanied by a letter from the Contractor (not from subcontractors or suppliers). Revisions of previous submissions shall be highlighted and the reasons for these shall be stated in the covering letter.

10.14.1.3 Endorsed by a Licensed Engineer, registered in the appropriate discipline with the respective engineering professional qualification in the Philippines.

- 10.14.2 All designs, drawings and documents submitted by the Contractor to the Engineer for review and issuance of no objection certificate shall be checked by the Contractor before submission. The Contractor shall likewise check and integrate submissions from the Subcontractors or from any other source before passing on such submissions to the Engineer for approval.
- 10.14.3 On completion of review, the Engineer will return the submission, in accordance with disposition.
- 10.14.4 The Engineer will designate the address of the review office in respect of particular disciplines or work from time to time during the Contract. All submissions shall be made sufficiently early to allow the Engineer time for review and approval of drawings, documents and samples which are required to be approved before commencement of manufacture of plant or of installation or construction on site as the case may be, and for the Contractor to provide and submit revisions or alternatives, or carry out further tests if, in the opinion of the Engineer, the initial submissions do not meet the requirements of the Contract.

#### **10.15 Form of documents and drawings**

##### **10.15.1 Form of Drawings**

10.15.1.1 The Contractor shall conform to the Employer's Standard Engineering Specifications (SES 1) in Appendix 15 when developing the drawings.

10.15.1.2 Every drawing shall have a title box in the bottom right corner showing:

- 1 Manila Water's name and logo;
- 2 Title of scheme;
- 3 Title of Contract;
- 4 Contractor's name;
- 5 Title of work location and area code;
- 6 Title of drawing;
- 7 Drawing number;
- 8 Date;
- 9 Author; and
- 10 Signature of Contractor (to the effect that the drawing, whether their own or from any other source, has been checked before submission to Manila Water).

10.15.1.3 All design drawings shall include the following as minimum:

- 1 Cover page indicating the name of the project and the Employer
- 2 List of drawings
- 3 Perspective – for all structures

10.15.1.4 Each drawing shall also have a separate revision box with space for up to 5 revisions, and including revision number, revision date, revision description and revision check. It shall also include adequate clear space for the Manila Water's markings.

10.15.1.5 All corrections, revisions and additional drawings shall be highlighted on the re-submitted drawings using revision clouds.

10.15.1.6 Drawings shall include cross references where appropriate and key information such as vital levels and dimensions. All plans shall show the "north" direction.

10.15.1.7 The Engineer will not review any unclear or ambiguous drawings.

10.15.2 Form of Designs and Document

10.15.2.1 The design submissions shall consist of the following:

- 1 Design Report including all studies/assessments/survey used as reference of design,
- 2 Design Drawings, and
- 3 Technical specifications for materials and equipment for which no details are provided by specifications and standards set herein.

10.15.2.2 The submissions shall be in one (1) hard copy and one (1) electronic copy. The electronic copy of design calculations shall be in Excel format, if applicable, showing the formulas for convenience in checking. All design assumptions shall be defined and provided with standard references acceptable to the Engineer. Links shall be provided such that changing one design parameter will automatically give the end results. Drawings shall be in CAD format generated from a BIM system. Level of development to be used shall be LOD 300, showing sufficient information to be used during construction stage.

10.15.3 The hard copies of the final submissions (after all corrections have been incorporated) shall be signed and sealed by duly licensed professionals.

10.15.4 Numbering and Titling

10.15.4.1 The Contractor shall conform to the Employer's standard documents naming and numbering system.

10.15.4.2 The numbering and title information on designs, drawings and documents shall be designed so that management, transmittal and communication in connection therewith can be carried out expeditiously.

10.15.4.3 All designs shall be carried out according to specified or relevant Standards and Codes of Practice, and shall comply with all Building and Safety Regulations including the National Building Code of the Philippines. The Contractor shall be liable for any defects/damage arising out from nonconformity and all necessary remedial work shall be carried out at the Contractor's own cost and time.

10.15.4.4 Functional plans and designs shall be based on the proposals submitted with the Contractor's Tender if any, subject to such modifications to comply with the Specifications the Engineer may require.

- 10.15.4.5 The Contractor shall be fully responsible for the contents of all submissions to the Engineer and the Employer irrespective of the source or origin of information contained in such submissions. All submissions irrespective of the source or origin of information shall be checked by the Contractor and endorsed as such before submission to the Engineer. The Engineer and/or the Employer will not accept submissions for review unless these requirements have been met.

#### 10.15.5 Requirements for Drawings

The Contractors shall conform to the requirement of the Employer stated in Standard Engineering Specifications. This section states the requirements specific to the content of various types of drawings.

##### 10.15.5.1 Piping and Instrumentation Diagrams

- 1 The Contractor shall provide comprehensive P&IDs for the whole of the Works. These shall include but not be limited to showing every line, channel, tank, valve, pump, fan, instrument, system for control or automation or other item of equipment in symbolic form. Any demarcation of contract scope shall be clearly shown and shall interface with others. All equipment names and tag numbers shall be shown. Functions and signals embedded within the PLC's and SCADA system shall also be shown in accordance with ISA and other appropriate standards. This shall include a clear depiction of the operation of every analogue control loop and a summarized or indicative indication of the operation of any logic interlocks. The P&ID's shall also indicate the interface between such items as control panels, separate installations, buildings, rooms etc. Every item of equipment and every line shall be numbered in accordance with the specified numbering system. Full use of varying line thickness and the like shall be made to optimize the readability of the P&IDs.
- 2 The P&IDs shall be one of the early WTP related documents and drawings to be submitted by the Contractor for the Engineer's review. Until the Engineer has given no-objection to the P&ID's, the Contractor shall not be issued no-objection to other submissions.

##### 10.15.5.2 Hydraulic Profile

- 1 Hydraulic profile drawing for the RWTL and WTP shall show top water for the flow conditions of minimum, average, peak and all other flow scenarios defined as necessary in Section 11.3. The hydraulic profile shall also depict clearly all possible hydraulics conditions, such as one process unit out of operation, bypass scenarios, etc. The Contractor shall ensure that there is freeboard of a minimum 500mm for all possible flow and operating conditions. The Contractor shall ensure that no component of the WTP overflows at any flow and operational conditions. The Drawing shall show freeboard, overflow weir levels and upstream water levels under overflow situations. The drawing shall be supported by detailed calculations.
- 2 All formulae and coefficients used with source references (with copies of the references) and assumptions made in the calculations shall be detailed and agreed with the Employer.

##### 10.15.5.3 Structural Drawings

- 1 Structural drawings shall be in sufficient detail to enable the Engineer to check the Contractor's structural design or identify any structural modifications proposed by the Contractor to the Tender Drawings. They shall show plans and sectional views which shall be dimensioned and shall show in detail the necessary works to be provided including details of loads to be carried and the positions and dimensions of foundation supports, large diameter pipe runs, pipe anchors ducts, openings in walls and floors and the like.
- 2 The Contractor shall note that all information given for the existing facilities is to assist the Contractor at the time of tendering. The Contractor shall verify the information before making use of and interpreting the same. Where additions and extensions to existing works are required the Contractor shall ascertain by measurement at site, the actual lines, levels and dimensions of existing works to enable them to detail the plant, pipe work and equipment to be provided so that they will fit in with the existing works. In providing no-objection to these drawings, the Engineer does not accept any responsibility for errors on lines, levels or dimensions.
- 3 The Contractor shall also provide the structural calculations made for each of the drawings for the Engineer's approval. The Contractor shall submit both structural drawings and respective calculations to the Engineer for review.

#### 10.15.5.4 Plant Working Drawings

- 1 Drawings for all items of plant constituting an operating plant and equipment system shall be submitted to the Engineer concurrently and shall include diagrams showing circuit functioning and details for erection.
- 2 Plant working drawings prepared by subcontractors and manufacturers employed by the Contractor shall be checked by the Contractor for accuracy and compliance with the Contract as specified before being forwarded to the Engineer. Working drawings, deemed to be not checked by the Contractor, will be rejected and returned to the Contractor without further examination.

#### 10.15.5.5 Complementary Drawings

- 1 The Contractor shall submit such further detailed drawings of the RWTL and WTP and any other equipment being provided under the Contract as the Engineer may require for a proper understanding of the Works.
- 2 These complementary drawings will not form part of the reviewed drawings, but shall be included as appropriate with the record drawings, the operating instructions and the O&M manual.
- 3 Such drawings may include but not necessarily be limited to:
  - (A) Sectional and detail arrangement drawings;
  - (B) Circuit diagrams for electrical equipment which shall include wire and terminal numbers and circuit references and ratings for all components;
  - (C) Component part schedules for each item of plant with references to the associated drawings; and

- (D) Valve schedule listing each valve with identification number, size, type, connections, rating, figure number and duty.

10.15.5.6 Shop Drawings

- 1 Shop drawings are prepared for materials that are to be fabricated. These are typically required from the supplier or manufacturer or fabricator of a certain component. The shop drawings show more detail than the construction drawings. It is drawn to explain the method of fabrication of items. Shop drawings are required to be submitted to give The Employer the opportunity to review the installer's version of the item, prior to fabrication. Since shop drawings are manufacturer's drawings, a quick review is expected from the Employer. Should there be any concerns, The Employer may comment or suggest. No acceptance from The Employer is necessary for shop drawings, unless the fabrication poses major hazards or risks.
- 2 The Contractor shall start submitting shop drawings in two (2) hard copies and one (1) reproducible copy.

**10.16 Revision after No Objection**

The Contractor shall seek no objection from the Engineer prior to implementation of any change in the previously submitted documents and / or design. The Contractor shall demonstrate the impact of the change on other documents and / or design; and shall make all necessary changes in all other documents and design deliverables.

**10.17 As-Built Records**

10.17.1 As-built drawings

- 10.17.1.1 The Contractor shall submit the As-Built Drawings before the commencement of Tests on Completion.
- 10.17.1.2 Prior to the Employer's Taking Over, the Contractor shall submit the updated As-Built Drawings in case of any modifications to the Works during the period of Test on Completion.
- 10.17.1.3 The Contractor shall submit three (3) sets in A1 paper prints, one (1) reproducible copy in Mylar form, four (4) sets in A3 paper prints, two (2) electronic copies in PDF format on USB flash drive, one (1) electronic copy in PDF format on an external hard disk, and an electronic copy on CD ROM in AutoCAD format.
- 10.17.1.4 The Contractor shall provide As-Built Drawings of the Works endorsed "as-built" by the Licensed Engineer to show the whole RWTL and WTP as installed and incorporating any modifications made during erection and commissioning. These shall include all such drawings, diagrams and schedules as are necessary for a complete understanding of the Works including details of any "bought-in" items and any items shown as "blocks" on the main drawings.



- 10.17.1.5 Information given on record drawings shall include tolerances, clearances, loadings, finishes, materials and ratings of plant. The Contractor shall ensure that the approved and complementary drawings are marked up to show the plant as installed and two copies of such marked up prints shall be submitted to the Employer for approval prior to the preparation of record drawings. Submission to and approval by Manila Water of record drawings shall be a condition precedent to the issue of the Completion Certificate.
- 10.17.1.6 Final as-built drawings shall be submitted to the Engineer not lesser than 91 days before the Employer's Taking Over. However, the Employer may require the early submission of structural, architectural, civil outline or any other type of drawing as may be required for submissions to statutory authorities in order to achieve Certificate of Occupancy and other certification required for handover of the Works. The Contractor shall submit these drawings in the required format to allow either hard copy submission or e-submission.
- 10.17.1.7 In addition to the sets specified above, one copy of each record drawing at reduced scale (A3 folded) shall be included in each copy of the O&M manuals. The drawings, and particularly dimensions and notes, shall be prepared so that the drawings are still legible at this size. If in the Engineer's and / or the Employer's opinion the drawing is not legible or clear at this reduced size then the drawing shall be inserted in a clear pocket at the original size.
- 10.17.1.8 As-built drawings shall include but not be limited to documents and drawings mentioned above.
- 10.17.1.9 In addition to the as-built drawings detailed above the Contractor shall prepare as-built drawings in a format to assist with the final submissions to the regulatory authorities. The copy shall be marked up as required by the authorities to indicate all the changes from the preliminary submission drawings. There shall be short descriptions to indicate the basis for each change. The format of these drawings shall comply with the requirements of the relevant authorities to ensure swift approval of the required permits.

#### 10.17.2 Other Records

- 10.17.2.1 Conducting land surveys: All land surveys, including but not limited to as-built and project control surveys, shall be conducted by Geodetic Engineers as mandated by **RA 8560**. Project control accuracy shall be as prescribed by **DAO 98-12, DAO 07-29, DAO 10-13**. All inlets, chambers, sump pits, bends and network appurtenances shall be indicated in the plan along with its PRS 92 and WGS 84 coordinates. Vertical accuracy shall be at +/- 0.05m accuracy or better. Project Control points must be verified by Asset Management Department.

10.17.2.2 Preparation and submission of Asset Register: The Contractor shall prepare, and keep up-to-date, complete asset register records showing the list of assets, and when applicable, spare parts, as defined in and nested per location or process in compliance to Appendix 27 Asset Hierarchy Policy and related policies, consistent with as-built drawings and process diagrams, with all pertinent asset information, not limited to but must include installation date, dimensions, specifications, identification numbers, asset code, and other information as prescribed by the Engineer, in editable MICROSOFT EXCEL FORMAT and in four (4) A4 hard copies. These records shall be provided prior to commencement of the Performance Tests and kept on the Site and shall be used exclusively for the purposes of Sub-Clause 5.6 of the General Conditions of Contract.

## 11 Flows and Loads

### 11.1 Raw Water Characteristics

11.1.1 An extensive investigation was conducted from July 2018 to September 2019 on the anticipated raw water quality. The table below summarizes the target parameters, including the range of data collected, to be treated by the WTP. The range is shown to give the Contractor an indication of the different loads that can be encountered during the operation of the WTP. The WTP shall be designed using the maximum values from the table in compliance with the mandatory requirement of delivering potable water to the public. Performance at minimum and average concentrations shall be checked through the process calculations.

11.1.2 Appendix 4 Raw Water Sampling Data summarizes the full extent of raw water quality data collected. This data is provided for reference only. It is the responsibility of the Contractor to summarize and interpret this data to flag any other parameters of concern, which can put the design and operations of the WTP at risk. This should be conducted before developing the process design of the WTP, to develop mitigating measures against these risks.

| PARAMETER              | UNIT | AVERAGE | 99 <sup>TH</sup> PERCENTILE | MAXIMUM |
|------------------------|------|---------|-----------------------------|---------|
| Color                  | TCU  | 6.50    | 15.00                       | 25.00   |
| Turbidity              | NTU  | 6.90    | 63.00                       | 125.00  |
| TSS                    | mg/L | 12.00   | 100.00                      | 165.00  |
| pH                     | -    | 7.80    | 8.70                        | 8.80    |
| Temperature            | °C   | 26.90   | 32.00                       | 33.00   |
| Aluminum               | mg/L | 0.17    | 3.40                        | 4.40    |
| Iron                   | mg/L | 0.16    | 3.40                        | 4.10    |
| Manganese              | mg/L | 0.01    | 0.09                        | 0.10    |
| Ammonia                | mg/L | 0.10    | 0.70                        | 0.90    |
| Alkalinity             | mg/L | 135.00  | 211.00                      | 228.00  |
| Total Hardness         | mg/L | 92.00   | 120                         | 124     |
| Total Dissolved Solids | mg/L | 166.00  | 207.00                      | 237.00  |

| PARAMETER      | UNIT       | AVERAGE   | 99 <sup>TH</sup> PERCENTILE | MAXIMUM    |
|----------------|------------|-----------|-----------------------------|------------|
| Chloride       | mg/L       | 4.40      | 10.80                       | 11.00      |
| Sulfate        | mg/L       | 9.30      | 12.00                       | 12.00      |
| Arsenic        | mg/L       | 0.008     | 0.008                       | 0.008      |
| Cadmium        | mg/L       | 0.001     | 0.001                       | 0.001      |
| Lead           | mg/L       | 0.005     | 0.005                       | 0.005      |
| Nitrate        | mg/L       | 1.00      | 1.00                        | 1.00       |
| Total Coliform | MPN/100 mL | 11,810.00 | 122,600.00                  | 160,000.00 |
| Fecal Coliform | MPN/100 mL | 8,902.00  | 114,440.00                  | 160,000.00 |
| HPC            | CFU/mL     | 16,037.00 | 234,800.00                  | 270,000.00 |

11.1.3 The design of WTP shall accommodate all the expected loads such as sludge and backwash water resulting from these concentrations.

11.1.4 The design of each treatment process shall consider additional load brought about by site returns to the plant inlet.

## 11.2 Raw Water Verification Study

11.2.1 The Contractor shall conduct a raw water verification study once Kaliwa Low Dam is constructed. Raw water samples must be obtained from the dam intake structure and a comprehensive sampling and testing plan shall be proposed by the Contractor.

11.2.2 Samples shall be collected by grab sampling over a minimum period of 12 months, considering the dam’s construction timeline. The Contractor shall submit quarterly data reports of the results during this period. At the time of the second quarterly data report submission, the Contractor shall conduct a workshop to discuss the summary of results of the sampling activities.

11.2.3 Method of analysis shall follow the PNDSW guidelines. The following parameters shall be analysed and frequency of sampling shall be as follows:

| CLASSIFICATION | WATER QUALITY PARAMETERS  | FREQUENCY |
|----------------|---------------------------|-----------|
| Biological     | Phytoplankton Count (Bio) | Weekly    |

| <b>CLASSIFICATION</b> | <b>WATER QUALITY PARAMETERS</b> | <b>FREQUENCY</b> |
|-----------------------|---------------------------------|------------------|
| Biological            | Chlorophyll-a                   | Weekly           |
| Microbiological       | Total coliform                  | Weekly           |
| Microbiological       | Thermotolerant Coliform (Fecal) | Weekly           |
| Microbiological       | Heterotrophic plate count (HPC) | Weekly           |
| Physical              | pH                              | Weekly           |
| Physical              | Color                           | Weekly           |
| Physical              | Conductivity                    | Weekly           |
| Physical              | Odor                            | Weekly           |
| Physical              | Taste                           | Weekly           |
| Physical              | Temperature                     | Weekly           |
| Physical              | Turbidity                       | Weekly           |
| Physical              | Dissolved Oxygen (DO)           | Weekly           |
| Inorganic             | Alkalinity                      | Weekly           |
| Inorganic             | Aluminum                        | Weekly           |
| Inorganic             | Antimony                        | Monthly          |
| Inorganic             | Arsenic                         | Monthly          |
| Inorganic             | Barium                          | Monthly          |
| Inorganic             | Boron                           | Monthly          |

| <b>CLASSIFICATION</b> | <b>WATER QUALITY PARAMETERS</b>                   | <b>FREQUENCY</b> |
|-----------------------|---------------------------------------------------|------------------|
| Inorganic             | Cadmium                                           | Monthly          |
| Inorganic             | Chloride                                          | Monthly          |
| Inorganic             | Chromium, Total                                   | Monthly          |
| Inorganic             | Cyanide as Free Cyanide                           | Quarterly        |
| Inorganic             | Fluoride                                          | Monthly          |
| Inorganic             | Lead                                              | Monthly          |
| Inorganic             | Mercury                                           | Monthly          |
| Inorganic             | Nickel                                            | Monthly          |
| Inorganic             | Nitrate as NO <sub>3</sub> -N                     | Weekly           |
| Inorganic             | Nitrite as NO <sub>2</sub>                        | Weekly           |
| Inorganic             | Selenium                                          | Monthly          |
| Inorganic             | Total hardness (as Calcium Carbonate)             | Weekly           |
| Inorganic             | Hydrogen Sulfide (Total Sulfide) H <sub>2</sub> S | Monthly          |
| Inorganic             | Iron                                              | Weekly           |
| Inorganic             | Manganese                                         | Weekly           |
| Inorganic             | Phosphates (PO <sub>4</sub> )                     | Monthly          |
| Inorganic             | Silicates (SiO <sub>2</sub> )                     | Monthly          |
| Inorganic             | Sodium (Na)                                       | Monthly          |

| <b>CLASSIFICATION</b> | <b>WATER QUALITY PARAMETERS</b>                | <b>FREQUENCY</b> |
|-----------------------|------------------------------------------------|------------------|
| Inorganic             | Sulphate (SO <sub>4</sub> )                    | Monthly          |
| Inorganic             | Zinc                                           | Monthly          |
| Inorganic             | Total Dissolved Solids (TDS)                   | Weekly           |
| Inorganic             | Total Suspended Solids (TSS)                   | Weekly           |
| Organic               | Total Organic Carbon (TOC)                     | Monthly          |
| Organic               | Dissolved Organic Carbon (DOC)                 | Monthly          |
| Organic               | Oil and Grease                                 | Monthly          |
| Organic               | Biological Oxygen Demand (BOD <sub>5</sub> )   | Monthly          |
| Organic               | Chemical Oxygen Demand (COD)                   | Monthly          |
| Organic               | Surfactant as MBAS                             | Monthly          |
| Organic               | Total Organic Carbon (TOC)                     | Weekly           |
| Pesticide             | Aldrin                                         | Quarterly        |
| Pesticide             | Dieldrin                                       | Quarterly        |
| Pesticide             | Atrazine and its chloro-s-triazine metabolites | Quarterly        |
| Pesticide             | Carbofuran                                     | Quarterly        |
| Pesticide             | Chlordane                                      | Quarterly        |
| Pesticide             | DDT                                            | Quarterly        |

| <b>CLASSIFICATION</b> | <b>WATER QUALITY PARAMETERS</b>        | <b>FREQUENCY</b> |
|-----------------------|----------------------------------------|------------------|
| Pesticide             | 1,2-Dibromo-3-chloropropane (DBCP)     | Quarterly        |
| Pesticide             | 2,4-dichlorophenoxyacetic acid (2,4-D) | Quarterly        |
| Pesticide             | Endrin                                 | Quarterly        |
| Pesticide             | 1,2-dibromoethane (Ethylenedibromide)  | Quarterly        |
| Pesticide             | Glyphosate                             | Quarterly        |
| Pesticide             | Lindane                                | Quarterly        |
| Pesticide             | Pendimethalin                          | Quarterly        |
| Others                | Benzene                                | Monthly          |
| Others                | Benzo(a)pyrene                         | Monthly          |
| Others                | Carbon Tetrachloride                   | Monthly          |
| Others                | 1,2-Dichlorobenzene                    | Monthly          |
| Others                | 1,4-Dichlorobenzene                    | Monthly          |
| Others                | 1,2-Dichloroethane                     | Monthly          |
| Others                | 1,2-Dichloroethene                     | Monthly          |
| Others                | Dichloromethane                        | Monthly          |
| Others                | Di(2-ethylhexyl)phthalate              | Monthly          |
| Others                | Ethylbenzene                           | Monthly          |
| Others                | Styrene                                | Monthly          |



| <b>CLASSIFICATION</b> | <b>WATER QUALITY PARAMETERS</b> | <b>FREQUENCY</b> |
|-----------------------|---------------------------------|------------------|
| Others                | Tetrachloroethene               | Monthly          |
| Others                | Toluene                         | Monthly          |
| Others                | Vinyl chloride                  | Monthly          |
| Others                | Xylenes (total)                 | Monthly          |
| Radiological          | Radon 222 (Bq/L)                | Quarterly        |
| Radiological          | Gross alpha (Bq/L)              | Quarterly        |
| Radiological          | Gross beta (Bq/L)               | Quarterly        |

11.2.4 The corresponding costs entailing the verification shall be covered by a provisional sum. The scope of the provisional sum shall be prepared by the Contractor and to be submitted for review and acceptance of the Engineer and Employer.

11.2.5 By the end of the 12-month verification study, the Contractor shall then submit a final report to the Client indicating the following:

11.2.5.1 Statistical analysis of the sampling data;

11.2.5.2 Comparison of the tested parameters against the design basis in Section 11.1, highlighting any significant differences;

11.2.5.3 Any additional parameters of concern detected from what was considered in the design of the WTP;

11.2.5.4 Any risks or impacts on the current design and plant performance;

11.2.5.5 Any additional process units needed to treat the newly detected parameters of concern;

11.2.6 The recommendations from the submitted report shall be evaluated for any potential contract variation that may result from the verification study.

11.2.7 It is assumed that the construction of Kaliwa Low Dam and dam intake structure shall be completed prior to the Tests of Completion of the WTP. With the Employer’s endorsement, the Contractor shall be responsible in the necessary coordination with other contractors and acquiring construction progress of the dam to provide an estimated timeline for the verifications tests. If the estimated raw water verification study timeline is proven to be beyond of the agreed construction and testing period of the WTP, the Contractor and Employer shall come to a decision whether to pursue the verification study or not. This decision should materialize as early as the pre-commissioning stage of the WTP.

### 11.3 Flow Management and Hydraulic Capacity

- 11.3.1 The Contractor shall design the RWTL coming from the water portal up to the Flow Diverting Structure with an ultimate capacity of 1200MLD and peak factor of 1.15. From the Flow Diverting Structure going to the Stage 1 WTP, the RWTL should be designed with an ultimate capacity of 300MLD with peak factor 1.15, and a minimum flow of 100MLD. Both segment of RWTL shall be designed using twin steel pipe to provide reliability and provision for maintenance.
- 11.3.2 The WTP shall be designed to receive recovered water generated from the treatment process to minimize plant losses.
- 11.3.3 The Contractor shall design the ultimate capacity of WTP to treat 300 million liters per day (MLD) of raw water at maximum load.
- 11.3.4 During the first year of the WTP, it is expected to produce at least 100MLD of treated water. The Contractor shall design the WTP with flexibility to operate at this intermediate flow, demonstrating this through process and hydraulic calculations, using the entire range of raw water quality.
- 11.3.5 The Contractor should be able to demonstrate hydraulic allowance of 10% in the design of the WTP. The design shall anticipate raw water flows of 100MLD and 300MLD and accommodate the flows in between, i.e., flow variations throughout the day. Deviations on actual hourly flows shall be evaluated on a case to case basis and subject to Employer's approval.
- 11.3.6 In addition, the WTP shall be designed to recover all water generated from the treatment process to minimize hydraulic losses. All site returns are expected to be a minimum of 5% of the raw water flows. This shall be accounted in hydraulics, process unit sizing and estimating the raw water flows needed to produce maximum treated water flows.
- 11.3.7 Design of the process units and equipment configuration shall include a maintenance scenario, such that units can be isolated and put offline. This shall be demonstrated at the entire range of hourly flows.
- 11.3.8 The Contractor shall demonstrate the maximum amount water produced from 300 MLD of raw water. Plant losses shall not be greater than 3% of the incoming raw water flow and shall be demonstrated by calculations. In the development of the design, The Contractor shall account plant losses due to evaporation, chemical dilution, entrapped water in the dewatered sludge, washing and building services, domestic water use within the plant and others as identified by the Contractor.
- 11.3.9 Treated water flow shall be measured from the flow meter from the WTP's final product water line, prior to the treated water reservoir.
- 11.3.10 It is essential that the WTP be hydraulically designed to operate efficiently at minimum and maximum flows, with provision such as isolation and draining down facilities to allow each process unit to be off line individually for maintenance services. These design conditions shall be checked to ensure hydraulic challenges are mitigated. The design shall accommodate the full range of hydraulic conditions specified. Typical issues, which shall be addressed in the Contractor's design, include but are not limited to:
  - 11.3.10.1 Minimum flows exceed maximum turn down on pumps;

- 11.3.10.2 Minimum velocities are too low resulting in solids deposition;
- 11.3.10.3 Head over control weirs is insufficient for accurate measurement and control; and
- 11.3.10.4 Limitation of variable frequency drives (VFDs) for pump operation in terms of start-up and turndown.
- 11.3.10.5 The Contractor shall monitor the flow and load going to the WTP during the Trial Operations and Process Proving Period.
- 11.3.10.6 The Contractor shall ensure that performance requirements are achieved by the end of the PPP with the range of design flows and loads specified.

11.3.11 After the design is finalized, the Contractor shall provide a simulation indicating the maximum water production, at the average raw water quality condition, with the proposed design. The Contractor shall clearly indicate the design's limitations on the maximum production provided.

#### 11.4 Treated Water Quality Requirements

11.4.1 The treated water quality targets identified in the table below are required to be met under all operational conditions.

11.4.2 Parameters not specified on the list shall comply to PNSDW 2017.

| PARAMETERS                                         | UNIT                 | LIMIT           |
|----------------------------------------------------|----------------------|-----------------|
| <b>Microbiological</b>                             |                      |                 |
| Total coliform - Multiple tube fermentation (MTFT) | MPN/100mL            | <1.10           |
| Total coliform – EST                               | MPN/100mL            | Absent or <1.00 |
| Total coliform - Membrane filter (MFT)             | Total colonies/100mL | <1.00           |
| Heterotrophic Plate Count - all methods            | CFU/mL               | ≤10.00          |
| E.Coli – MTFT                                      | MPN/100mL            | <1.10           |
| E.Coli – EST                                       | MPN/100mL            | Absent or <1.00 |
| E.Coli – MFT                                       | Total colonies/100mL | <1.00           |

| PARAMETERS                                 | UNIT | LIMIT  |
|--------------------------------------------|------|--------|
| <b>Inorganic</b>                           |      |        |
| Antimony                                   | mg/L | 0.02   |
| Arsenic                                    | mg/L | 0.01   |
| Barium                                     | mg/L | 0.70   |
| Boron                                      | mg/L | 2.00   |
| Cadmium                                    | mg/L | 0.003  |
| Chromium (Total)                           | mg/L | 0.05   |
| Cyanide (Total)                            | mg/L | 0.50   |
| Fluoride                                   | mg/L | 1.50   |
| Lead                                       | mg/L | 0.01   |
| Manganese                                  | mg/L | <0.021 |
| Mercury (Total)                            | mg/L | 0.001  |
| Nickel                                     | mg/L | 0.07   |
| Nitrate                                    | mg/L | 50.00  |
| Nitrite                                    | mg/L | 3.00   |
| Selenium                                   | mg/L | 0.04   |
| <b>Organic (from Industrial Pollution)</b> |      |        |
| Benzene                                    | mg/L | 0.01   |
| Benzo(a)pyrene                             | mg/L | 0.0007 |
| Carbon Tetrachloride                       | mg/L | 0.004  |

| PARAMETERS                                     | UNIT | LIMIT   |
|------------------------------------------------|------|---------|
| 1,2-Dichlorobenzene                            | mg/L | 1.00    |
| 1,4-Dichlorobenzene                            | mg/L | 0.30    |
| 1,2-Dichloroethane                             | mg/L | 0.03    |
| 1,2-Dichloroethene                             | mg/L | 0.05    |
| Dichloromethane                                | mg/L | 0.02    |
| Di(2-ethylhexylyl)phthalate                    | mg/L | 0.008   |
| Ethylbenzene                                   | mg/L | 0.30    |
| Styrene                                        | mg/L | 0.02    |
| Tetrachloroethene                              | mg/L | 0.04    |
| Toluene                                        | mg/L | 0.70    |
| Vinyl chloride                                 | mg/L | 0.0003  |
| Xylenes (total)                                | mg/L | 0.50    |
| <b>Organic (Pesticides)</b>                    |      |         |
| Aldrin and Dieldrin (combined)                 | mg/L | 0.00003 |
| Atrazine and its chloro-s-triazine metabolites | mg/L | 0.10    |
| Carbofuran                                     | mg/L | 0.007   |
| Chlordane                                      | mg/L | 0.0002  |
| DDT                                            | mg/L | 0.001   |
| 1,2-Dibromo-3-chloropropane (DBCP)             | mg/L | 0.001   |

| PARAMETERS                             | UNIT      | LIMIT                                                                           |
|----------------------------------------|-----------|---------------------------------------------------------------------------------|
| 2,4-dichlorophenoxyacetic acid (2,4-D) | mg/L      | 30.00                                                                           |
| Endrin                                 | mg/L      | 0.0006                                                                          |
| 1,2-dibromoethane (Ethylenedibromide)  | mg/L      | 0.0004                                                                          |
| Glyphosate                             | mg/L      | 1.00                                                                            |
| Lindane                                | mg/L      | 0.002                                                                           |
| Pendimethalin                          | mg/L      | 0.02                                                                            |
| <b>Physicochemical</b>                 |           |                                                                                 |
| Taste                                  | -         | No objectionable Taste Analysis and Testing Procedures - SMEWW 2160 SMEWW 2170B |
| Odor                                   | Odor Unit | No objectionable Odor Analysis and Testing Procedures - SMEWW 2150 SMEWW 2170B  |
| Color (Apparent)                       | CU        | <5.00                                                                           |
| Turbidity                              | NTU       | <2.50                                                                           |
| Aluminum                               | mg/L      | <0.12                                                                           |
| Chloride                               | mg/L      | <200.00                                                                         |
| Copper                                 | mg/L      | 1.00                                                                            |
| Hardness, total                        | mg/L      | <250.00                                                                         |
| Hydrogen Sulfide                       | mg/L      | 0.05                                                                            |
| Iron                                   | mg/L      | <0.40                                                                           |

| PARAMETERS                                   | UNIT | LIMIT                                            |
|----------------------------------------------|------|--------------------------------------------------|
| pH                                           | mg/L | 6.5 - 8.0                                        |
| Sodium                                       | mg/L | 200.00                                           |
| Sulfate                                      | mg/L | 200.00                                           |
| Total Dissolved Solids, TDS                  | mg/L | <400.00                                          |
| Zinc                                         | mg/L | 5.00                                             |
| <b>Contaminants from Treatment Chemicals</b> |      |                                                  |
| Acrylamide                                   | mg/L | 0.0005                                           |
| Epichlorohydrin                              | mg/L | 0.0004                                           |
| <b>Disinfection Chemicals</b>                |      |                                                  |
| Chlorine Residual                            | mg/L | 0.90 - 1.5 for treatment plant and WTP reservoir |
| Chlorine Dioxide Residual                    | mg/L | 0.2 min and 0.4 max                              |
| <b>Disinfection by-products</b>              |      |                                                  |
| Bromate                                      | mg/L | 0.01                                             |
| Chlorite                                     | mg/L | 0.70                                             |
| Chlorate                                     | mg/L | 0.70                                             |
| Dibromoacetonitrile                          | mg/L | 0.07                                             |
| Dichloroacetate                              | mg/L | 0.05                                             |
| Dichloroacetonitrile                         | mg/L | 0.02                                             |
| Monochloroacetate                            | mg/L | 0.02                                             |
| Trichloroacetate                             | mg/L | 0.20                                             |

| PARAMETERS                             | UNIT | LIMIT |
|----------------------------------------|------|-------|
| 2,4,6-trichlorophenol                  | mg/L | 0.20  |
| <b>Trihalomethanes</b>                 |      |       |
| Bromoform                              | mg/L | 0.10  |
| Bromodichloromethane (BDCM)            | mg/L | 0.06  |
| Chloroform                             | mg/L | 0.30  |
| Dibromochloromethane (DBCM)            | mg/L | 0.10  |
| Total trihalomethanes                  | mg/L | 1.00  |
| <b>Radiological Constituents</b>       |      |       |
| Gross alpha activity (excluding radon) | Bq/L | 0.50  |
| Gross beta                             | Bq/L | 1.00  |
| Radon                                  | Bq/L | 11.00 |

## 11.5 Wastewater and Sludge Quality

- 11.5.1 The WTP shall be designed to minimize water losses from the treatment process by recovering supernatant from filter backwash and filtrates from sludge treatment back to the plant inlet.
- 11.5.2 The Contractor must design for all waste streams to be recovered. If the Contractor finds that full recovery is not possible, the Contractor must flag this information to the Client and must incorporate wastewater treatment in the design under a provisional sum. The discharge shall be routed to Yapak Creek.
- 11.5.3 Aside from DAO 2021-19 effluent standards, the Contractor shall treat any waste leaving the plant following the limits set below are in accordance to MWCI standards for wastewater quality required for minimum standard pH, Total Suspended Solids, Chloride, Fluoride, and Iron.



| PARAMETERS     | UNIT       | LIMIT                                                                                   |
|----------------|------------|-----------------------------------------------------------------------------------------|
| TSS            | mg/L       | 100                                                                                     |
| TDS            | mg/L       | Should not increase the TDS of receiving body by >10% outside the 5 hectare mixing zone |
| Fecal Coliform | MPN/100 ml | 400.00                                                                                  |
| Chlorides      | mg/L       | 300.00                                                                                  |
| pH             | -          | 6.5-9.0                                                                                 |
| Fluoride       | mg/L       | 2.00                                                                                    |
| Iron           | mg/L       | <b>7.5</b>                                                                              |

11.5.4 Sludge shall have a minimum dry solids content of 18% by weight for disposal and transportation offsite. The sludge thickening and dewatering and its associated polymer dosing system shall be designed for a target dry solids content of 18-25% dewatered sludge.

## 11.6 Design Flows

The Scope of Work includes the construction of facilities for the following capacity as part of this contract:

| Structure / Design Element                                                                                                            | Average Capacity |
|---------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Raw Water Interface Chamber– design                                                                                                   | 1.15 x 1200 MLD  |
| Raw Water Interface Chamber – civil work                                                                                              | 1.15 x 1200 MLD  |
| Raw Water Interface Chamber – equipment installation                                                                                  | 1.15 x 1200 MLD  |
| Raw Water Flow Diverting Structure – design<br>(Emergency overflow for flows higher than 1.15Q upstream of inlet pumping station)     | 1.15 x 1200 MLD  |
| Raw Water Flow Diverting Structure – civil work<br>(Emergency overflow for flows higher than 1.15Q upstream of inlet pumping station) | 1.15 x 1200 MLD  |

|                                                                                                                                                   |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Raw Water Flow Diverting Structure – equipment installation<br>(Emergency overflow for flows higher than 1.15Q upstream of inlet pumping station) | 1.15 x 1200 MLD |
| WTP Interface Chamber – design                                                                                                                    | 300 MLD         |
| WTP Interface Chamber – civil work                                                                                                                | 300 MLD         |
| WTP Interface Chamber – equipment installation                                                                                                    | 300 MLD         |
| Raw water pumping station – design                                                                                                                | 300 MLD         |
| Raw water pumping station – civil work                                                                                                            | 300 MLD         |
| Raw water pumping station – installation of mechanical and electrical works                                                                       | 300 MLD         |
| Coagulation – design                                                                                                                              | 300 MLD         |
| Coagulation – civil works                                                                                                                         | 300 MLD         |
| Coagulation – equipment installation                                                                                                              | 300 MLD         |
| Flocculation and Sedimentation – Design                                                                                                           | 300 MLD         |
| Flocculation and Sedimentation – civil works                                                                                                      | 300 MLD         |
| Flocculation and Sedimentation – equipment installation                                                                                           | 300 MLD         |
| Filtration – design                                                                                                                               | 300 MLD         |
| Filtration – civil work                                                                                                                           | 300 MLD         |
| Filtration – equipment installation                                                                                                               | 300 MLD         |
| Reservoir – design                                                                                                                                | 300 MLD         |
| Reservoir – civil works                                                                                                                           | 300 MLD         |
| Reservoir – equipment installation                                                                                                                | 300 MLD         |
| Sludge Treatment Facility – design                                                                                                                | 300 MLD         |
| Sludge Treatment Facility – civil works                                                                                                           | 300 MLD         |

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## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

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|                                                                                                               |                                                |
|---------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| Sludge Treatment Facility – equipment installation                                                            | 300 MLD                                        |
| Chemical building including storage and dosing facilities – design                                            | 300 MLD                                        |
| Chemical building including storage and dosing facilities – civil works                                       | 300 MLD                                        |
| Chemical building dosing facilities – equipment installation                                                  | 300 MLD                                        |
| All common facilities including roads, access, area lighting, drainage, utilities, various buildings, fencing | For requirement equivalent of plant at 300 MLD |
| Site Plan Design                                                                                              | 300 MLD                                        |
| WTP– Plant Hydraulics                                                                                         | 300 MLD                                        |
| Electrical site utilities HV and LV installation – design                                                     | 300 MLD                                        |
| Electrical site utilities HV and LV installation – civil works                                                | 300 MLD                                        |
| Electrical site utilities HV and LV installation – installation                                               | 300 MLD                                        |

## **12 Individual RWTL and WTP Process Requirements**

### **12.1 Raw Water Interface Chamber from water portal**

#### **12.1.1 General**

12.1.1.1 The raw water interface connection from the water portal shall be the battery limit for this project. The water portal Contractor shall provide the steel pipe stub out with a diameter of 2.5m and length of 7.3m as shown in Appendix 5 Drawing sheet 45429S-05507-E01 Rev 00. The location and configuration of the raw water interface chamber as reflected in Appendix 9 shall be retained. The coordinates of the raw water interface chamber is Latitude: 14°34'54.10"N; Longitude: 121°14'57.14"E based on WGS 1984.

12.1.1.2 The Contractor shall provide a suitable design of raw water interface connection between the RWTL to the Manila Water allocated outfall in the MWSS water portal. The design shall include the pipe connection such as but not limited to, a flange or elbow. The design shall be provided to the Engineer for review and acceptance.

12.1.1.3 The Contractor shall be responsible in all necessary coordination with the other Contractor constructing the water portal. All coordination, correspondences, and exchange of information shall be documented and informed to the Engineer and Employer.

12.1.1.4 Changes in the design due to adjustments implemented during the progress of water portal construction shall be relayed to the Engineer and Employer immediately. Any costs incurred for the re-design of the interface connection shall be handled by the Contractor.

#### **12.1.2 Performance Requirements**

12.1.2.1 The Contractor shall ensure that the raw water flow can be automatically and remotely adjusted by the operators for any changes necessary align with the WTP's operation.

12.1.2.2 The raw water shall be conveyed via gravity-fed transmission line as to limit power consumption, maintenance works, and operation management. The material of the transmission line shall be in accordance with MWCI SES 2.

12.1.2.3 A minimum velocity of 0.6 m/s shall be maintained in the raw water transmission line.

#### **12.1.3 Specific Requirements**

12.1.3.1 The raw water transmission line connecting the RWTL interface chamber to the flow diverting structure shall be designed with not less than two (2) delivery lines.

12.1.3.2 The construction of pipelines shall be in accordance with MWCI SES 5. The necessary excavation, backfilling, and construction methodologies for RWTL are reflected in Section 16.

- 12.1.3.3 The Contractor shall provide an automatic intake screening system in the RWTL to remove any floating debris present in the raw water. A minimum freeboard of 0.5m shall be considered in the design of mechanical screening system.
- 12.1.3.4 The screen structure shall be structurally designed to withstand maximum head loss and shall allow automatic and effective removal of debris under all flow conditions. Operation of the screen shall require minimum maintenance. The screens shall be easily removable and replaceable.
- 12.1.3.5 A minimum of one (1) duty and one (1) standby screening unit shall be provided by the Contractor. One (1) unit of standby equipment with equivalent capacity and performance to the individual duty units shall be provided. The screens shall be designed for effective operation under the full range of flows. The design capacity shall be such that when one (1) unit is out of service, the remaining units are able to treat the design flow.

## **12.2 Raw Water Flow Diverting Structure**

### **12.2.1 General**

- 12.2.1.1 The flow diverting structure shall be designed to provide proper allocation of flow for the following:
- 1 300MLD for the Stage 1 WTP;
  - 2 900MLD for the Stage 2 WTP (to be constructed on the nearby area);
  - 3 Overflow provision
- 12.2.1.2 Motorized gates and weirs shall be provided to manage the flow distribution within the structure.
- 12.2.1.3 An alternative location of the flow diverting structure can be proposed by the Contractor, subject to the review and acceptance of the Engineer and Employer. The Contractor must demonstrate and prove that the proposed location shall provide greater value to the Employer and operation of RWTL. A block out shall be provided in the structure for future interface connection to the Stage 2 WTP. The location, size, and design shall be part of the Contractor's scope. The Contractor shall ensure that the tapping point, complete with stub outs, blinds and isolation, is made available for future interface connection to Stage 2 WTP (900MLD), with no interruptions to the operations of Stage 1 WTP. The Contractor shall include in their design provide the steel pipe stub out with a minimum length of 2m.
- 12.2.1.4 The structure shall be covered to prevent any external contamination.
- 12.2.1.5 Flow meters shall be provided at the upstream (prior entering the flow diverting structure) to monitor incoming raw water flow.

### **12.2.2 Performance Requirements**

- 12.2.2.1 Overflow provision shall be designed in accordance with MWCI SES 11.
- 12.2.2.2 The structure shall be designed to properly split the flow and provide raw water to the respective WTP at all times.

- 12.2.2.3 A minimum freeboard of 0.5m from the maximum flow shall be considered in the design.

### 12.2.3 Specific Requirements

- 12.2.3.1 An emergency overflow shall be provided at the structure for the diversion of excess flow to the same waterway as the portal overflow. The level of the emergency overflow shall be designed to manage the incoming flow in excess of the hydraulic capacity of the WTP and shall seek consent from the Employer for approval.
- 12.2.3.2 The design of the Contractor shall consider the siltation occurrence in the structure. The dimension and design flows within the structure shall incur minimal siltation. Siltation analysis shall be conducted by the Contractor and to be submitted to the Engineer for review.
- 12.2.3.3 CFD modelling shall be conducted to demonstrate the probable flow patterns, flow distribution, flow velocities, and siltation/particle settlement occurrence. This shall be conducted during the outline design stage of the project to incorporate improvements in the developed design prior to proceeding to construction.

## 12.3 WTP Interface Chamber

### 12.3.1 General

- 12.3.1.1 The WTP Interface Chamber shall be constructed and located within the WTP site boundary, approximately at the farthest east side of the site, near to Roman-Rojas road.
- 12.3.1.2 The WTP Interface Chamber shall be the battery limit between the RWTL and WTP designs. The Contractor shall be responsible for the design and construction of the connection from the reception point to the process unit of the WTP.
- 12.3.1.3 An alternate location of the reception point can be proposed by the Contractor, subject to the review and acceptance of the Engineer and Employer. The Contractor must demonstrate and prove that the proposed location shall provide greater value to the Employer and operation of WTP.
- 12.3.1.4 The overall hydraulic design and profile of the RWTL, including the arrangement of the transmission lines, and flow diverting structure shall be provided by the Contractor as part of the Outline Design. The WTP Interface Chamber shall be properly sized and an appropriate hydraulic loading of the structure shall be adopted.
- 12.3.1.5 The WTP Interface Chamber shall be designed such that siltation, accumulation of sediments, debris and aquatic plants are significantly reduced to ensure clogging or blockage are avoided. The Contractor shall provide schemes for cleaning of the structure in its design. Manual desilting is not acceptable. The WTP Interface Chamber shall incorporate an automated, mechanical facility to remove debris out continuously. The structure design shall prevent any external contamination.

### 12.3.2 Performance Requirements

12.3.2.1 The raw water transmission line connecting the flow diverting structure to the WTP Interface Chamber shall be designed not less than two (2) delivery lines.

12.3.2.2 The design of the pipelines including the material shall be in accordance with MWCI SES 11.

12.3.2.3 A minimum velocity of 0.6m/s shall be maintained in the raw water transmission line.

12.3.2.4 A minimum freeboard of 0.5m from the maximum flow shall be considered in the design.

### 12.3.3 Specific Requirements

12.3.3.1 The construction of pipelines shall be in accordance with MWCI SES 5. The necessary excavation, backfilling, and construction methodologies for RWTL are reflected in Section 16.

12.3.3.2 The design of the Contractor shall consider the siltation occurrence in the structure. The dimension and design flows within the structure shall incur minimal siltation. Siltation analysis shall be conducted by the Contractor and to be submitted to the Engineer for review.

12.3.3.3 CFD modelling shall be conducted to demonstrate the probable flow patterns, flow distribution, flow velocities, and siltation/particle settlement occurrence. This shall be conducted during the outline design stage of the project to incorporate improvements in the developed design prior to proceeding to construction.

12.3.3.4 The Contractor shall provide particle size analyser and zeta potential analyser to monitor the sediments entering the WTP Interface Chamber. The data recorded shall be transmitted to the WTP control room.

12.3.3.5 The WTP Interface Chamber shall be provided with pH, turbidity, TSS, ammonia, aluminum, iron and manganese analysers, level transmitters and level switches. The readings shall be displayed onsite from the instrument as well as on the SCADA system. All interlocks, alarms and trends shall be provided and viewable in the SCADA system.

12.3.3.6 In relation to the raw water pumping station, the reception point shall have the following features:

- 1 Where baffles or flow diverters are incorporated they shall be designed such that they are not prone to the build-up of solids. Adequate allowance shall be provided for manual clearing of the baffles.
- 2 The structure shall be designed with benching to minimize solids settlement. Normally a minimum of 45° (to the horizontal) shall be used. Where high levels solids are expected, a minimum of 60° (to the horizontal) shall be used.
- 3 The design shall minimize solids accumulation, and shall be incorporate an arrangement and isolation to allow removal of solids during maintenance.

## **12.4 Raw Water Pumping Station**

### **12.4.1 General**

- 12.4.1.1 The WTP Interface Chamber and and pumping station shall be designed to transfer 300MLD of raw water. The Contractor shall fit out the pumping station with mechanical and electrical equipment sufficiently such that raw water flow rate of 100MLD can be achieved.
- 12.4.1.2 The required minimum level of redundancy for the pumping station and discharge pipes is N+1. The pipeline design shall take into consideration all operation and maintenance concerns. Due consideration shall be given to constructing two delivery pipelines to allow one to be temporarily taken out of service for maintenance.
- 12.4.1.3 All flows shall be measured by electromagnetic flow meters. The flow meters shall also record the total flow received and shall incorporate a local readout giving both the cumulative daily flow and the instantaneous flow. The flow meters shall have an accuracy of  $\pm 1\%$  or better with due consideration of instrumentation and installation issues such as minimum straight pipe length upstream and downstream of the flow meter. The Contractor shall also measure the pumped flow downstream of the Pumping Station.
- 12.4.1.4 All pipes and/or sections shall be capable of being isolated for maintenance without disruption to plant operations.
- 12.4.1.5 The raw water pumping station shall be installed downstream of the intake screening system. A stone trap and pit shall be provided ahead of the raw water feed pumps.
- 12.4.1.6 A minimum of two (2) duty pump units with one (1) standby unit shall be provided and shall be designed for effective operation under the full range of flows specified in Section 11. The number of units shall be selected to ensure that the most efficient operation shall be achieved. The design capacity of the raw water pumping system shall be such that when one (1) unit is out of service, the remaining units are able to deliver the design flow.
- 12.4.1.7 The raw water pumping station design shall incorporate automatic rotation of the duty pump operation on a timer or cyclical basis to best suit the application, to prevent constant running of individual pumps.
- 12.4.1.8 The control philosophy of the raw water pumping station shall include a snore (draw down) cycle to clear debris. The duration and frequency of this cycle shall be fully operator adjustable.
- 12.4.1.9 The discharge lines of the raw water pumping station shall include flow measurement with flow being recorded at the SCADA system of the WTP.
- 12.4.1.10 The design shall incorporate an air release / suction valves with isolation valves.



- 12.4.1.11 The design shall consider appropriate lifting equipment, access hatches to safely dismantle the pumps and deliver to a hauling vehicle. This shall include all necessary auxiliary equipment and appurtenances as well as access and maintenance facilities.

#### 12.4.2 Performance Requirements

- 12.4.2.1 The raw water feed pumps shall be suitable and achieve the best energy efficiency for all operating and flow conditions specified.
- 12.4.2.2 Pump performance test shall meet the acceptance criteria in accordance with recognized international standard or industry practices. Test data, including head, capacity, speed and power shall be taken at a minimum of five points.
- 12.4.2.3 The flow distribution and particle settling prevention design of the pumping station shall be endorsed by means of a commercial 3D computational fluid dynamic (CFD) model using the latest version of either Flow3D or Fluent. The design shall ensure that minimum deposition of particles and the flow is uniform through the works. This shall be conducted during the outline design stage of the project to incorporate improvements in the developed design prior to proceeding to construction.

#### 12.4.3 Specific Requirements

- 12.4.3.1 Good flow presentation to the pumps shall be incorporated into the design. The design shall be such that flow does not impact directly onto the pumps and that there is no air entrainment into the pump sets.
- 12.4.3.2 The raw water feed pumps to be used shall be non-clogging type with solids handling capability and non-overloading characteristic, which are suitable to be installed in a dry pit. Each pump shall have a solids handling capacity of at least the value specified in SES 13.
- 12.4.3.3 The pump selection and design of the pumping station shall accommodate the characteristic of the incoming flows, the nature of the raw water, and potential presence of debris in the water, noting that there are automatic screens upstream of the pumping station.
- 12.4.3.4 VFDs shall be provided to minimize life cycle cost. The pump selection and pumping station design shall accommodate the characteristic of the incoming raw water flows, and potential presence of debris in the combined raw water.
- 12.4.3.5 Valves, pipes and fittings shall be sized and selected to minimize system losses whilst maintaining sufficient velocities.
- 12.4.3.6 Individual swing, non-slam check valve, dismantling joint and isolation gate valves shall be included for each pump.
- 12.4.3.7 Raw water pumping station shall have a separate valve chambers.
- 12.4.3.8 Discharge headers shall be at low level, just above the valve chamber.

- 12.4.3.9 Swept bends and tees shall be used throughout the station. Mains shall be fitted with air valves to prevent air build up, if required.
- 12.4.3.10 Monitoring systems shall be provided, which shows the hours run for each pump and the pump characteristics, including current usage. Within SCADA a trend shall be provided that shows the current usage against flow, such that the operators can determine if equipment requires maintenance.
- 12.4.3.11 In addition, the instantaneous flow, the cumulative daily flow and the total cumulative flow, in both cubic metres and MLD, must be possible to be seen in the SCADA. Flows shall be shown on a trend.
- 12.4.3.12 A means of isolating the flow shall be provided to allow the removal of flowmeters and the fitting of the flanged spool pieces. The Contractor shall provide a suitable size flanged spool piece. All underground flowmeters shall be installed in chambers.
- 12.4.3.13 Factory Acceptance Test report and ISO 9001 Certificates for the inlet pumps and associates shall be provided for checking prior to equipment delivery.
- 12.4.3.14 Pump discharge shall be provided with mechanical pressure gauges, electrical pressure transmitting devices. These equipment shall be provided with isolating valves to allow maintenance with out shutting down the force main.
- 12.4.3.15 A sampling facility intended for both grab and composite sampling to monitor the raw water quality shall be provided along the discharge line of the raw water feed pumps. An automatic outdoor type automatic sampler shall be provided and installed along the discharge pipe of the raw water pumps.

## **12.5 Coagulation**

### **12.5.1 General**

- 12.5.1.1 From the WTP interface structure, the raw water shall be directed evenly to atleast two (2) raw water discharge lines leading to the flocculation distribution chamber.
- 12.5.1.2 The raw water discharge lines shall be provided with redundancy to ensure operation at full capacity even when one of the modules or any of its components is turned down for maintenance. The remaining units in service shall be able to accommodate the full capacity.
- 12.5.1.3 One (1) in line static mixer shall be installed in raw water discharge line to ensure sufficient mixing of dosing chemicals.
- 12.5.1.4 Static mixer shall be wet-tested to prove that design values are achieved throughout the range of raw water flow rates and coagulant dosing rates.
- 12.5.1.5 The static mixers shall be serviceable even when operating. Appropriate lifting equipment shall also be provided, as well as all necessary auxiliary equipment and appurtenances as well as access and maintenance facilities.

12.5.1.6 Flow meters shall be provided at the upstream end to monitor incoming raw water flow to the coagulation channels.

#### 12.5.2 Performance Requirements

12.5.2.1 The static mixer shall provide a coefficient of variation (CoV) of less than 0.05 and mixing intensity (G value) of not less than  $1000 \text{ s}^{-1}$  at all raw water flows and coagulant dose rate.

12.5.2.2 CFD modelling shall be conducted to demonstrate the probable flow patterns, flow distribution, flow velocities, and mixing performance of static mixer and the proposed dosing point arrangements. This shall be conducted during the outline design stage of the project to incorporate improvements in the developed design prior to proceeding to construction.

#### 12.5.3 Specific Requirements

12.5.3.1 Alum and PACl shall be used as primary coagulants for the WTP.

12.5.3.2 PACl shall be used at a raw water turbidity not greater than 20 NTU. Alum shall be used at raw water turbidity higher than 20 NTU.

12.5.3.3 The contractor shall perform jar testing to identify optimum dose of Alum and PACl in relation to their proposed design. The test shall be performed from the lowest to the highest turbidity recorded. An alternative coagulating agent shall be considered if the contractor can prove that it has the same or better performance compared to Alum and PACl, subject to approval by the Employer.

12.5.3.4 The contractor shall establish the set points for the coagulant dosing through jar tests. These set points shall be adjustable by the operator for flexibility in the WTP's operation

12.5.3.5 The coagulant dosing arrangement shall ensure that coagulant will be properly and evenly distributed among process modules.

12.5.3.6 Isolation of the coagulant dose for each discharge line shall be made possible from the distribution weir box, such that supply to one (1) channel can be discontinued at any given time.

12.5.3.7 For each discharge line, the dosing arrangement shall be installed before and nearest to the static mixer.

12.5.3.8 Coagulant dosing pumps shall be VFD driven. The flow of dosed coagulant shall be measured by a suitable flow meter. Rotameters are acceptable for dilution water lines only. Pressure gages shall be fitted to the feed and dilution water lines;

12.5.3.9 Each dosing arrangement shall be designed such that the coagulant is released throughout the discharge line, distributed in different points along the width.

- 12.5.3.10 The Alum and PACI dosing pumps shall be controlled automatically based on the chemical concentration, incoming raw water flow and feedback from the pH, turbidity, particle size and zeta potential analysers, which will be located at the WTP Interface Chamber.

## 12.6 Flocculation and Sedimentation

### 12.6.1 Flocculation

#### 12.6.1.1 General

- 1 From the raw water discharge lines, the coagulated water shall be directed to flocculation basins.
- 2 The basins shall be provided with redundancy to ensure operation at full capacity even when one of the process modules or any of its components is turned down for maintenance. The remaining units in service shall be able to accommodate the full capacity.
- 3 Each flocculation tank will periodically have to be isolated for cleaning purposes. Each flocculation tank shall be able to be cleaned independently without the need for any personnel to enter the tank. Flow distribution to the tanks shall be designed such that units may be isolated and taken out of service without disrupting operation and flow distribution to the remaining units.
- 4 Each tank shall have a draining system to enable tank emptying and sludge removal, when necessary. The drain system shall be capable of emptying a tank within 8 hours.
- 5 Flocculation shall be done through the use of hydraulic flocculators, where energy required for mixing shall be achieved through gravity using the available head.
- 6 The contractor shall identify in their design the minimum flow by which their design parameters can be maintained without compromising floc formation.
- 7 Flow meter and level sensors shall be provided at the upstream end to monitor incoming raw water flow and to monitor water level. These signals shall be used to control the gates inlet/outlet gates of the flocculation and sedimentation basins.

#### 12.6.1.2 Performance Requirements

- 1 The inlet and outlet arrangement to the basins shall be designed to prevent destruction of flocs. The inlet and outlet velocity should not be less than 0.15m/s, and not more than 0.45m/s, with a detention time for floc formation of at least 30 minutes.
- 2 The flocculation shall have three (3) stages with the mixing velocity tapered throughout these three (3) stages. The 1st stage shall have the highest mixing intensity, while the 3rd stage shall have the lowest.
- 3 The flocculation shall have the following design parameters:

| PARAMETER | UNIT | VALUE |
|-----------|------|-------|
|-----------|------|-------|

|                                                 |                 |                     |
|-------------------------------------------------|-----------------|---------------------|
| Number of Stages                                | -               | 3                   |
| Type of flocculator                             | -               | Hydraulic (gravity) |
| Maximum mixing intensity<br>(for the 1st stage) | s <sup>-1</sup> | 100.00              |
| Minimum mixing intensity<br>(for the 3rd stage) | s <sup>-1</sup> | 30.00               |
| Total hydraulic retention<br>time (minimum)     | minutes         | 30.00               |

- 4 CFD modelling shall be conducted to demonstrate the probable flow patterns, flow distribution, flow velocities, and mixing performance of the hydraulic flocculators and the proposed dosing point arrangements. This shall be conducted during the outline design stage of the project to incorporate improvements in the developed design prior to proceeding to construction.
- 5 The Contractor shall optimize the physical dimensions, control and arrangement of the dosing arrangements based on feedback from the model test, and then update the model test to verify that the changes appear to have provided optimized performance.

#### 12.6.1.3 Specific Requirements

- 1 PolyDADMAC shall be used as flocculant for the WTP. The contractor shall perform jar testing to identify optimum dose of polyDADmac in relation to their proposed design. An alternative polymer or flocculating agent shall be considered if the contractor can prove that it has the same or better performance compared to polyDADMAC, subject to approval by the Employer.
- 2 The flocculant dosing arrangement shall ensure that flocculant will be properly and evenly distributed among process modules. Dosing lines shall have provisions to allow regular cleaning and to avoid clogging.
- 3 For each process train, the dosing arrangement shall be installed nearest to the 1<sup>st</sup> stage of flocculation.
- 4 The flocculating agent shall be dosed into the coagulated water upon entering the 1st stage of flocculation.
- 5 Isolation of the flocculant dose for each flocculator shall be made possible from the distribution weir box, such that supply to one (1) flocculator can be discontinued at any given time.
- 6 Each dosing arrangement shall be designed such that the flocculant is released throughout the basin width.

- 7 Flocculant dosing pumps shall be VFD driven. The flow of dosed flocculant shall be measured by a suitable flow meter. Rotameters are acceptable for dilution water lines only. Pressure gages shall be fitted to the feed and dilution water lines;
- 8 The flocculant dosing pumps shall be controlled automatically based on the chemical concentration, incoming raw water flow and feedback from the pH, turbidity, particle size and zeta potential analysers, which will be located at the WTP Interface Chamber.
- 9 The contractor shall establish the set points for the flocculating agent dosing through jar tests. These set points shall be adjustable by the operator for flexibility in the WTP's operation.

## 12.6.2 Sedimentation

### 12.6.2.1 General

- 1 Sedimentation basins shall be hydraulically connected to the flocculation basins to allow flocculated water to flow through.
- 2 The remaining units in service shall be able to accommodate the full capacity. Each sedimentation basin will periodically have to be isolated for cleaning purposes. Each basin shall be able to be cleaned independently without the need for any personnel to enter the tank. Flow distribution to the tanks shall be designed such that units may be isolated and taken out of service without disrupting operation and flow distribution to the remaining units.
- 3 Each tank shall have a tank draining system to enable tank emptying and sludge removal, when necessary. The drain system shall be capable of emptying a tank within 8 hours.
- 4 The sedimentation basins shall include an assembly of inclined settlers, either plate or tube type, in each of the tanks.
- 5 The clarified water flowing through the inclined settler assembly shall be collected into launders through adjustable v-notch weirs. The v-notch weirs shall be designed to prevent submergence under all flow conditions.
- 6 After passing through the launders, the clarified water will be collected into a common outlet channel, which leads to the filtration.
- 7 Each sedimentation tank shall be equipped with bottom scrapers to collect sludge from the entire basin. Facilities shall be provided to allow easy and safe access into the area below the settlers for maintenance of the sludge scrapers. Mechanical details of the scraper are provided in Section 13
- 8 Each sedimentation tank shall be installed with a sludge blanket detector to monitor the level of sludge inside the basins.

### 12.6.2.2 Performance Requirements

- 1 The projected area (excluding transition length) of the inclined settler assembly shall be based on a surface loading rate of no more than 1.00 m/h, even in the event of 1 basin being out of service.

- 2 The transition length shall always be subtracted from the plate or tube length in calculating the projected area of the inclined settler. Plan area of the basins occupied by the settlers shall be 50% at minimum and 70% at maximum of the total length of sedimentation basin.
- 3 In addition, the inclined settlers shall have the following design parameters:

| PARAMETER                                                     | UNIT    | VALUE         |
|---------------------------------------------------------------|---------|---------------|
| Inclination Angle                                             | degree  | 55.00 – 60.00 |
| Profile Distance – minimum spacing between settlers           | mm      | 60.00         |
| Minimum Hydraulic Retention Time in inclined settler assembly | minutes | 20.00         |

- 4 The inclined settler assembly shall be able to produce a clarified water turbidity of less than 7.00 NTU based on a raw water turbidity of 125 NTU.
- 5 The clarified water launders shall have the following design parameters:

| PARAMETER                                                             | UNIT                | VALUE       |
|-----------------------------------------------------------------------|---------------------|-------------|
| Launder Weir Loading                                                  | m <sup>3</sup> /m-h | 4.00 – 6.00 |
| Minimum Coverage of Launders (percentage of sedimentation basin area) | %                   | 12.00       |

- 6 The design of the sludge scrapers shall be based on the efficiency of sludge collection and operational cost.
- 7 CFD modelling shall be conducted to demonstrate settlement capacity and sludge removal. The aim of the CFD is to determine if the performance of the settlers will be sufficient and to optimise the flow through the settlers by checking launder positions. The model shall extend from the WTP inlet through to the flocculation to the sedimentation basins and outlet launders.

#### 12.6.2.3 Specific Requirements

- 1 The contractor shall provide all required appurtenances to ensure proper flow distribution from the entrance of the sedimentation basins up to the clarified water launders.
- 2 The inclined settlers shall be made from stainless steel with minimum grade of SS304, PP or PVC.
- 3 Both settler and launder materials shall be UV resistant.

- 4 The contractor shall provide a proper support system for the inclined settler assembly, such that the support structure shall have no adverse effect on flow distribution and sludge scraper operation. In addition support shall not be from the tank walls; to ensure the existing and checked seismic performance is not compromised.
- 5 In designing the support for the assembly, the minimum consideration shall include the load of the inclined settlers, the load of the sludge accumulated in the settlers, the load of the water in the clarified water launders, and the load of a person standing on top of the inclined settlers.
- 6 The area of inclined settlers and launders shall be covered with a high level canopy made from corrosion resistant material, at least 2.4m (at the lowest point of any support structure) above the walkways in the area of the settlers and launders. Canopies are intended to minimize sunlight penetration and therefore limit algal growth.
- 7 The canopy shall have a roof structure and is open at the sides.. The canopy shall be equipped with lighting and lifting equipment. Permanent access is to be provided when accessing the settlers.
- 8 Walkways around the basins shall be not less than 0.80 m wide.
- 9 Sedimentation basins shall be designed with a drain or sump, with minimum bottom slope of 0.5% to no more than 1% for mechanical sludge collection.
- 10 The sedimentation basins shall be designed with flushing and cleaning valves and fittings to facilitate periodic removal of accumulated sludge. All piping and fittings used for sludge shall be fitted with water flushing and air sparge connections.
- 11 The sludge scrapers shall direct all settled sludge into a sludge collection channel at the bottom of the tank.
- 12 The sludge collection line should be sized to based on at least 2.5 hours of maximum sludge production.
- 13 Sludge collected in the sludge collection channel shall be removed from the sedimentation basin using a desludge valve. This desludge valve shall be motorized to allow automatic operations.
- 14 Valves shall be located outside the tank for accessibility.
- 15 The desludging line shall be designed to prevent clogging.
- 16 The contractor shall set the maximum allowable sludge accumulation inside the tanks such that sludge carry over to the clarified water shall be prevented.
- 17 During normal operations, sludge removal for each sedimentation tank shall be for 10 minutes (operator adjustable) in every 2 hours preventing sludge accumulation inside the tanks. This shall be a time based automatic control.
- 18 The set point for the maximum sludge level shall be adjustable by operators for flexibility in WTP operations.
- 19 This duration and frequency shall be automatically adjusted by the control system to prevent buildup of sludge during high turbidity events.



- 20 When the set point for the sludge level is reached, the sludge blanket detector shall trigger a desludge sequence to decrease the sludge level to an allowable limit. This automatic control shall be based on the sludge level.
- 21 Sludge blanket detectors and all other control and monitoring equipment shall be easily removed without the need for complex tools or significant work outside of the handrails of the plant.
- 22 All set points shall be displayed on SCADA and shall be operator adjustable. In the event of an equipment failing to operate the average of other similar instruments shall be automatically used by the control system as an alternative or manual control shall also be possible, based on operator intervention.
- 23 The sedimentation tank outlet shall be provided with pH, turbidity, TSS, chlorine, potassium permanganate, aluminum, iron and manganese analysers. The readings shall be displayed onsite from the instrument as well as on the SCADA system. All interlocks, alarms and trends shall be provided and viewable in the SCADA system.

## **12.7 Filtration**

### **12.7.1 Filters**

#### **12.7.1.1 General**

- 1 Clarified water from the sedimentation basins shall be directed to filters.
- 2 The filters shall be provided with redundancy to ensure operation at full capacity even when one of the units or any of its components is turned down for maintenance. The remaining units in service shall be able to accommodate the full capacity.
- 3 The Contractor shall ensure that the process and hydraulic performance of the filters will be maintained even when two units are turned down (one out of service and one under backwash).
- 4 The Contractor shall ensure that the clarified water flow shall be evenly distributed at uniform velocities to all filters units on duty, even when any of these units is on backwash sequence.
- 5 Each filter unit will periodically have to be isolated for backwashing purposes. Only one unit will be backwashed at a time and shall be able to be cleaned independently without the need for any personnel to enter the tank. Flow distribution to the tanks shall be designed such that units may be isolated and taken out of service without disrupting operation and flow distribution to the remaining units.
- 6 Each tank shall have a tank draining system to enable tank emptying and arrangement for media removal, when necessary. The drain system shall be capable of emptying a tank within 8 hours.
- 7 The design of the filters shall consider dual media, with a top layer of anthracite coal and silica sand at the bottom.
- 8 The filter shall be equipped with the necessary considerations as stated, but are not limited to the following: media support system to prevent media loss, filter media, underdrain system to ensure even distribution of air for scouring and backwashing (sequentially or concurrently) for a more efficient media cleaning.
- 9 Media support using graded gravel shall not be accepted.
- 10 Penstocks or gates shall be motorized to facilitate automatic control and operations of the filters.

#### **12.7.1.2 Performance Requirements**

- 1 Filters shall be designed with a minimum permissible headloss not greater than 2.50 m and a clean bed head-loss of not less than 0.30 m.
- 2 The backwash shall be maintained with a backwash duration of 20 minutes.
- 3 Filter performance tests such as solids retention analysis, bed expansion and core sampling shall meet the acceptance criteria in accordance with recognized international standard or industry practices.
- 4 Media traps shall be provided in the dirty backwash stream to prevent media loss. Media loss shall not exceed 0.25% of media volume per quarter

- 5 Air scouring shall last for a duration of 8 – 15 minutes depending on the contractor's optimized design. It shall be triggered 5 minutes after the backwash has started to ensure that trapped solids are already dislodged from the media.
- 6 Air distribution tests shall be carried out before and after putting in the filter media.
- 7 The Contractor shall demonstrate that the air scouring is optimized, with due consideration to the OPEX.

| PARAMETER                                                                                  | UNIT                              | VALUE              |
|--------------------------------------------------------------------------------------------|-----------------------------------|--------------------|
| Filter Loading Rate                                                                        | m <sup>3</sup> /m <sup>2</sup> -h | 7.50 – 12.00       |
| Filter Run Duration<br>– normal conditions                                                 | Hours                             | 48.00 – 64.00      |
| Filter Run Duration<br>– peak conditions minimum<br>time between backwash of<br>any filter | Hours                             | 24.00              |
| Backwash Rate                                                                              | m <sup>3</sup> /m <sup>2</sup> -h | 55.00              |
| Backwash Duration                                                                          | Minutes                           | 20.00              |
| Air Scour Rate                                                                             | m <sup>3</sup> /m <sup>2</sup> -h | 40.00 – 70.00      |
| Air Scour Duration                                                                         | Minutes                           | 8.00 – 15.00       |
| Minimum Air Scour Units                                                                    | -                                 | 1 duty + 1 standby |
| Maximum Filter Bed<br>Expansion                                                            | %                                 | 30.00              |

- 8 The supply of backwash water shall be designed to provide the required bed expansion at a maximum rate of backwash flow and the flow shall be manually adjustable.
- 9 The Contractor shall ensure that all seals are properly working to prevent contamination of filtered water during backwash cycle.
- 10 The Contractor shall provide a scheme to minimize the effect of the filter start up on the filtered water turbidity and ultimately the product water turbidity.
- 11 The filtration process shall be able to produce the following filtered water turbidity based on the clarified water turbidity with the normal filter run duration.

|                              |                             |      |
|------------------------------|-----------------------------|------|
| CLARIFIED WATER<br>TURBIDITY | FILTERED WATER<br>TURBIDITY | UNIT |
| ≤7.00                        | <2.50                       | NTU  |

- 12 The filter run duration shall be designed to be adjustable, such that a filtered water turbidity of 2.50 NTU can be maintained even if a clarified water turbidity greater than 7.00 NTU is sustained for more than 24 hours.
- 13 The Contractor shall design filter flow distribution such that, with two units out of service, process and hydraulic performance will be maintained and flow will be evenly distributed from the sedimentation basins to the remaining operational units. CFD modelling shall be conducted to demonstrate the probable flow patterns, flow distribution and flow velocities at the filter inlet.

#### 12.7.1.3 Specific Requirements

- 1 Each filter shall be designed complete with motorized inlet, backwash, dirty backwash collection, air scour and motorized outlet.
- 2 A flow meter shall be provided before and after the filters to monitor the total filtered water flow rate for post-chlorine dosing.
- 3 Air blowers shall be equipped with VFD to provide flexibility in operating under various flow patterns and water quality.
- 4 An automatic backwashing system complete with controls and motorized gates and valves shall be provided. Filtered water shall be used for backwash.
- 5 The backwash shall be maintained with a backwash duration of 20 minutes. Filter to waste connections shall be provided for all filters and shall be directed to a backwash recovery system.
- 6 The design shall incorporate facilities to accommodate disinfection of the filter media and the underdrains in times of bacterial growth on the media. The methodology of disinfection shall also be provided by the contractor.
- 7 The DCSs shall be housed in the Electrical Interface Cabinet (EIC) of the proposed control room.
- 8 The filters shall be housed in a building to prevent contamination of the filtered water.
  - (A) Building materials shall be compatible and suitable for chlorine gas exposure.
  - (B) The building shall be designed with proper ventilation for regular operator access. Ventilation should be sufficient to prevent chlorine levels to reach exposure limits and any perceivable sensory irritation to occur.
  - (C) The building shall be provided with a fully automatic alarm for chlorine gas detection beyond exposure limits.
  - (D) The filter area shall be kept sanitary and free from any infestation which may cause for the filtered water to be contaminated.

9 Walkways around the filters shall be not less than 0.80 m wide.

10 Filter Media Requirements:

(A) The filter media shall be designed based on the parameters presented below:

| PARAMETER                                  | UNIT | VALUE       |
|--------------------------------------------|------|-------------|
| Anthracite                                 |      |             |
| Specific Gravity (minimum)                 | -    | 1.60        |
| Minimum Depth                              | m    | 1.00        |
| Effective Size                             | mm   | 0.90 – 1.10 |
| Uniformity Coefficient                     | -    | 1.50        |
| Hardness (Mohs Scale)                      | -    | 3.00        |
| Minimum Carbon Content (dry weight basis)  | %    | 80.00       |
| Maximum Ash Content (dry weight basis)     | %    | 15.00       |
| Maximum Volatile Matter (dry weight basis) | %    | 7.00        |
| Maximum Acid Solubility                    | %    | 5.00        |
| Silica Sand                                |      |             |
| Specific Gravity                           | -    | 2.50 – 2.80 |
| Minimum Depth                              | m    | 0.50        |
| Effective Size                             | mm   | 0.45 – 0.55 |
| Uniformity Coefficient                     | -    | 1.30        |
| Maximum Acid Solubility                    | %    | 5.00        |

(B) A test report on the media shall be provided prior to delivery of the media to site. The testing shall be carried out by an independent third party approved by the Employer.

- (C) The test report shall also include the washability characteristic of anthracite coal tested by ASTM D4371, passing the following qualifications:
  - (i) Not more than 3% float when placed in a fluid of 1.45 specific gravity
  - (ii) Not more than 3% sink when placed in a fluid of 1.95 specific gravity
- (D) The filter media, both anthracite coal and silica sand, shall essentially be free of iron, sulfide, clay, shale, extraneous dirt and shall be in accordance with AWWA B100-01.
- (E) Upon delivery, a random sample of the all media types is to be taken witnessed by the employer's representative. A sieve analysis shall be carried out to ensure compliance with the typical sieve analysis data provided as part of the design and procurement submissions. The Contractor shall be responsible for all costs associated with the testing.
- (F) A methodology detailing the process of media replacement shall be provided by the contractor from the media supplier.
- (G) The placement of the media in the filter beds shall be under the supervision of the contractor.
- (H) A representative of the filter media supplier shall witness the installation, noting any deviation from their provided instructions or any irregular events occurring during installation.
- (I) The specification of media retention or media support shall be consistent with the recommendations of the underdrain manufacturer.
- (J) The filtrate underdrain system shall efficiently collect filtered water. The under-drain shall be designed to handle both the air and water backwashing system. An air release valve to the under-drain system shall be provided on the highest point of each filter.
- (K) The under drain system shall be of a proven commercially available type and shall incorporate media retention or media support. The system shall be capable of accepting the provision of air scour connections and shall be designed to ensure equal distribution of air and wash-water and collection of filtered water under all operational configurations. Nozzles for filter under-drains will not be accepted.
- (L) If a proprietary technology shall be used as media retention or media support component, it shall be able to retain the minimum particle size of 0.45 mm. It shall be factory tested for hydraulic loading and head loss.
- (M) As a minimum, the media support manufacturer shall be required to have an ANSI/NSF, or equivalent international certification to prove that the support material is nontoxic and suitable for drinking water applications.
- (N) The media support shall be easy to install and removable.

- (O) The media support shall provide uniform flow distribution throughout the cover area considering the flow of filtered water, backwash water flow, and air for scouring (in sequence and concurrent with the backwash water flow).
- 11 A filter control room shall be provided in such a position that the operator has a full and unobstructed view of all filters and its operation.
- 12 Each filter shall be provided with level transmitters and level switches, position indicating transmitter for the all gates/valves, differential pressure sensors for backwash control and turbidity analysers. The filter outlet shall be provided with pH, TSS, potassium permanganate, chlorine, iron and manganese analysers. The readings shall be displayed onsite from the instrument as well as on the SCADA system. All interlocks, alarms and trends shall be provided and viewable in the SCADA system.
- 13 The automatic control of the filter operation shall include the following:
  - (A) Time based control
    - (i) The filters shall be subject to a backwash cycle once the filter run duration has been reached. This shall be the basic automatic control of the filters.
    - (ii) It is the Contractor's responsibility to verify that the filter run duration shall correspond to the design solids loading of the filters.
  - (B) Level based control
    - (i) A level transmitter shall be placed in each filter the position of which shall depend on the contractor's design. This level transmitter shall facilitate the automatic backwash for the level based control.
    - (ii) The Contractor shall prove and verify that the design solids loading shall correspond to an increase in the water level in the filters.
    - (iii) Each filter shall be verified individually. The average of all this verification shall be used as the set point for the level control provided that the data is statistical acceptable.
    - (iv) The level based control shall be able to overwrite the time based control.
  - (C) Filtered water turbidity based control

- (i) On-line continuous read turbidity meters should be provided for all filters. The readout should be data-logged continuously and be connected to the SCADA system.
  - (ii) The turbidity meter shall be installed at the filtered water outlet of each filter. This shall monitor the filtered water turbidity of each filter at all times.
  - (iii) Once the filtered water turbidity has fallen above the 2.50 NTU limit, the filter shall be subject to a normal backwash sequence.
  - (iv) It is understood that the filtered water quality might fall above the 2.50 NTU limit during the 1st hour of filter run. This duration shall be an exemption to this automatic backwash control. The overall performance of the plant and all units in service shall ensure that the treated water quality achieves less than 2.50 NTU at all times in normal conditions.
  - (v) The filtered water turbidity based control shall be able to override the time based and level based control.
- (D) Backwash turbidity based control
- (i) On-line continuous read turbidity meters should be provided for all filters. The readout should be data-logged continuously and be connected to the SCADA system.
  - (ii) The turbidity meter shall be installed at the common outlet channel of the backwash water to monitor the backwash turbidity during a backwash sequence.
  - (iii) This turbidity meter shall control the duration of the backwash cycle.
  - (iv) The backwash cycle shall be stopped once the pre-set duration is reached or once the backwash water turbidity becomes consistent. The set point shall be identified by the contractor, and verified during commissioning. It shall also be adjustable by the operator for future changes in WTP operations.
  - (v) The backwash water turbidity shall overwrite the termination of the backwash cycle if the turbidity reading becomes consistent more than halfway through the backwash cycle (>10 minutes).
- (E) Differential pressure based control
- (i) A differential pressure transmitter shall be installed in each filter and continuously measure the total headloss across the filter media.
  - (ii) If the headloss exceeds a pre-set trip level for a pre-set time, the filter shall be placed in the backwash sequence and a 'headloss' status is flagged at the main HMI and SCADA.

## 12.7.2 Backwash Tanks

### 12.7.2.1 General

- 1 Dirty backwash water from filter cleaning shall be directed to backwash tanks.



- 2 At least two backwash tanks shall be provided. Each backwash tank shall be sized for one backwash cycle.
- 3 Each tank shall be provided with, as a minimum, level detection, sludge blanket level detection, inlet volume measurement, each outlet volume measurement and outlet dry solid measurement.

#### 12.7.2.2 Performance Requirements

- 1 The tank shall be able, as a minimum, to concentrate the solids content from 0.01% to at least 0.50%.

#### 12.7.2.3 Specific Requirements

- 1 The design and operation of these tanks shall assume a batch operation associated with a time based operation of the filters. The configuration shall match the Contractor's process design. The design shall allow for distinct periods of fill, settle and drain.
- 2 The sludge will be pumped to the sludge tank for further treatment and the supernatant will be directed to the recovered water tank.

### 12.8 Chlorination

#### 12.8.1 General

- 12.8.1.1 The Contractor shall supply and install all equipment necessary for disinfection using chlorine gas, and shall provide a disinfection system that will be used to kill off pathogenic microorganisms.
- 12.8.1.2 Chlorination shall be done in 3 stages: pre-chlorination prior to coagulation to inhibit aquatic growth, intermediate chlorination after sedimentation to replenish used up chlorine as needed and post-chlorination after filtration to maintain a detectable chlorine residual through out the distribution system.
- 12.8.1.3 The Contractor shall design and construct a fully automatic chlorination system to meet the disinfection and residual chlorine requirements of the Employer. Chlorination system shall be compatible with cylinders from different manufacturers. Equipment that is compatible to only one cylinder manufacturer is not acceptable.
- 12.8.1.4 The Contractor shall provide fully automatic facilities for dosing and storing liquefied chlorine gas in cylinder form, as well as chlorine gas detection, collection and treatment, scrubber system, lifting and safe handling.
- 12.8.1.5 Chlorine cylinders shall be of 1- ton capacity.

#### 12.8.2 Performance Requirements

- 12.8.2.1 The Contractor shall dose chlorine at the following rates:

| CHLORINATION STAGE | UNIT | VALUE       |
|--------------------|------|-------------|
| Pre-chlorination   | mg/L | 0.50 – 2.00 |

|                           |      |             |
|---------------------------|------|-------------|
| Intermediate chlorination | mg/L | 0.50 – 1.00 |
| Post-chlorination         | mg/L | 1.00 – 2.00 |

### 12.8.3 Specific Requirements

12.8.3.1 The Contractor shall provide a storage area capable of handling at least 30 days' requirement of chlorine.

12.8.3.2 The materials of construction shall be suitable for chlorine gas applications. Refer to Section 13 for guidelines on chlorine piping.

#### 1 Plant Configuration and Layout

- (A) Chlorine gas dosing area, chlorine gas cylinders storage room, and associated electrical rooms shall be constructed in separate rooms to ensure safety at all times and in cases where there is a presence of chlorine gas.
- (B) No interconnecting doors or access will be given in between rooms and only external access shall be provided. A window shall be provided to permit the operator to view the storage and feed rooms without entering.
- (C) External access provided should be designed such that personnel can exit quickly under emergency conditions. Doors for external access shall open outward equipped with panic hardware and lead outside to an unobstructed area.
- (D) Interior rooms shall be of fire-resistant construction and isolated from other areas of the plant. Storage room should be located away from heat sources, flammable substances and other compressed gasses.
- (E) Storage room shall be in a cool and well-ventilated area. The cylinders should be kept in temperatures below 40°C and should not be exposed to direct heat or sunlight.
- (F) Sufficient space and clearance is provided for storage and handling of duty and standby gas cylinders. Space should be allowed for at least two equal groups of containers (alternating service and reserve) plus unoccupied space for one container to help ease of operation.
- (G) The system shall come complete with chlorine consumption indicators which will enable the operator to identify when to switch over from containers in service to those in reserve. Chlorine gas cylinders equipped with vacuum regulators and rotameters shall be provided, positioned and stored vertically in the storage rooms during feeding.
- (H) Gas cylinders sack truck, restraint chains/clamps and guard rails shall be provided to secure the cylinders and protect them from falling and rolling. Chlorine cylinders shall be stored separately and secured to prevent damage to the cylinders and container transport equipment shall be used. The cylinders shall be handled with an appropriate lifting and transport equipment.

- (I) Electronic platform weighing scale shall be provided for each duty and standby gas cylinders to measure the amount of chlorine in the container. The scale shall be used to monitor chlorine usage and indicate when the container is empty. Digital scale readings in kilograms shall be wall mounted adjacent to each gas cylinder.
- (J) Weighing scale readings shall be viewable on the SCADA workstation/control system for verification of chlorine dosing calculations.
- (K) Sufficient access and pathways shall be provided for ease of operation, maintenance as well as movements during emergency scenarios where the operator is equipped with breathing apparatus.
- (L) Due considerations shall be given by the Contractor to the storage and feed room heating requirements to ensure the room environment does not allow green ice or chlorine hydrate to form which can clog the ejector (injector) and gas piping, creating maintenance problems.
- (M) Pipe labelling and color coding shall comply with the MWCI SES 2 and PSME code on color identification of pipe systems.
- (N) The Chlorination building shall be provided with a fire protection system compliant to the local Building Code, Fire Code and other relevant statutory requirements. The fire protection system construction and equipment materials shall be compatible and suitable for chlorine gas exposure.
- (O) The Chlorination Building shall be provided with a safe room, completely gas leak proof, air contained and with dedicated air handling - for the security of the operators.
- (P) A wind direction indicator shall be provided in the form of an orange wind sock for the operators to identify the direction of the wind. The indicator shall be installed in a clearly visible location within the plant and can viewed clearly from the Control Room.
- (Q) A wind measurement device shall be provided to measure wind speeds. Wind speed readings shall be viewable in the SCADA workstations/control system.

## 2 Chlorine Gas Dosing

- (A) An iterative control feedback loop based on residual free chlorine shall be required, complete with low and high alarms. Two (2) control feedback loop shall be provided and based on the following principles:

- (i) Flow proportional wherein the chlorinator feed rate shall be automatically adjusted proportional to a treated water flow signal and will maintain a constant chlorine feed rate proportional to the metered flow.
  - (ii) Based on residual free chlorine readings wherein the chlorinator feed rate is automatically adjusted proportional to a measured chlorine residual signal. By varying the chlorine feed rate, a constant chlorine residual is maintained.
- (B) All required instruments such as Flow Transmitters and online Residual Free Chlorine analyser shall be provided. Residual chlorine online analysers shall be provided at the reservoir. At the location of the Residual Free Chlorine analyser, a manual sampling point with isolation valves shall be provided to allow desktop laboratory analysis to be compared with the residual chlorine analyser readings.
- (C) Residual chlorine analysers shall be capable of providing accurate readings by itself. If electrode method is used, the residual chlorine sensor shall have a dedicated pH sensor bundled for correlation of the chloride and hypochlorous ions.
- (D) A minimum contact time (CT) of 30 minutes for liquid chlorine disinfection shall be considered in the design. This shall be provided in the treated water reservoir.
- (E) Automatic switching of chlorine gas duty and standby cylinders shall be provided. Automatic changeover shall take place when the duty container(s) reaches the minimum residual chlorine gas pressure, as detected by the vacuum regulator.
- (F) The pre-chlorination dosing point shall be located before coagulation. Post-chlorination after the filters shall be provided for attain the residual chlorine requirement at the distribution. Intermediate chlorination dosing point shall be provided after the sedimentation basin for operational flexibility.
- (G) Chlorine gas dosing lines shall be equipped with an ejector, a retractable injection quill for dispersal of the gas into the centre of the pipeline and isolation valves.

### 3 Chlorine Gas Collection and Treatment

- (A) Leaks can occur anywhere in the pressurised supply, including connections and piping joints, cylinders or containers and feed equipment; therefore sufficient ventilation shall be provided for each room in the Chlorination Building. The ventilation system shall be designed, such that in the event of chlorine gas leak, gas is properly contained and the minimum amount of gas escapes from the building.
- (B) The chlorination building shall be provided with a fully automatic chlorine gas detection, alarm and scrubber system. The scrubber control system must be fully aligned with the building's ventilation system such that in the event of a chlorine gas leak any ventilation fans or openings shall be in a closed state and all gas is extracted by the scrubber system until such time that an acceptable air quality inside the building has been recovered.

- (C) The chlorine detection and scrubber system shall include all ducting works, extraction fans, gas detectors, pumps, electrical panels internal and external components for a fully operational system. Materials of construction shall be corrosion resistant and suitable for chlorine gas applications.
- (D) The gas detectors shall detect chlorine leaks at chlorine levels of 1 mg/l or less. A minimum of two (2) detectors shall be provided in each storage and feed rooms. The detectors shall be located at the floor level. All required alarms shall be provided and viewable in the SCADA workstation/control system.
- (E) The gas detection system shall be fully equipped with gas alarms, which shall comprise at least two independent systems. Internal and external audio and internal and external visual alarms shall be provided. During normal operation systems shall display 'healthy' signals. If one system fails or different readings are found from the two different systems then a 'warning' signal, indicating no entry to the facility, shall be displayed. If high readings are seen, then 'alarms' shall be displayed and raised to the control room.
- (F) In the event that either of the systems fails then the external visual alarm shall be set to display a 'warning' signal and that entry should not be made.
- (G) In the event of a chlorine gas leak, fresh air from outside shall be introduced at the top of the rooms. Gas extraction points and/or openings shall be located near the floor to achieve proper gas extraction since chlorine is heavier than air.
- (H) In the event that either of the systems fails then the external visual alarm shall be set to display a 'warning' signal and that entry should not be made. The Contractor shall be required to define the distinct boundary limit in their layout where entry should not be made.
- (I) Materials of construction of non-process equipment (CCTV, PA system, lights, others) within the chlorination room shall be able to withstand chlorine leaks.

#### 4 Safety Provisions and Equipment

- (A) At least two (2) complete sets of each type of chemical hazard equipment stated below shall be provided by the Contractor to allow suitably trained operators to enter the facility in the event of an alarm.

- (i) Canister type gas mask with a full-face piece which shall only be used for short exposures and for chlorine gas concentrations of less than 1%.
- (ii) Self-contained breathing apparatus (SCBA) with (2) spare cylinders each, which shall be used for longer exposures and higher chlorine concentrations.
- (iii) Protective clothing including safety eyewear and chemical-resistant, boots, impervious gloves.
- (iv) First Aid Boxes
- (v) Chlorine gas leak kit approved by Chlorine Institute
- (vi) Personal chlorine gas detectors
- (B) All safety equipment mentioned above shall be stored close to, but not within, the Chlorination Building. Suitable storage and changing areas shall be provided as part of this contract.
- (C) Emergency showers and eye-wash stations with sufficient pressures shall be provided. These shall contain their own potable water break tank/supply tank. Safety showers and eye wash stations shall be located close to the Chlorination building. The shower shall be equipped such that, if operated, a high priority alarm is sent to the control room so that operators can attend to assist. In addition, audio and visual alarms shall be raised locally to alert others in the area of an incident.
- (D) Safety signages shall be provided for the entire Chlorination Building.
- (E) A container emergency kit shall be provided to counteract leaks that may occur in the container valve, the fusible plug, or the container itself.

## 5 Emergency Plan

- (A) The Contractor shall submit a Chlorine Gas Leak Emergency Response Plan that is included in the Construction Health and Safety Plan (refer to Section 3.7) and provide all necessary and relevant emergency procedures and trainings to the Employer during the Commissioning Stage.
- (B) The Emergency Plan shall include chlorine leak response procedures in terms of containment and clean-up, equipment to be used, emergency measures and risk management plans as a minimum. The Emergency Plan must be submitted for formal review and acceptance of the Employer and Engineer prior to HAZOP.
- (C) The accepted Emergency Plan must be in place one (1) week before the start of commissioning tests.

## 12.9 Contact Tank and Treated Water Reservoir

### 12.9.1 General

- 12.9.1.1 The treated water reservoir within the WTP shall be constructed to have a minimum capacity of 48 ML.

- 12.9.1.2 A minimum contact time (CT) for liquid chlorine disinfection shall be 30 minutes. This shall be provided in the treated water reservoir. The reservoir shall be designed such that the expected treated water quality requirements for free chlorine residual and absence of coliforms are met.
- 12.9.1.3 The contact tank and treated water reservoir shall be designed with at least two (2) compartments of equal volume to allow for cleaning and maintenance of one compartment while the other one remains in service. Each shall be able to be cleaned independently without the need for any personnel to enter the reservoir.
- 12.9.1.4 The contact tank and treated water reservoir shall have draining system to enable tank emptying, when necessary. The drain system shall be capable of emptying a tank within 8 hours.
- 12.9.1.5 The Contractor shall provide chlorine residual analysers to continuously measure free chlorine in the water after contact prior to distribution. The analysers shall be reagent free. The analysers shall record data and should be integrated to the SCADA system.
- 12.9.1.6 Tanks shall be designed to operate with a constant volume by the use of a level control weir to maintain water level.
- 12.9.1.7 The contact tank and treated water reservoir shall be arranged hydraulically to prevent flooding and shall be provided with suitably sized overflows and interlocks for the prevention of flooding or overflow.
- 12.9.1.8 Emergency over flow from the reservoir shall discharge to Yapak creek. The Contractor shall conduct an assessment if the existing natural creek could accommodate the possible overflow and discharge from the RWTL and WTP structures. Improvement or re-alignment of the creek shall be under the responsibility of the Contractor.
- 12.9.1.9 Both tanks shall be covered and fully watertight to prevent the ingress of rain or ground water and shall be fitted with sufficient ventilated covers and secure, stainless steel man-access hatches with ladders. The design shall be in accordance to MWCI SES 11.17
- 12.9.1.10 The reservoir design shall include an overflow feature, and discharge outlets provisions going to Antipolo Line (AL) and Long Term East Line (LTE). The invert level of the stub-outs in the reservoir shall not be deeper than 84.5m for both AL and LTE. It shall be the Contractor's responsibility to design the reservoir in such manner that will deliver the stub-out elevation required by the treated water pumping station. The Contractor shall also provide the necessary installation of blinds, isolation valves, fittings and bypass provisions as part of the interconnection design for each discharge line (refer to Section 4.11.2.3). The Contractor shall provide the stainless steel pipe stub outs with a minimum length of 2m and diameter of 3.2m for the LTE and 1.6m for the AL. However, the pipework going the treated water pumping station and distribution network are excluded from the Contractor's scope.
- 12.9.1.11 The tank shall be used as a tapping point for any treated water sampling. Sufficient facilities shall be provided in this tank to serve the purpose of safe and convenient sampling for operators.

### 12.9.2 Performance Requirements

- 12.9.2.1 The contact tank shall be designed to produce chlorinated water with a minimum of 30 minutes bulk residence time at maximum design flow. The contact tank shall be designed to give true plug flow characteristics with a maximum plug flow factor of 0.60 to ensure that all filtered water inside the WTP reservoir is fully chlorinated and meets the target free chlorine residual between 0.90 to 1.50 mg/l at all flows.
- 12.9.2.2 All materials that will come into contact with the treated/drinking water supply shall be corrosion resistant and NSF/ANSI/CAN 61 certified.
- 12.9.2.3 CFD modelling shall be conducted during outline design to demonstrate that adequate contact and uniform plug flow will be achieved by the proposed design. As for the reservoir, CFD modelling shall be used to demonstrate no stagnation, thermal stratification, and dead zones are observed in any of the simulated cases. As the method of distribution differs for AL and LTEL, efficient distribution of flow to AL (pumped via the treated water pumping station) and LTEL (by gravity) shall be demonstrated in order to prevent vortexing and uneven flow distribution.
- 12.9.2.4 Chlorine decay analysis shall be conducted further along AL transmission line until the Boso-Boso reservoir outlet to ensure residual chlorine levels are within limits specified in Section 11.4. Chlorine dosing rates shall be reviewed and adjusted based on the results of the analysis, duly reflected in the outline design.

### 12.9.3 Specific Requirements

- 12.9.3.1 Adequate mixing and circulation shall be maintained inside the reservoir to eliminate dead zones, thermal stratification and promote efficient chlorination. Baffles shall be provided as a minimum. A minimum of 0.50 baffling factor shall be provided in the reservoir. The Contractor shall conduct tracer study to determine the accurate baffling factor, if deemed necessary based on site-specific conditions.
- 12.9.3.2 Level transmitters shall be provided at the reservoir for controlling the treated water outlets' opening and closing. The treated water reservoir shall be provided with pH, turbidity, TSS, chlorine, aluminum, iron and manganese analysers. The readings shall be displayed onsite from the instrument as well as on the SCADA system. All interlocks, alarms and trends shall be provided and viewable in the SCADA system. The Contractor's design shall ensure that connection provisions are in place for the treated water pumping station (scope by others) to be able to fetch information from the reservoir's level transmitters and from the SCADA system.
- 12.9.3.3 All reservoir appurtenances should be designed to be water tight. These appurtenances must be designed to prevent entry by birds, animals, insects, excessive dust, and other potential sources of external contamination.

## 12.10 Sludge Treatment and Disposal

### 12.10.1 General



- 12.10.1.1 Sludge generated from the treatment process shall be further processed for final disposal.
- 12.10.1.2 For the design of the sludge treatment facility, the following streams shall be considered:
- 1 Backwash water from filtration
  - 2 Sludge from sedimentation basins
- 12.10.1.3 The Contractor shall be responsible for estimating the sludge produced from the WTP based on the specified range of raw water quality. The sludge production estimate shall be based on the following guidelines:
- 1 Sludge estimate shall be based on the inherent solids with the raw water, raw water turbidity, coagulant dose, and flocculating agent (polymer).
  - 2 The sedimentation process shall be designed to remove majority of the solids / sludge estimate.
  - 3 The filtration process shall only accommodate the solids not removed from sedimentation. The filters shall operate at a constant solids loading throughout its run time duration.
- 12.10.1.4 Number and size of equipment and tanks shall be based on the expected minimum, average and peak operating conditions.
- 12.10.1.5 The sludge processing shall include the following features complete with all associated civil, structural, mechanical, electrical and control infrastructure:
- 1 Sludge conveyance from the sedimentation basins and filter backwash tanks to the sludge holding tank/s;
  - 2 Sludge reception;
  - 3 Sludge holding and mixing such that homogenous feed of sludge is achieved;
  - 4 Fully automatic polymer storage, preparation and dosing;
  - 5 Sludge feed pumping facilities of stored sludge to sludge thickener and dewatering units;
  - 6 Sludge cake handling and storage.
- 12.10.1.6 The sludge equipment shall be selected based on the following features:
- 1 Compact arrangement
  - 2 Energy efficient
  - 3 Low polymer consumption
  - 4 Low operator attention
- 12.10.1.7 A sludge tank shall be provided which shall receive sludge from the sedimentation basins and filter backwash tanks.

12.10.1.8 The tank shall be of sufficient capacity to provide a sufficient quantity of sludge to be available for further treatment and storage of sludge during non-dewatering periods.

12.10.1.9 The sludge tank shall be designed with at least two (2) compartments to allow for cleaning and maintenance of one compartment while the other one remains in service. Each shall be able to be cleaned independently without the need for any personnel to enter the tank.

12.10.1.10 The sludge tank shall have draining system to enable tank emptying and sludge removal, when necessary. The drain system shall be capable of emptying a tank within 8 hours

12.10.1.11 Mixing arrangements shall be included within each tank for sludge blending to allow a consistent quality of sludge for treatment. Equipment that are exposed to sludge shall be made of SS 316.

12.10.1.12 Sludge tanks shall be equipped with level transmitters.

12.10.1.13 The Contractor shall demonstrate that the proposed equipment has a proven track record (more than three (3) years successful operation) at similar WTPs.

12.10.1.14 A minimum of two (2) duty and one (1) standby units of the sludge treatment units shall be provided.

## 12.10.2 Sludge Thickening and Dewatering

### 12.10.2.1 General Requirements

- 1 Mechanical thickeners such as gravity belt thickener, decanter centrifuge, or multi-disc screw press shall be used for thickening. Dewatering equipment may be selected between belt filter press and filter press. Use of other technologies or integrated thickening and dewatering units shall only be employed upon the approval of the Employer.
- 2 Pumped feed sludge to the sludge thickening and dewatering systems shall be the stored sludge from an upstream sludge storage system
- 3 All sludge tanks shall be equipped with mixers which shall be able to ensure a homogenous feed of sludge to the thickening and dewatering units.
- 4 Materials of construction shall be suitable for the corrosion environment in water treatment plants.
- 5 Facilities shall include all necessary sludge feed and transfer pumps, filtrate drainage, and polymer solution make-up, dosing and mixing facilities.
- 6 Sludge feed pipe shall be provided with a bypass line prior to reaching the dewatering units. This shall enable reliability equipment to used (geotextile bags, etc.) as needed.

### 12.10.2.2 Performance Requirements

- 1 Average conditions shall be times where the turbidity of the inlet water to the treatment plant is at 60 NTU or less. In average conditions, there shall be at least one standby dewatering unit available at all times.
- 2 Peak conditions shall be times where the turbidity of the inlet water to the treatment plant is above 60 NTU. In peak conditions the standby unit shall be utilized to maximise the throughput volumes.
- 3 As a minimum, the thickener shall be capable of treating feed sludge with 0.50 to 1.00% solids content.
- 4 Thickened sludge shall have a minimum of 2.00% dry solids content by weight in the outlet sludge.
- 5 Dewatered sludge shall be no less than 18% dry solids content by weight. The design of the sludge dewatering and polymer dosing system shall consider a target dry solids content of 18-25%.
- 6 Minimum solids capture rate for thickeners shall be 90% and 95% for dewatering units.
- 7 Dewatering equipment shall be operated automatically and capable of dewatering sludge on solids capture rate 16hours a day and 7days a week schedule. The design shall incorporate flexibility to operate in batch mode if incoming solids concentration is too low.
- 8 The Contractor shall provide CFD analysis to demonstrate that sludge tanks' mixing system is capable of fully utilizing the entire tank content and providing the required mixing energy to achieve the fully mixed state.

#### 12.10.2.3 Specific Requirements

- 1 Each belt filter press shall consist of a dedicated inline polymer dosing system for sludge conditioning.
- 2 Filtrate shall be directed to a recovery system and recycled back to the plant inlet.
- 3 Filtrate flow and solids monitoring shall also be provided such that solids loading to return to the plant inlet can be calculated.
- 4 The capacity of each unit shall be such that when one is taken out service for inspection and maintenance, the total plant capacity is not reduced.
- 5 The sludge thickening and dewatering facilities shall be designed such that the whole system is fully automated from the thickening and dewatering processes to continuous transfer of dewatered sludge cake to storage and transfer/hauling of stored sludge cake to disposal trucks.
- 6 The sludge thickening and dewatering facilities shall be elevated above cake conveyance system to allow automatic conveyance of dewatered sludge from the dewatering units to the sludge cake storage provided.
- 7 The level of redundancy of N+1 shall apply for each stream of sludge treatment facility. In this regard, one standby (1) sludge thickening and dewatering stream shall include one (1) feed pump and one (1) thickening and dewatering unit together with its connection pipework and associated ancillaries instead of single equipment item.
- 8 A washing system shall be provided for washing down the units.
- 9 Bunding provision shall be included around discharge points to contain all sludge spillages. The spillage shall be drained to the plant drainage.

- 10 Each unit shall be designed and constructed in such a way as to provide maximum protection for operators against injury by moving machinery, and harm to health from the bio-hazards present in air borne particles from sprays containing sludge.
- 11 The enclosure panels shall be easily removable by operators to allow full access for inspection and cleaning purposes. It shall be possible to operate the machine with the enclosure panels removed.
- 12 Sludge withdrawal from the process shall be periodic and conducted with enough flexibility to operationally deal with potential blockages in transfer lines. Operator adjustable interface is preferred.
- 13 Each unit shall have dedicated sampling points for feed and filtrate. Sampling points for the thickened and dewatered product shall also be provided.
- 14 The Contractor shall determine the number of trucks required per day for sludge disposal and shall propose corresponding sludge storage and out loading system, as well as a sludge transportation plant that shall be included in the Sludge Management Plan. The Sludge Management Plan shall be included in the Commissioning Plan of the Contractor.
- 15 The Contractor shall provide automatic sludge cake weighing system, automatic truck monitoring system, measure weight in and out with logging system, linked with the SCADA system.
- 16 Sludge balancing or blending tanks shall be provided as required in the Contractor's design. If integrated thickening and dewatering units are used, the upstream feed sludge holding tank/s as described in Sub-Clause 12.10.2.1 item 2, shall be sized to accommodate non-dewatering periods.
- 17 All solids or precipitates generated from upstream chemical dosing reactions and/or activities shall be considered in the design.

#### 12.10.3 Sludge Pumping and Conveyance

12.10.3.1 Sludge pumping systems shall be carefully designed and selected to avoid pulsation effects and gas entrainment. Screw impeller pumps, or positive displacement progressive cavity pumps shall be selected for thickened sludge pumping. Refer to MWCI SES 7 for more specific requirements.

12.10.3.2 Sludge and filtrate piping shall be designed to minimize struvite and solids deposition with provision for cleaning. Redundancy shall be provided to facilitate pipe cleaning and replacement. For long piping, adequate flushing point shall be provided. Sharp bends and other fittings that might cause cavitation/stripping are to be avoided.

12.10.3.3 The sludge pipework and pumping system shall be designed in a way to prevent operational problems related to caking of the sludge.

12.10.3.4 All sludge pumping systems shall be equipped with flow meters and solids analyser.

12.10.3.5 The use of air lift pumps for sludge extraction/transfer is unacceptable.

#### 12.10.4 Polymer Preparation and Dosing

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- 12.10.4.1 A polymer make-up and dosing system is required for the sludge treatment system. It shall be the Contractor's responsibility to determine the best point or points of chemical addition.
- 12.10.4.2 The polymer make-up and dosing system shall be fully automatic in operation, including polymer storage, bag handling (if required), and polymer feed, preparation and dosing. The system shall include a polymer preparation tank and a polymer storage tank. Each tank shall incorporate a cover top mounted mixer. The covers shall be removable for inspection. The tanks and mixers shall be equipped with the corrosion protection. The mixer blade and shaft shall be SS 316L.
- 12.10.4.3 The tanks shall be provided with level gauges of the sight glass type, level indicators/transmitters for analogue level and level switches for alarms and dosing pump trip.
- 12.10.4.4 The mixing equipment for polymer preparation mixing shall achieve homogenous mixing and shall be designed with a sufficient velocity gradient (G) of at least 30/s or 15 W/m<sup>3</sup>.
- 12.10.4.5 Polymer solution shall be prepared and dosed to the sludge prior to dewatering to aid the dewatering process. The average and 90th percentile polymer dose shall be nominated by the Contractor. A minimum polymer solution of 0.20 %w/v and minimum polymer dosage of 2.00 g/kg DS shall be considered in the design.
- 12.10.4.6 Polymer solution shall be prepared from either a powder or liquid polymer concentrate and delivered to the dosing point via dosing pumps. Unless otherwise agreed with the Employer, powder polymer shall be used.
- 12.10.4.7 Polymer selection: Jar or pilot testing shall be carried out to select the polymer type suitable for the dewatering process based on the feed and target sludge water contents and solids recovery rate.
- 12.10.4.8 Polymer make-up and dosing equipment shall be located within a bunded area with minimum 300 mm high bund wall to contain spillage. Design of the bund wall shall ensure no overflow or spillage from the tank in case of leak. The bund area shall be easy to clean and connected to a permanent drainage system. A grating platform shall be provided and built within the bunded area to prevent slippage.
- 12.10.4.9 The requirements for make-up tank for powdered polymer are as follows as a minimum:
- 1 Polymer make-up shall be fully automatic. Diluted solution needs to be matured before application. The diluted polymer may require further dilution (e.g. in-line dilution with treated water) to ensure good contact with the sludge solids when mixed;
  - 2 Multiple tanks shall be installed to allow continuous dosing to the dewatering equipment;
  - 3 Corrosion resistant;
  - 4 Potable water shall be used for batch make-up; and

- 5 The polymer make up unit shall be sized based on the number of operating hours specified as a minimum and based on 24 hours' continuous operation as a maximum. Peak flow/load shall be taken into account when sizing the polymer make up unit.

12.10.4.10 The requirements for polymer pumps are as follows as a minimum:

- 1 Polymer transfer and dosing pumps shall be VFD driven;
- 2 Polymer dosing pump type shall be in accordance with SES 13.16.
- 3 Each dewatering machine shall have an individual polymer dosing pump;
- 4 Automatically controlled;
- 5 The dosing rate of the polymer shall be sludge flow proportional controlled;
- 6 The flow of polymer into each dewatering unit shall be measured by a suitable flow meter. Rotameters are acceptable for dilution water lines only. Pressure gages shall be fitted to the polymer feed and dilution water lines;
- 7 The measurements signals from the flow meters including all necessary instruments for automatic operation and monitoring for polymer dosing shall be transmitted to a SCADA system;
- 8 Mixing shall be provided at the polymer dosing points. Inline mixers shall be considered for inline mixing. The inline mixers shall be easily disassembled and have union couplings to allow removal for regular cleaning. There shall be a non-return valve prior to the dosing annulus to prevent sludge from blocking the dosing pipes.
- 9 Pumps shall be located above the bund, such that they will not become flooded.
- 10 At least one (1) duty and one (1) standby unit shall be provided for each polymer preparation unit.

12.10.4.11 The requirements for polymer storage room are as follows as a minimum:

- 1 Moisture-proof storage facility shall be designed according to the chemical storage requirement at peak flow/load. The storage area shall be kept dry by dehumidifiers and with suitable temperature to prevent chemical from clogging;
- 2 Provision shall be taken to prevent fly-off of powder polymer during unloading and chemical make-up operations;
- 3 Provision of non-slipping floors shall be made within the room;
- 4 Large enough to store chemicals for 30-day average use and 14-day 90<sup>th</sup> percentile use;
- 5 Located inside or adjacent to the same building containing the chemicals injection equipment for more convenient carrying in and out; and
- 6 Suitable lifting equipment shall be provided to easily remove bags of polymer from the delivery vehicle to the storage area to the dosing point.
- 7 Means of transporting the chemical from drums or bag to the hopper without the need for manual lifting.

12.10.5 Sludge Cake Handling, Storage and Disposal

- 12.10.5.1 Sludge cake handling system shall match the maximum capacity of the dewatering plant.
- 12.10.5.2 Cake storage for at least five (5) days of production in worst case conditions shall be provided and seven (7) days during normal conditions.
- 12.10.5.3 Covered storage facilities shall be provided where required to suit sludge outlet requirements.
- 12.10.5.4 The sludge shall be collected by the Employer's accredited sludge hauler.
- 12.10.5.5 The automatic sludge cake discharge facilities shall be able to dislodge the sludge cake from the sludge dewatering facilities without the operator intervention. Automatic cleaning facilities shall be installed to minimize the manual operation.
- 12.10.5.6 The facility shall be equipped with a wash water supply and drainage in order to routinely clean the area.
- 12.10.5.7 The quantity of sludge leaving the WTP for disposal shall be weighed. The weight, date and time of sludge disposal shall be recorded.
- 12.10.5.8 Safe and convenient vehicular access shall be provided for transporting the sludge with efficient management of tanker movements.
- 12.10.5.9 The design of the sludge cake handling, storage and disposal system shall minimize odor generation.
- 12.10.5.10 As minimum, sludge cake storage shall be provided with level transmitters. The readings shall be displayed onsite from the instrument as well as on the SCADA system. All interlocks, alarms and trends shall be provided and viewable in the SCADA system.

**12.11 Recovered Water Facility**

12.11.1 General

- 12.11.1.1 Supernatant from the backwash tanks and filtrate from sludge thickeners, and dewatering machine shall be directed to the recovered water tank.
- 12.11.1.2 The Contractor shall provide a pumping station to recover the water and return as much recycle flow to the plant inlet.
- 12.11.1.3 The design of each treatment process (from coagulation to filtration, chemical dosing and sludge treatment) shall consider the additional flow and load brought about by recycling the recovered water to the plant inlet.
- 12.11.1.4 The Contractor shall provide the sufficient number of recovery pumps in a duty and standby configuration.

12.11.1.5 The recovered water tank shall be designed with at least two (2) compartments to allow for cleaning and maintenance of one compartment while the other one remains in service. Each shall be able to be cleaned independently without the need for any personnel to enter the tank.

12.11.1.6 The recovered water tank shall have a draining system to enable tank emptying and solids removal, when necessary. The drain system shall be capable of emptying a tank within 8 hours

12.11.1.7 Tank design shall include an overflow provision going to Yapak Creek.

12.11.1.8 The Contractor shall be responsible for obtaining all consents, approvals and licences for discharging recovered water from the WTP.

#### 12.11.2 Performance Requirements

12.11.2.1 It is intended to recover as much water from the treatment process. The Contractor must design for all flows to be recovered. If the Contractor finds that full recovery is not possible, the Contractor must flag to this information to the Client and must incorporate wastewater treatment in the design under a provisional sum.

12.11.2.2 The quality of recovered water to be recycled back to the plant inlet shall not degrade the final treated water quality.

#### 12.11.3 Specific Requirements

12.11.3.1 The intake of the recovery pumps shall be designed in a way that minimizes the entrainment of suspended solids from the recovery tank.

12.11.3.2 Recovery pumps shall be equipped with VFD to provide flexibility in operating under various flow patterns and water quality.

12.11.3.3 A flow meter shall be provided in the recovered line with sufficient isolation capability.

12.11.3.4 The recovered water tank shall be provided with turbidity, TSS, aluminum, iron and manganese analysers, level transmitters and level switches. The readings shall be displayed onsite from the instrument as well as on the SCADA system. All interlocks, alarms and trends shall be provided and viewable in the SCADA system.

### 12.12 Chemical Dosing

#### 12.12.1 General

12.12.1.1 For added flexibility in plant operations, provisions for dosing of the following chemicals shall be provided. Should the Contractor deem to adopt the use of other chemicals, the Contractor must demonstrate that their proposed design will create a greater value for the Employer and that such scheme is properly backed up with supporting calculations, simulations, documentations or other submittals.

- 1 Sulfuric acid and sodium hydroxide for adjustment of pH and improvement of downstream coagulation and flocculation processes



- 2 Potassium permanganate to oxidize any remaining iron and manganese after the sedimentation process

12.12.1.2 CFD modelling shall be conducted to demonstrate mixing performance of proposed chemical dosing point arrangements.

12.12.2 pH Adjustment

12.12.2.1 Sulfuric acid shall be used to decrease pH while sodium hydroxide shall be dosed to increase pH of the raw water. The contractor shall perform jar testing to identify optimum pH in relation to their proposed design. Alternative acid or alkali shall be considered if the contractor can prove that it has the same or better performance compared to sulfuric acid and sodium hydroxide, subject to approval by the Employer. The Contractor shall prove that the proposed alternative acid or alkali is available in the local market and has at least three (3) suppliers.

12.12.2.2 It shall be the Contractor's responsibility to determine the best point/s of chemical addition. In relation to chlorination, the location of the pH adjustment dosing point shall be provided before and after pre-chlorine dosing.

12.12.2.3 The contractor shall establish the set points for the dosing through jar tests. These set points shall be adjustable by the operator for flexibility in the WTP's operation.

12.12.2.4 The chemical storage and dosing system shall be fully automatic and complete with: level sensors, mixers, dosing pumps, suction and discharge pipework, service water, motor and variable speed drive and controls, cabling, lifting and hoisting machinery, safety shower with eye bath and necessary ancillaries.

12.12.2.5 The tanks shall be provided with level gauges of the sight glass type, level indicators/transmitters for analogue level and level switches for alarms and dosing pump trip.

12.12.2.6 There shall be a provision for pH adjustment prior to the coagulation mixing.

12.12.2.7 Another dosing point shall also be provided downstream of the treatment process, which shall be normally closed and shall only be used if necessary.

12.12.2.8 The dosing rate shall be raw water flow proportional controlled and shall consider feedback from the pH analysers within the plant. pH values of the final treated water shall be maintained within the allowed 6.50 to 8.00 range.

12.12.2.9 pH adjustment solutions shall be in liquid form and delivered to the dosing point via dosing pumps.

12.12.2.10 The requirements for dosing pumps are as follows as a minimum:

- 1 Dosing pumps shall be VFD driven;
- 2 Automatically controlled;

- 3 The dosing rate of the chemicals shall be raw water flow proportional controlled and shall consider feedback from the pH analysers within the plant.
- 4 The flow of pH adjusters shall be measured by a suitable flow meter.
- 5 The measurements signals from the flow meters including all necessary instruments for automatic operation and monitoring for dosing shall be transmitted to a SCADA system;
- 6 Mixing shall be provided at dosing points. Inline mixers shall be considered for inline mixing. The inline mixers shall be easily disassembled and have union couplings to allow removal for regular cleaning.
- 7 Pumps shall be located above the bund, such that they will not become flooded.
- 8 At least one (1) duty and one (1) standby dosing pump unit shall be provided for each chemical.

#### 12.12.3 Chemical Oxidation

- 12.12.3.1 Potassium permanganate shall be used as oxidant for flexibility of WTP operations. The contractor shall perform jar testing to identify optimum dose of potassium permanganate in relation to their proposed design. An alternative chemical oxidant shall be considered if the contractor can prove that it has the same or better performance compared to potassium permanganate, subject to approval by the Employer. The Contractor shall prove that the proposed alternative chemical oxidant is available in the local market and has at least three (3) suppliers.
- 12.12.3.2 It shall be the Contractor's responsibility to determine the best point or points of chemical addition.
- 12.12.3.3 The contractor shall establish the set points for the oxidant dosing through jar tests. These set points shall be adjustable by the operator for flexibility in the WTP's operation.
- 12.12.3.4 The oxidant preparation and dosing system shall be fully automatic and complete with: dry chemical hopper with level sensors, hopper cover, dry chemical feeder system, preparation tanks equipped with mixers, dosing pumps, suction and discharge pipework, potable water, motor and variable speed drive and controls, cabling, lifting and hoisting machinery, safety shower with eye bath and necessary ancillaries.
- 12.12.3.5 The system shall include a preparation tank and a day tank. Each tank shall incorporate a cover top mounted mixer. The covers shall be removable for inspection. The tanks and mixers shall be equipped with the corrosion protection. The mixer blade and shaft shall be SS 316L.
- 12.12.3.6 The tanks shall be provided with level gauges of the sight glass type, level indicators/transmitters for analogue level and level switches for alarms and dosing pump trip.

- 12.12.3.7 In case a spike in iron and/or manganese levels is received by the plant, potassium permanganate shall be used to oxidize any remaining iron and manganese after the sedimentation process. There shall be a provision to dose potassium permanganate within this area.
- 12.12.3.8 Another dosing point shall also be provided upstream of sedimentation, which shall be normally closed and shall only be used if necessary.
- 12.12.3.9 The optimum dose shall be nominated by the Contractor. Typical potassium permanganate strength of solution used for WTP applications is 1.00 – 5.00%.
- 12.12.3.10 Iron and manganese values of the final treated water shall be less than 0.40 mg/L and 0.021 mg/L respectively.
- 12.12.3.11 Oxidant solution shall be prepared from concentrate and delivered to the dosing point via dosing pumps. Unless otherwise agreed with the Employer, potassium permanganate powder shall be used.
- 12.12.3.12 Potassium permanganate when underdosed, will not oxidize all iron and manganese and when overdosed will result to pinkish color of water. As a minimum, potassium permanganate, iron and manganese analysers shall be provided for control and monitoring of dosing. Under no condition shall dosing cause discoloration of water exiting the treated water reservoir.
- 12.12.3.13 The requirements for preparation tank are as follows as a minimum:
- 1 Potassium permanganate preparation shall be fully automatic.
  - 2 Shall be made from corrosion resistant material
  - 3 Potable water shall be used for dilution
  - 4 The day tank shall sized based on 24 hours' continuous operation as a maximum.
- 12.12.3.14 The requirements for dosing pumps are as follows as a minimum:
- 1 Dosing pumps shall be VFD driven;
  - 2 Automatically controlled;
  - 3 The dosing rate of the potassium permanganate shall be raw water flow proportional controlled and shall consider feedback from the iron, manganese, and potassium permanganate analysers within the plant.
  - 4 The flow of dosed oxidant shall be measured by a suitable flow meter. Rotameters are acceptable for dilution water lines only. Pressure gages shall be fitted to the feed and dilution water lines;
  - 5 The measurements signals from the flow meters including all necessary instruments for automatic operation and monitoring for oxidant dosing shall be transmitted to a SCADA system;
  - 6 Mixing shall be provided at dosing points. Inline mixers shall be considered for inline mixing. The inline mixers shall be easily disassembled and have union couplings to allow removal for regular cleaning.

- 7 Pumps shall be located above the bund, such that they will not become flooded.
- 8 At least one (1) duty and one (1) standby unit shall be provided for each potassium permanganate preparation unit.

12.12.3.15 The minimum requirements for a powder storage room are as follows:

- 1 Potassium permanganate storage shall be compliant to PDEA guidelines.
- 2 Moisture-proof storage facility shall be designed according to the chemical storage requirement at peak flow/load. The storage area shall be kept dry by dehumidifiers and with suitable temperature to prevent chemical from clogging;
- 3 Provision shall be taken to prevent fly-off of powder during unloading and chemical make-up operations;
- 4 Provision of non-slipping floors shall be made within the room;
- 5 Minimum storage capacity for the powder is good for 30 days of use.
- 6 Suitable lifting equipment shall be provided to easily remove bags of powder from the delivery vehicle to the storage area to the dosing point.
- 7 Means of transporting the chemical from drums or bag to the hopper without the need for manual lifting.

## **12.13 Process Control and Monitoring**

### **12.13.1 Process Control and Monitoring**

12.13.1.1 The process control and monitoring system shall include as minimum, flow meters, pressure measuring devices, water level sensors, on-line pH, temperature, TSS, turbidity, sludge blanket detectors, on-line chlorine, potassium permanganate, ammonia, iron, manganese and aluminum analysers and 24-hour automatic sampling equipment to provide the appropriate level of data for the monitoring and assessment of the flow and process performance of the WTP and its constituent parts. All instruments shall be provided with necessary transmitters and indicating devices. Indicating devices shall be provided locally and in the SCADA system. The Contractor shall outline the cleaning and calibration requirements of all on-line monitoring equipment. Where available, preference should be given to self cleaning, automatic calibration and low maintenance monitoring equipment.

12.13.1.2 The control and monitoring equipment shall have remote and local audio-visual panels and alarms, both at control room, sub-stations and equipment location as appropriate. This shall include but not be limited to:

- 1 Individual continuous incoming raw water and recovered water flow and quality recording shall be provided by fixed equipment at plant inlet. For the final combined influent, 24-hour automatic samplers shall also be provided.
- 2 A local panel shall be provided for each of these flow meters, as well as the necessary connections to the control system in the MCC and SCADA.

- 3 Fixed equipment to continuously monitor and record final treated water flow and quality shall be provided. Automatic samplers shall also be provided.
- 4 Automatic sampling at the inlet and outlet of the main process units, including but not limited to the inlet works, flocculation, sedimentation, filtration, disinfection, sludge and storage facilities.
- 5 Process and water quality monitoring parameters shall be provided at any other point necessary for the efficient control of operations of the proposed facilities.

12.13.1.3 pH adjustment, oxidant and chlorine dosing shall be controlled automatically online, with the dosing rate to be adjusted manually.

12.13.1.4 The Contractor shall be required to provide at least two (2) portable pH monitors with their calibration kits.

12.13.1.5 Flow and quality measurements shall be provided for each process unit or tank such that it is possible to quickly identify process performance and monitor all the flows (including all water, sludge, sludge cake, backwash, chemicals, air and recovered water flows).

12.13.1.6 The Contractor shall provide a mass / flow balance for their design. The flow meter provided for the process lines above shall be able to handle the expected range of flows indicated in the mass / flow balance.

12.13.1.7 The following tabulates the minimum required instruments for each unit operations aside from the identified instruments in the previous sub-sections. Redundancy shall also be considered in all applications. For example, there shall be redundant level switches in for all tanks.

| Process Area                          | Sub-process      | Minimum Required Sensors, Analysers and Instruments                                                                                                                                                                                                                                                                          |
|---------------------------------------|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Raw Water Interface From Water Portal |                  | <ul style="list-style-type: none"> <li>■ Flowmeter (raw water – 1200 MLD)</li> <li>■ Position indicating transmitter for the discharge gates</li> </ul>                                                                                                                                                                      |
| Raw Water Flow Diverting Structure    |                  | <ul style="list-style-type: none"> <li>■ Level sensors and switches</li> <li>■ Position indicating transmitter for the discharge gates</li> </ul>                                                                                                                                                                            |
| WTP Interface Chamber                 | Intake Structure | <ul style="list-style-type: none"> <li>■ pH, turbidity, TSS, ammonia, aluminum, iron and manganese analysers</li> <li>■ particle and zeta potential analysers</li> <li>■ Hydrostatic level sensors for level measurement for pump control with redundant level switches for (extreme low and extreme high levels)</li> </ul> |

| Process Area  | Sub-process               | Minimum Required Sensors, Analysers and Instruments                                                                                                                                                                                                                                                                                                                                                                    |
|---------------|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|               | Raw water pumping station | <ul style="list-style-type: none"> <li>■ Electromagnetic flow meters</li> <li>■ Pump pressure indicators</li> <li>■ Pump and motor winding temperature sensor and transmitter</li> </ul>                                                                                                                                                                                                                               |
| Sedimentation | Sedimentation Basin       | <ul style="list-style-type: none"> <li>■ Sludge Blanket Detector {Sludge Level}</li> <li>■ Torque limiting switches (scraper)</li> <li>■ pH, turbidity, TSS, chlorine, potassium permanganate, aluminum, iron and manganese analysers (outlet)</li> </ul>                                                                                                                                                              |
| Filtration    | Filter Bed                | <ul style="list-style-type: none"> <li>■ Level sensors and switches</li> <li>■ Position indicating transmitter for the all gates/valves</li> <li>■ Flowmeter (inlet)</li> <li>■ Flowmeter (outlet)</li> <li>■ Differential pressure sensors for backwash control</li> <li>■ pH, turbidity, TSS, potassium permanganate, iron and manganese analysers (outlet)</li> <li>■ chlorine (after post-chlorination)</li> </ul> |
|               | Air Blower                | <ul style="list-style-type: none"> <li>■ Pressure indicating transmitter at blower discharge</li> <li>■ Pressure gauge and switch at blower discharge</li> <li>■ Air flowmeter</li> <li>■ Blower vibration sensor and transmitter</li> <li>■ Blower winding temperature sensor and transmitter</li> <li>■ Blower bearing temperature sensor and transmitter</li> <li>■ Powermeter for main MCC</li> </ul>              |
|               | Backwash Tank             | <ul style="list-style-type: none"> <li>■ Flowmeter (inlet)</li> <li>■ Flowmeter (sludge)</li> <li>■ Flowmeter (supernatant)</li> <li>■ Level sensors and switches</li> <li>■ Sludge Blanket Detector {Sludge Level}</li> <li>■ Dry solid analyser</li> </ul>                                                                                                                                                           |

| Process Area                  | Sub-process                              | Minimum Required Sensors, Analysers and Instruments                                                                                                                                                                                                                                                    |
|-------------------------------|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Treated Water Storage         | Contact Tank and Treated Water Reservoir | <ul style="list-style-type: none"> <li>■ Level sensors and switches</li> <li>■ pH, turbidity, TSS, chlorine, aluminum, iron and manganese analysers</li> </ul>                                                                                                                                         |
| Sludge Treatment and Disposal | Sludge Tank/s                            | <ul style="list-style-type: none"> <li>■ Level sensors and switches</li> <li>■ Flowmeter (inlet)</li> <li>■ Flowmeter (outlet)</li> <li>■ Torque Sensor for mixers</li> <li>■ Position indicating transmitter for the all gates/valves</li> </ul>                                                      |
|                               | Sludge Pumps                             | <ul style="list-style-type: none"> <li>■ Flowmeter (outlet)</li> <li>■ Pressure indicating transmitter at pump discharge</li> <li>■ Pressure gauge and switch at pump discharge</li> <li>■ Pump vibration sensor and transmitter</li> <li>■ Pump winding temperature sensor and transmitter</li> </ul> |
|                               | Polymer Preparation Unit                 | <ul style="list-style-type: none"> <li>■ OEM package (using VFD recommended instrumentation)</li> <li>■ Flowmeter for water</li> <li>■ Flowmeter for each polymer dosing line</li> <li>■ Level sensors and switches (hopper and tank)</li> </ul>                                                       |
|                               | Thickener                                | <ul style="list-style-type: none"> <li>■ OEM package (using VFD recommended instrumentation)</li> <li>■ Flowmeter for feed sludge</li> <li>■ Flowmeter for filtrate</li> <li>■ Pressure indicating transmitter for air (if applicable)</li> <li>■ Pressure switch for air (if applicable)</li> </ul>   |
|                               | Dewatering                               | <ul style="list-style-type: none"> <li>■ OEM package (using VFD recommended instrumentation)</li> <li>■ Flowmeter for feed sludge</li> <li>■ Flowmeter for filtrate</li> <li>■ Pressure indicating transmitter for air (if applicable)</li> <li>■ Pressure switch for air (if applicable)</li> </ul>   |
|                               | Sludge Cake Storage                      | <ul style="list-style-type: none"> <li>■ Level indicating transmitter</li> </ul>                                                                                                                                                                                                                       |

| Process Area              | Sub-process               | Minimum Required Sensors, Analysers and Instruments                                                                                                                                                                                                                                                                                                                                                    |
|---------------------------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Recovered Water Facility  | Recovered Water Tank      | <ul style="list-style-type: none"> <li>■ Level sensors and switches (tank)</li> </ul>                                                                                                                                                                                                                                                                                                                  |
|                           | Recovery Pumps            | <ul style="list-style-type: none"> <li>■ Flowmeter (recovered water)</li> <li>■ Pump and motor vibration sensor and transmitter</li> <li>■ Pump and motor winding temperature sensor and transmitter</li> <li>■ Pressure indicating transmitter and gauge each line</li> <li>■ Pressure switch at discharge line</li> <li>■ Turbidity, TSS, aluminum, iron and manganese analysers (outlet)</li> </ul> |
| Chemical dosing           | Pumps                     | <ul style="list-style-type: none"> <li>■ Flow meters (feedback control for chemical addition)</li> </ul>                                                                                                                                                                                                                                                                                               |
|                           | Preparation/storage tanks | <ul style="list-style-type: none"> <li>■ Level sensors</li> <li>■ Redundant level switches (for extreme low and extreme high levels)</li> </ul>                                                                                                                                                                                                                                                        |
| Critical pumps and motors |                           | <ul style="list-style-type: none"> <li>■ Condition based monitoring (vibration for motor load side, pump load side, and pump free side, bearing temperature and winding temperature)</li> </ul>                                                                                                                                                                                                        |

12.13.1.1 For pipelines the Contractor shall use electromagnetic flow meters for fluid measurement (water/sludge/chemical). Electromagnetic flow meters shall deliver accuracies of all +/- 2% of flow or better. Spool pieces, at least one for each diameter of flow used and shall be provided for all electromagnetic flow meters. The Contractor shall ensure continuous plant operations during maintenance of the flowmeters.

12.13.1.2 For open channel measurement systems, measurement by velocity are to be used; level based measurement which convert to flow shall not be used. Accuracy of installation of +/- 4% is requirement for open channel measurement systems.

12.13.1.3 All instruments and electronic equipment shall be protected against electrical surge due to internal switching by means of individual repairable/replaceable surge arrestors.

12.13.1.4 All supplied instruments shall be factory calibrated complete with relevant certifications and documents of proof. All installed instruments shall be properly field setup, verified and tested by the manufacturer or their representative onsite, test reports shall be submitted by the Contractor to the Employer.



12.13.1.5 All sensors/analysers/flow meters/monitors shall be provided with transmitters and indicators. The transmitters shall be provided with suitable "isolators" to avoid interruptions of the communication signals between the SCADA system and the instruments.

12.13.1.6 All on-line instruments requiring in-tank, submerged installations shall be provided with suitably designed protection guards/sieves against damages by the moving activated sludge. The design of the protection guards/sieves shall comply with the following requirements:

- 1 Not interfere with the measurements of the protecting instrument in any circumstances;
- 2 Not cause stack-up of activated sludge;
- 3 Easily removable for cleaning without any special tools; and
- 4 Made of stainless steel 316L.

## 12.14 SCADA Requirements

### 12.14.1 Scope of Works for SCADA

12.14.1.1 The WTP shall be equipped as a minimum with a SCADA for user interface control and monitoring, DCS/ Local PLC for control automation, communication equipment with package system equipment and field instrumentation. The DCS/SCADA system shall enable the WTP to fully operate in automation and remotely monitored with minimum intervention from operators. The SCADA system at the Site shall be provided to receive the display status signals from the WTP process equipment and instrumentation.

12.14.1.2 The WTP SCADA system shall be capable to receive a communication signal from Boso-Boso reservoir's level transmitter.

12.14.1.3 The contractor shall include as a minimum the costs for all labour, tools, materials for design, manufacture, factory testing, supply, storage, delivery to site works, loading, unloading, construction, erection, installation, site testing and commissioning of the following works, but not be limited to:

- 1 Electrical Interface Cabinet (EIC) referred as 'WTP EIC' housing all control and monitoring equipment containing one set of hot-standby DCS Controller, network switch/router, firewall, modem for short message service (SMS), power supply and field distribution components, etc. The WTP EIC shall be located in a Control Room;
- 2 One (1) set of redundant DCS's (referred as WTP DCS Controller) shall be provided including DCS programming and configuration works to control the overall WTP;
- 3 The SCADA system including graphics development, configuration works, programming and other necessary interfacing works shall include but not be limited to the following:

Two (2) servers (redundant) including programming and configuration works with full control and SCADA monitoring capability for the complete WTP treatment process;

One engineering station for development of graphics and facilitating changes in the control for the PLC programming.

Two client station in the Control Room for the independent operation of the processes by the operators.

- 4 A provision of SMS from the WTP control system to designated operator(s) for any emergency alert including SMS modem and communication configuration works shall be provided;
- 5 Plant telemetry for remote monitoring using RTU's with GSM/Radio Modem.
- 6 Required number of Local PLC's, RIO's and UPS's shall refer to Control System Architecture.

- 7 Field instrumentation, controls, indicators, power supplies, equipment and all necessary interconnecting cabling and supports for the correct, efficient and safe operation of the WTP. The contractor shall provide all the instruments listed at the time of tender in the Technical Schedules which shall include but not be limited to those shown on the drawings and described elsewhere in the Specification as required for the proper functioning of the complete system;
- 8 Safety interlocks including emergency stop buttons shall be provided as required or as specified.
- 9 One (1) Uninterruptible Power Supply (UPS) unit located in the WTP Control Room to provide back-up power supply for all control and monitoring equipment.
- 10 Control room shall have control console and work desks of free-standing for monitors, key board, printers and suitable power points. The design shall use high quality material and design approved by the Employer from a reputable manufacturer. The chairs for engineers and operator shall be castor swivel type.
- 11 The Control room shall be strategically located with a view of the entire WTP.

12.14.1.4 The contractor shall appoint a System Integrator (SI) to provide the complete ICA detailed design, engineering and integration works for proper functioning of the ICA system. The contractor and their SI shall coordinate and liaise any interfacing works with other works within the development area for fully functioning of complete system. System Integrator (SI) shall be approved and or recommended by the Employer.

12.14.1.5 Upon substantial completion of the Works and when all testing and commissioning of the system has been completed to the satisfaction of the Employer, the contractor shall submit all software of the system and sub-systems to the Employer. Two (2) sets of all contractor-engineered, customized and developed software used under the Subcontract shall be submitted to the Employer in USB flash drive. The intellectual property rights of all software shall belong to the Employer.

12.14.1.6 Any electrical and mechanical equipment forming part of the equipment or system in this Section shall also comply fully with the requirements described in relevant Electrical and Mechanical Specifications.

#### 12.14.2 Overall Control System Configuration

12.14.2.1 The overall treatment process shall be controlled by redundant hot-standby DCS/ Local PLCs and monitored by the SCADA systems. The DCSs shall be a master controller to the WTP and subsystems within.

- 1 The DCSs shall be housed in an EIC in the proposed control room.
- 2 Communication within controllers, control system and interfaces shall be designed and selected based on an open protocol system.
- 3 A provision of SMS from the WTP control system to designated operator(s) for any emergency alert is proposed.
- 4 Conceptual control and monitoring system for the WTP shall be as shown in the Control System Architecture drawing as a minimum.

12.14.3 Control and Monitoring Interfaces with Operation

SMS modem shall be provided to send any alarm/alert the designated operator(s) via SMS.

12.14.4 Submittals

12.14.4.1 The contractor shall provide the following submittals as a minimum for ICA Works in addition to the submittals specified in other section of the Specifications:

1 Two (2) sets of softcopies and hardcopies of the following documents:

- (A) System/process and control descriptions;
- (B) Process Control Narrative (PCN);
- (C) Loop descriptions;
- (D) Operating procedures;
- (E) As-built system drawings;
- (F) Input/ Output (I/O) lists;
- (G) Configuration and programming documentation;
- (H) Test reports;
- (I) Alarm listing;
- (J) Interlocks;
- (K) Process design criteria;
- (L) Process overview and function;
- (M) Standard operating procedure;
- (N) Control procedure;
- (O) SMS communication configuration; and
- (P) Trouble shooting procedure.

12.14.5 Application Software Submittals

During the applications software development stage, the contractor shall submit a detailed description of the SCADA configuration and DCS/PLCs program on a unit process basis as follow:

12.14.5.1 Documented PLCs program;

12.14.5.2 Color print out of SCADA displays;

12.14.5.3 A database and database applications for documenting of SCADA database points, PLCs points, PLC/ I/O addresses along with the information access.

12.14.6 Overall User Interface Control and Monitoring System

- 12.14.6.1 New graphical user interface (GUI) or SCADA screens shall be developed in the WTP touch screen SCADA using latest GUI/SCADA software suitable for the SCADA to provide a platform for control, monitoring and operator interface.
- 12.14.6.2 The GUI/SCADA software shall include the graphic symbols, colour schemes, function blocks, programming code, trending, alarm management, report generation (via portable laptop/workstation connection), and header and footer bars with screen view optimized on HMI. It shall be designed with ISA 88 standard layout.
- 12.14.6.3 The GUI/SCADA software shall also consist of a real time supervisory system to access the plant via graphic screens which display the mimic of the plant to the SCADA. All processes and process equipment shall generally be operable from the GUI/SCADA system in the SCADA.
- 12.14.6.4 The SCADA facilities shall include manual/auto operation, start/stop or open/close control of equipment, set-point adjustment for process and dosing equipment, control of main process valves, process plant inhibits as required and reset of automatic sequences for chemical dosing, power failure, overflow condition etc. Trend graph records shall also be provided in the touch screen SCADA.
- 12.14.6.5 The contractor shall integrate all instrumentation's and equipment's monitoring signals to the HMI graphics. All PLC I/Os shall be represented in the SCADA system.
- 12.14.6.6 Software tag points shall use associated physical equipment tag numbers as their basis, with additional suffixes to suit.
- 12.14.6.7 Controls shall operate modulating valves incrementally with a sufficient interval between successive adjustments for the plant to respond.
- 12.14.6.8 After the required necessary values throughput for the Subcontract Works have been entered manually, the control system shall exercise control over the individual sections of the works to satisfy the demand in the most advantageous way, i.e: by bringing into service or taking out of service certain items of equipment.
- 12.14.6.9 This shall be achieved via the operator by display of the appropriate alarms and comprehensive prompts.

#### 12.14.7 SCADA Graphics

Graphics for the WTP shall be created and developed to show the following as a minimum:

- 12.14.7.1 Contractor shall design and program the SCADA graphics requirement based on the latest standards of MWCI.

12.14.7.2 An overview of the functional area showing the process equipment, pipework, pump system, all process variables associated with each area and all interfaces with every sub-system. The contractor shall design a series of SCADA images forming a clear, live display covering the entire plant. These displays shall give a schematic representation of each section of the works, generally based on the P&IDs, fully annotated and linked to other associated areas in a clear hierarchical manner. The graphics shall show the numerical value of each analogue measurement or set-point within that section and the status of each digital signal. Where suitable, each parameter shall also be depicted in an animated form, for example as a vertical bar or area fill which shall move as the parameter varies. The contractor shall make full use of pseudo 3-dimensional graphical capabilities. Displays shall also show the status of each component as a minimum such as:

|                                   |                                                                                                              |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------|
| (i) Machines:                     | running, stopped, fault, available and selected to <b>SCADA</b> ;                                            |
| (ii) Valves:                      | open, closed, opening, closing, fault, % open (where applicable), discrepancy and selected to <b>SCADA</b> ; |
| (iii) Circuit breakers:           | open, closed, tripped on fault;                                                                              |
| (iv) Instruments/Analyser/ Meter: | fault, discrepancy and range (where applicable); totaliser and a pop-up to reset                             |
| (v) Flowmeter:                    | the totaliser.                                                                                               |

12.14.7.3 Status changes shall be represented by a change in colour. Failure conditions shall also cause the device icon to flash and the appropriate entries to appear in the alarm list and, until acknowledged, in the reserved banner on every page.

12.14.7.4 Access via pop-up windows to the operation, status indication, alarm, and trending associated with each variable item of the equipment such as a motor, pump or actuator shall be provided. The pop-up windows shall display at least the following information of the equipment where such information is available in the DCS/PLCs for the functioning of the complete system:

- 1 Running status;
- 2 Stopped indication;
- 3 Tripped indication;
- 4 Selected to SCADA;
- 5 Ready to start;
- 6 Emergency stop;
- 7 Valve opened/opening indication;
- 8 Valve closed/closing indication;
- 9 Auto/manual indication;
- 10 Auto/manual selector switch;
- 11 Running hours;
- 12 Energy consumed;
- 13 Start;
- 14 Stop;
- 15 Command confirm button;
- 16 Command cancel button;
- 17 Window close button;
- 18 Trending;
- 19 PID control setting;
- 20 Manual, Local and Automatic mode and status;
- 21 Automatic Sequence status display;
- 22 Process setup;
- 23 Diagnostic function for DCS/PLC(s), batteries, DC supply units and UPS;

12.14.7.5 Stop/start stations (LCSs) shall be provided in the field and shall be enabled from a field (local)/remote switch located on either each respective MCC or the LCS itself. The activation of the switches to the field (local) control mode shall signal the control system that the particular equipment is no longer available for auto control. Safety interlocks shall apply for field (local) control mode when the process flow interlocks with the equipment.

12.14.7.6 Each graphic page shall contain an appropriate amount of information. The pages shall not be cluttered but neither shall they have so little content as to require the user to unduly switch back and forth between many graphics pages in order to conduct routine tasks. An overview screen shall be provided for any process area that is spread over more than four graphics pages; however, navigation buttons in each screen shall normally link to the next detailed screen; i.e. the user needs not go via an overview screen.

12.14.7.7 The contractor shall replicate the features such as pushbuttons and indicating lamps as shown on the MCC starter panel for rotating machinery (i.e. pumps, etc.) on SCADA graphics such that there is uniformity and consistency exists between the pop-up graphics and field equipment at site.

12.14.7.8 The SCADA graphic displays shall include the following as a minimum:

- 1 Each process area based on the P&IDs and grouped into logical areas;
- 2 Overview display page for the overall treatment process;
- 3 All indicating devices in each process area;
- 4 Sedimentation Basins – sludge blanket indicator;
- 5 Filtration and Backwash – turbidity meters and differential pressure transmitter;
- 6 Chlorination – chlorine weighing scale, wind measuring device, and chlorine gas detectors;
- 7 Contact Tank and Treated Water Reservoir – Chlorine analysers;
- 8 Sludge Thickening and Dewatering;
- 9 Sludge Cake Transport;
- 10 Polymer Dosing System;
- 11 Flow meters for pH adjusters;
- 12 Oxidant Dosing System;
- 13 Recovered Water Facility;
- 14 Emergency Generator;
- 15 Fuel Storage; and
- 16 Electrical System

12.14.7.9 Data entry points shall be distinguishable from simple data display points. This may be achieved using shading or other system features.

12.14.7.10 The contractor shall submit colour printouts of the proposed SCADA graphic displays for approval in a structured and professional manner. The submission shall consist of:

- 1 Initial submission when all the graphic pages have been created by the contractor. The Employer will give their initial comments which shall be incorporated and re-submitted by the contractor for approval prior to the next stage of submission.
- 2 Final submission to allow the Employer for a final round of review and comments. The final round of comments shall be incorporated and re-submitted for final approval before the graphics are considered acceptable.
- 3 The final submission of the graphics shall not relieve the contractor from making necessary changes to the graphics for the satisfactory functioning of the Subcontract Works. Each submission shall contain three (3) colour copies with a table of contents showing the full list of graphic displays being implemented.

12.14.8 Control Communication Network



12.14.8.1 100 Mbps minimum network speed shall be configured in a network configuration with required spares. Network switches shall be provided with sufficient ports and spare ports for proper functioning of the complete system.

12.14.8.2 Network switch(es) shall be provided in the WTP EIC and Local PLC's/RIO's for connection interface as shown on the Drawings as a minimum. The network switches provided under the Subcontract shall comply with technical requirements.

12.14.8.3 The Fibre Patch Panel(s) shall be provided with sufficient number of ports with necessary internal connections such as pigtail, and other necessary accessories including fibre patch cords, termination etc for complete fibre optic cables connection for proper functioning of the complete system.

12.14.8.4 The Contractor shall provide a complete network configuration as required for the proper functioning of the complete system. All works and components which are not mentioned above but required for a complete installation and functioning of the overall PLC/SCADA system shall be deemed to be included in the Subcontract pricing.

12.14.8.5 All alarm conditions shall be resolved to the satisfaction of the Employer before handover to the Employer.

#### 12.14.9 System Integrator

12.14.9.1 The Contractor shall engage a System Integrator with following requirements as a minimum:

- 1 To provide the control system equipment and ancillaries:
  - (A) Coordinate completing detailed ICA including control, monitoring, DCS/Local PLC/SCADA design, wireless remote monitoring;
  - (B) Coordinate required ICA submittals;
  - (C) Coordinate supply of ICA equipment and ancillaries;
  - (D) Coordinate supply of instructions, detailed procedures, and recommendations to, and co-ordination with the contractor for all necessary calibration certificate and relevant installation drawings;
  - (E) Verify readiness for operation;
  - (F) Verify the correctness of final power and signal connections (phasing, type, voltage, application, labelling, lugging and connecting);
  - (G) Coordinate the control and monitoring network configurations; and
  - (H) Coordinate testing and commissioning.
- 2 The System Integrator shall have a minimum of 10 years of experience in ICA works in water and wastewater treatment.

#### 12.15 Process Monitoring and Sampling Requirements

Raw and treated water process sampling shall be carried out as stated in the section on Tests on Completion.

### **12.16 Chemical Storage and Bund Wall**

- 12.16.1 All chemical storage tanks shall be sized based on 30-day average plant flow and average dosage requirement.
- 12.16.2 Material of storage tanks shall be either HDPE, FRP or PP. Should the contractor opt to use concrete for large volume tanks, it shall be subject for approval of the Employer and Engineer.
- 12.16.3 All chemical storage tanks, transfer system and dosing pumps shall be located within bund walls. Dedicated bund walls shall be provided for different chemical storage tanks. The minimum effective volumetric size of the bunding structure shall be at a minimum of 110% volumetric capacity of the largest chemical tank for the contained chemical in storage.
- 12.16.4 If the chemicals are compatible and are safe to be mixed, the bund wall can be designed to contain more than two types of chemical storage tanks. In this case, the minimum volumetric size of the bunding structure shall be at a minimum of 110% volumetric capacities of the largest chemical tank within the bund wall.
- 12.16.5 Each bunding structure shall be coated with a suitable finish to ensure minimum corrosion due to the stored chemical and WTP's environment.
- 12.16.6 Chemical storage tanks or facilities shall have externally mounted measuring devices (where appropriate) that allow the operator to quickly and clearly estimate the volume of stored chemical by visual means.
- 12.16.7 The storage area shall be moisture-proof and kept dry by dehumidifiers and with suitable temperature to prevent chemical from clogging;
- 12.16.8 Provision shall be taken to prevent fly-off of powder chemical during unloading and chemical make-up operations if applicable;
- 12.16.9 Lifting facilities shall include equipment for moving or transferring chemicals. Manual handling shall not be acceptable.
- 12.16.10 Provision of non-slipping floors shall be made within the room;
- 12.16.11 Drainage within the bunding structure shall be isolated from the storm water drainage system in the WTP. The drainage within the bunding structure shall be sent to a drain sump for further treatment/testing before final disposal or recycled back to the head of the WTP. Isolation valves shall be provided and be normally closed.
- 12.16.12 Dedicated tanker loading bays are required and shall be provided with containment and isolation drain.
- 12.16.13 Wash down points shall be provided to serve the bunded area.
- 12.16.14 Each bunding structure shall be complete with a sump which is easily accessible from outside the bund. Portable pumps of suitable material complete with hoses shall be provided for emptying the bunds for off-site disposal. The sumps in the bunds shall be provided with level switches to feedback to the SCADA.

12.16.15 Each tank shall be equipped with level gage(s) for local monitoring and level transmitter(s) that feedback the amount of chemical to the SCADA. Local alarm panel shall be provided adjacent to the chemical tank to provide high level alarm.

12.16.16 The following safety equipment shall be provided:

- 1 Safety showers complete with eye wash at the appropriate location of each chemical storage areas;
- 2 A minimum of five (5) sets of personal protective equipment (PPE) shall be provided for operators to handle chemical. Risk assessment shall be conducted to determine the adequate number of PPE sets required.
- 3 All required safety signs and notices to comply with local safety legislation.

## **12.17 Support Facilities**

### **12.17.1 Plant Water Supply**

The Contractor shall make use of potable water for domestic use and the service water for use within the WTP. A permanent connection of water supply lines should be in place prior to any testing.

#### **12.17.1.1 Potable Water Supply**

Potable water shall be extracted from the treated water storage tank and supplemented by a metered potable water supply when necessary. The Contractor shall make a connection from an existing potable water distribution network. The Contractor shall be responsible for all costs, permanent or temporary, associated with organizing the connection.

The Contractor shall design and supply a pressurized potable water distribution system for the following facilities in the WTP:

- 1 Laboratory;
- 2 Potable use tap points;
- 3 Operator's shower facilities;
- 4 Operator's hand washing basin;
- 5 Make-up and dilution lines;
- 6 Firefighting; and
- 7 Safety shower and eyewash.

The potable water distribution system shall include, but not be limited to, the following equipment:

- 8 Potable water storage tank;
- 9 Potable water booster pump;
- 10 Pressure vessels; and
- 11 Distribution pipe work, valves and accessories.

The potable water distribution system shall not cause contamination to the upstream water supply network.

#### **12.17.1.2 Service Water Supply**

Service water shall be taken from filtered water produced from the plant, separate from metered potable water supply. The Contractor shall provide service water supply for equipment and plant wash down, cleaning, landscape irrigation, etc.

The Contractor shall install lockable valves on all wash water connections and provide 10-meter hoses with appropriate hose reels for each area of the plant. Wash water pressures at hose points shall be high enough to facilitate good cleaning of tanks and

structures. It shall include all connections, valves, pumps, pipe work and instrumentation for the full automatic operations and control of the system.

#### 12.17.2 Site Drainage System

12.17.2.1 Storm water runoff generated from rainfall or storm events in the WTP site shall be conveyed to surface drainage. The Contractor shall conduct rainfall analysis and runoff estimation to serve as basis for the design capacity of the drainage system. The design flow shall be in accordance to MWCI SES 11.

12.17.2.2 Process water drainage from all elements of the additional treatment process (including filtrates, retentates, tank and channel drainage etc.) shall be collected and returned to the sludge treatment system or to a more suitable headwork location. No water drained from process elements shall be discharged to the storm water drainage system.

12.17.2.3 Soakways shall be provided alongside the access roads.

12.17.2.4 Drainage outlets for the WTP shall be installed with flap valves to prevent possible back flow from the receiving drains. Proper hydraulic design shall be employed to allow adequate discharge at submerged flow conditions otherwise mechanical intervention shall be used.

12.17.2.5 All facilities within the WTP shall be positioned and/or their structural configured in such a way to avoid storm water entering the facilities, treatment system or operation areas. Suitable slope shall be provided on Site to avoid any storm water runoff inundation.

#### 12.17.3 Lifting and Transport Facilities

12.17.3.1 Adequate lifting and transport facilities shall be provided for the safe operation, removal and replacement of items of plant and equipment that are unsuitable to be lifted manually, either because of the equipment's weight or size, or space or operational limitation. The type of lifting arrangements to be provided shall depend on the type of plant/equipment, its location, weight and size and the frequency of carrying out that particular operation.

12.17.3.2 For all maintainable elements of the plant greater than 20 kg, but less than 200 kg, fixed lifting davit socket shall be provided for each process area. At least two (2) further portable lifting davits rated for a Safe Working Load of 200 kg shall be provided at the workshop or storage area.

12.17.3.3 For all maintainable items of plant greater than 200 kg or of a size that precludes the use of a fixed lifting davit, overhead lifting facilities, that may include electrically operated overhead traveling cranes or jib cranes, shall be provided.

12.17.3.4 For areas where vehicular access is limited or not possible, electrically operated overhead crane shall be provided to allow the removal of the whole or parts of the plant for maintenance. A sufficient set-down area shall be provided to allow the transfer of any part of the plant directly from the overhead crane to a delivery vehicle.

12.17.3.5 For large and critical equipment, the Contractor shall provide dedicated electric chain hoist with guiderail.

12.17.3.6 If any part of the plant cannot be directly lifted by the overhead crane and transferred to the set-down area described, then a secondary crane or monorail hoist shall be provided to allow the transfer of the plant component from its normal location either directly to the set-down area or else to an alternative set-down area where it can be lifted by the overhead crane.

12.17.3.7 The paths for moving plant components shall be clear and unobstructed. It shall be so designed in a way that it is not necessary to remove any plant component to allow any other component to be moved.

12.17.3.8 Lifting equipment shall be supplied for all items that require lifting as part of the routine and reactive maintenance as well as checking and inspection. Lifting equipment shall be tested and certified prior to use.

12.17.3.9 During installation of lifting equipment, necessary permits and certificates shall be secured from regulatory or governing body and initial load testing shall be undertaken prior to the completion of the Work. An annual load testing shall be conducted following initial installation. All costs associated with the conduct of such test shall be shouldered by the Contractor.

12.17.3.10 The Contractor shall:

- 1 Prepare a plant handling and lifting strategy as part of the WTP design;
- 2 Have all fixed lifting equipment agreed with the Employer; and
- 3 Provide portable/fixed lifting and transport equipment in accordance with the accepted plant handling and lifting strategy.

#### 12.17.4 Security System

##### 12.17.4.1 Fence, Gate and Residential Community Path

- 1 The Contractor shall design and build permanent perimeter and gate in accordance with MWCI SES 14 and Appendix 21 Security Design and Construction Guidelines. The perimeter fence shall surround the entire property and structures of MWCI, including the shaded areas within the boundary of the lot and along Roman Rojas Road. Refer to Conceptual Plant Layout provided in Appendix 7.
- 2 The Contractor shall design and construct the fencing to withstand the 1 in 100 year flooding, designed to allow passage of storm water in all the conditions of the storm.
- 3 The site entrance path shall be extended. The extension path shall be 6 m wide and made outside of WTP peripheral fence.

##### 12.17.4.2 Guard House

A guard house with an area to accommodate at least two (2) guards and equipped with a toilet and wash basin shall be provided at each entry and exit point of the WTP. It shall serve as a control for incoming and outgoing staff and visitors, and a base for all security personnel. A telephone line system shall be installed for ease of communication with the

guard on duty. The security personnel that shall be on duty during the Process Proving Period shall be provided by the Employer. The guard house shall be manned by the Contractor’s personnel before the Process Proving Period.

The overall design of the guard house for each entry or exit point of the site shall be in accordance to MWCI SES 14.

#### 12.17.4.3 Security Surveillance

A CCTV system shall be provided to monitor security risk in the WTP. More specific requirements will be covered in the CCTV section.

### 12.17.5 Administration/Office Building

12.17.5.1 An administration building shall be provided to efficiently service the needs of the RWTL and WTP. The design of the Contractor shall be in accordance to MWCI SES 14. Sufficient floor area shall be provided to include the following:

- 1 WTP Manager’s room with a desk and office chair, a discussion table (suitable for A1 drawings) with modular chairs, a lockable steel cupboard, sufficient shelving/cabinets, drawing and document storage provisions, wall mounted white board, a wall mounted soft board and airconditioning;
- 2 Staff Office (for a minimum of 15 staff) with modular desks and chairs, lockable pedestals, lockable steel cupboards, lockable key cabinets, wall mounted white boards, wall mounted soft boards and one (1) laser printer, one (1) photocopier and airconditioning;
- 3 Conference room with a 10-seater table, 10 chairs and ceiling-mounted projector, projector screen, wall mounted whiteboards and airconditioning;
- 4 Visual display with physical scaled down model of the RWTL and WTP and 3D walkthrough of all WTP processes;
- 5 Control and monitoring room with field view of the WTP to the widest extent;
- 6 Pantry complete with storage shelves/cabinets/drawer wash basin with faucet, microwave oven, refrigerator, electrical thermal flask, tables and chairs for eight (8) staff;
- 7 Sleeping quarters for 4 staff with minimum area of 16-sqm, complete with beds, cabinets, desks, chairs and airconditioning
- 8 General storeroom;
- 9 Separate toilet facilities for male and female, each with at least one shower cubicle for each;
- 10 Separate locker rooms for 10 males and 10 females; and
- 11 Janitorial room with wash area, toilet bowl, shower cubicle, janitorial closet and three (3) lockers.

### 12.17.6 Laboratory room and equipment for on-site monitoring

The Contractor shall provide a laboratory in the Administration Building with a minimum area of 20 m<sup>2</sup> and the materials shall be in accordance with MWCI SES 14. The laboratory equipment shall conform to the requirements stated below.

The Laboratory shall adhere to best practice and conform to the following standards:

- 1 I.E.E. Regulations
- 2 Electrical safety requirements for laboratories
- 3 BS3202 Laboratory furniture and fittings
- 4 NFPA 45 for fire protection system

The following shall be provided at the Laboratory on site, complete with associated glassware and chemical inventory, as a minimum. The laboratory shall be suitably sized to allow for free flowing movement of the analyst, and to house the listed equipment:

| Item              | Qty. | Specifications                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-------------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| pH meter          | 1    | pH range : -2.00 - 20.00<br>mV range: ±2000.0 mV<br>Temp range: (-5.0 to 105.0 °C)<br>pH buffer options: 2,4,7,10,12<br>Memory: 10,000 data sets<br>Power: 9VDC, 3.3A center negative                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Spectrophotometer | 1    | Beam Height: 10 mm<br>Data Logger: 2000 measured values (Result, Date, Time, Sample ID, User ID)<br><br>Display Type: Colored touch-screen<br>Enclosure Rating: IP30<br>Includes: Adapter "A" for 1" round + Accuvac/1 cm rectangular cuvettes, manual in m 5 languages (GB, D, F, I, E), power supply 100 - 240V, 47 - 63Hz.<br>Interfaces: USB type A (2)<br>Light Source: Gas-filled Tungsten (visible)<br>Max. operating humidity:80 %<br>Max. Storage Humidity:80 %<br>Operating Conditions:10 °C - 40 °C<br>Operating Mode: Transmittance (%), Absorbance and Concentration, Scanning<br>Optical System: Reference beam, spectral<br>Photometric Accuracy: 5 mAbs @ 0.0 - 0.5 Abs<br>Photometric Accuracy 2: 1 % at 0.50 - 2.0 Abs<br>Photometric Linearity: < 0.5 % - 2 Abs<br>Photometric Linearity 2: ≤ 0.01 % at >2 Abs with neutral glass at 546 nm<br>Photometric Measuring Range: ± 3.0 Abs (wavelength |



| Item          | Qty. | Specifications                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|---------------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|               |      | range 340 - 900 nm)<br>Power Requirements: With external power supply<br>Power Requirements (Hz): 60 Hz<br>Power Requirements (Voltage): 110 - 240 V AC<br>Power Supply: Benchtop Power Supply<br>Preprogrammed Methods: > 240<br>Sample Cell Compatibility:<br>Rectangular: 10, 20, 30, 50 mm, 1 inch; round: 13 mm, 16 mm, 1 inch<br>Scanning Speed: > 8 nm/S (in steps of 1 nm)<br>Specific Technology: RFID for easy method update, sample ID and<br>Spectral Bandwidth: 5 nm $\pm$ 1 nm<br>Storage Conditions: -30 °C to 60 °C<br>Stray Light: < 0.1 % T at 340 nm with NaNO <sub>2</sub><br>Wavelength Accuracy: $\pm$ 1.5 nm (wavelength range 340 - 900 nm)<br>Wavelength Calibration: Automatic<br>Wavelength Range: 320 - 1100 nm<br>Wavelength Reproducibility: $\pm$ 0.1 nm<br>Wavelength Resolution: 1 nm<br>Wavelength Selection: Automatic, based on method selection<br>Weight: 4.2 kg |
| Thermoreactor | 1    | Heating Rate: 20 to 150 °C in 10 minutes<br>Number of cuvettes: 15 vials x 16 mm (single block)<br>Operating Temperature Range: 10 - 45 °C<br>Power Requirements (Hz): 50 - 60 Hz<br>Power Requirements (Voltage): 115 V AC<br>Temperature Range: 37 - 165 °C (99 - 329 °F)<br>Temperature Stability: $\pm$ 2 °C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Vacuum pump   | 1    | Max. power : 80 W<br>Max. current : 0.4 A<br>Max. vacuum : 670 mmHg<br>Max. flow rate : 34l/min<br>Motor rotation : 1300 RPM<br>Horse power : 1/6 HP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

| Item               | Qty. | Specifications                                                                                                                                                                                                                                                                                  |
|--------------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Analytical Balance | 1    | Capacity: 320 g max<br>Min. Display: 0.1 mg<br>Repeatability: $\leq 0.1$ mg<br>Linearity: $\pm 0.2$ mg<br>Stabilization time: 3s<br>Operating Temp and Humidity: 5-40°C 20-85%*2<br>Temp Coefficient for Sensitivity: $\pm 2$ ppm/°C<br>Pan size (mm) approx: $\Phi 91$<br>Power req't: 12V, 1A |
| Oven               | 1    | Temp range: min. 5°C above ambient up to +300°C<br>Volume: 32 L<br>Max loading of Chamber: 60kg<br>Max loading per internal: 20kg<br>Stainless steel Door<br>Timer: Digital backwards counter with target time setting, adjustable from 1 minute to 99 days<br>Touch screen Panel               |
| Desiccator         | 1    | Electrical: 134041-115VAC, 134241-115VAC (or 134041-2-230V, 134241-2-230V) 50/60 Hz 35 W*<br>Dricycler automatically regenerates desiccant every five hours                                                                                                                                     |
| Incubator          | 2    | Temp range: min. 5°C above ambient up to +80°C<br>Volume: 32 L<br>Max loading of Chamber: 60kg<br>Max loading per internal: 20kg<br>Voltage Electric load: 230 V, 50/60 Hz approx. 1600 W<br>Ambient Temp: +5 °C to +40 °C<br>Humidity rh: max. 80 %, non-condensing                            |
| Quantitray Sealer  | 1    | Weight: 16 kg<br>Dimensions: 30cm H x 27cm D x 39cm W<br>Ambient Temp: 0-32°C<br>Power: 230V, 50Hz, 3Amp (model 99-10896-00)                                                                                                                                                                    |

| Item              | Qty. | Specifications                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-------------------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Manometer         | 1    | psi: 0.5psi (0.001psi)<br>inH <sub>2</sub> O: 13.85inH <sub>2</sub> O (0.01inH <sub>2</sub> O)<br>mbar: 34.47mbar (0.01mbar)<br>kPa: 3.447kPa (0.001kPa)<br>inHg: 1.018inHg (0.001inHg)<br>mmHg: 25.85mmHg (0.01mmHg)<br>ozin <sup>2</sup> : 8.00ozin <sup>2</sup> (0.01ozin <sup>2</sup> )<br>ftH <sub>2</sub> O: 1.154ftH <sub>2</sub> O (0.001ftH <sub>2</sub> O)<br>cmH <sub>2</sub> O: 2.59cmH <sub>2</sub> O (0.01cmH <sub>2</sub> O)<br>kgcm <sup>2</sup> : 0.035kgcm <sup>2</sup> (0.001kgcm <sup>2</sup> )<br>bar: 0.034bar (0.001bar)<br>Basic Accuracy: ±0.3%FS<br>Dimensions/Weight: 8.2x2.9x1.9" (210x75x50mm)/<br>9.8oz (280g)                                                                     |
| Moisture Analyser | 1    | Measuring method: Infrared heat drying mass measurement<br>Sample pan size: ø130 mm<br>Minimum display in weighing: 0.001g<br>Measurement range of moisture content: 0.01% to 100.00%<br>Moisture content minimum display: 0.01%<br>Maximum sample capacity: 120 g<br>Measurement mode: Automatic or Timed halting modes, Rapid, Slow and Step drying modes, Predictive Measuring mode<br>Drying heater: Mid-wave infrared quartz heater<br>Setting temperature range: 30°C to 180 °C (by 1°C increments)<br>Dimensions & weight: W220xD415xH190 (mm), 4.5 kg<br>Operational temperature and humidity range: 5 °C to 40°C, 85% RH maximum<br>Power requirements: 100 V to 127 V/220 V to 240 V AC, 640 W maximum |
| Refrigerator      | 1    | Refrigerant: R404A- CFC- free<br>Defrosting: completely automatic, thermostat controlled.<br>The condensate water is automatically channelled into an heated tray, located in the cabinet backside, for the automatic evaporation of the condensate water<br>Temp range: infinitely adjustable to +2°C/ +15°C<br>Voltage: 220-230/1/50<br>noise level: ≤ 54 dB                                                                                                                                                                                                                                                                                                                                                   |

| Item                       | Qty. | Specifications                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------------------|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Thermohygrometer           | 1    | Humidity range: 10 to 99%RH<br>Basic RH accuracy: $\pm 5\%$ (25 to 80%)<br>Temperature range: 14 to 140°F (-10 to 60°C)<br>Basic Temperature Accuracy: $\pm 1.8^\circ\text{F}/1^\circ\text{C}$ (14 to 122°F)<br>Dimensions: 4.3 x 3.9 x 0.78"(109 x 99 x 20mm)<br>Weight: 6oz (169g)                                                                                                                                                                    |
| Jar tester                 | 1    | RPM: Each bank may be programmed with paddle speeds from 5 to 300 rpm in 1-rpm increments<br>Time: 1 second to 59 minutes and 59 seconds<br>Programmable Audio Signals<br>Six B-KER2 square, acrylic, 2-liter jar testing jars, along with a dust cover and a one-year manufacturer's warranty.<br>Power: 24VDC w/ adapter from 120V- 220V, 50/60 HZ power sources                                                                                      |
| Water Purifier             | 1    | Capacity: 30 L<br>Type I Water (Resistivity): 18.3 MΩ-cm<br>Type I Water (TOC): <1 ppb<br>Type I Water (Conductivity): 0.055 μS/cm<br>Type I Water (Bacteria): <1 CFU/mL<br>Type I Water (Endotoxins: )<0.001 EU/mL                                                                                                                                                                                                                                     |
| Microscope X magnification | 20   | Head:<br>Binocular, 360° rotating, 30° inclined<br>Eyepieces:<br>Wide Field 10x/18mm<br>Nosepiece:<br>Quadruple, reversed<br>Objectives:<br>Achromatic 4x, 10x, 40x, 100x<br>Stage:<br>Double layer, 125×115 mm with 70x30mm X-Y moving range<br>Focusing:<br>Coaxial coarse and fine focusing<br>Condenser:<br>N.A. 1.25 Abbe type with adjustable height and iris diaphragm<br>Illuminator:<br>3W X-LED <sup>2</sup> system with adjustable intensity |

| Item               | Qty. | Specifications                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UV- cabinet        | 1    | UV- lamp: 4, 5 or 6 watts in combinations of LW, MW, SW                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Fumehood           | 1    | Temperature: 0-1,300 °C<br>Voltage: 220V<br>Power: 8KW                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Autoclave          | 1    | Chamber Capacity: 0.054247 m3<br>Maximum Pressure: 0.255 Mpa<br>Electric Power: 2.0 kW<br>Voltage: 120V, 50-60Hz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| O&G Analyser       | 1    | Name: Oil Content Analyser<br>Measurement method: Solvent extraction - non-dispersive infrared absorption analysis method<br>Measured objects: Infrared absorption near wavelength 3.4-3.5um<br>Measurement range: 0 mg/L to 200 mg/L<br>Resolution: For mg/L 0 to 99.9: 0.1, 100 to 200:1<br>Repeatability: 0 mg/L to 9.9 mg/L: $\pm 0.2$ mg/L $\pm 1$ dig.<br>10.0 mg/L to 99.9 mg/L: $\pm 2.0$ mg/L $\pm 1$ dig.<br>100 mg/L to 200 mg/L: $\pm 4$ mg/L $\pm 1$ dig. *For standard liquids<br>Extraction solvent: S-316<br>Operating Temp: 0 °C to 40 °C (no condensation)<br>Power supply: AV 100 V to 240 V $\pm 10\%$ , 50/60 Hz<br>Power Consumption: AC 100 V: Approx. 60 VA, AC 240 V: Approx. 90 VA<br>External dimensions: 342 (H) X 200 (W) X 313 (D) mm<br>Mass: Approx. 7 kg |
| Beaker             | 10   | 50 ml                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                    | 10   | 100ml                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                    | 6    | 250 ml                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                    | 6    | 500 ml                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                    | 6    | 1 L                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Graduated Cylinder | 4    | 10 ml                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Item               | Qty. | Specifications |
|--------------------|------|----------------|
|                    | 4    | 25 ml          |
|                    | 6    | 50 ml          |
|                    | 6    | 100 ml         |
|                    | 4    | 250 ml         |
|                    | 4    | 500 ml         |
|                    | 5    | 1 L            |
| Volumetric Flask   | 4    | 50 ml          |
|                    | 6    | 100 ml         |
|                    | 5    | 250 ml         |
|                    | 5    | 500 ml         |
|                    | 4    | 1 L            |
| Erlenmeyer flask   | 2    | 250 ml         |
|                    | 2    | 1 L            |
| Buchner funnel     | 2    | 1 L            |
| Buchner flask      | 2    | 1 L            |
| Vacuum clamp       | 1    |                |
| Crucible           | 30   |                |
| Crucible tong      | 2    |                |
| Evaporating dish   | 25   |                |
| Glass Stirring rod | 2    |                |
| Steel Tray         | 1    |                |

| Item           | Qty. | Specifications |
|----------------|------|----------------|
| Test tube rack | 1    |                |
| Finn Pipette   | 1    |                |
| pipette        | 4    | 10 ml          |
|                | 4    | 1 ml           |
|                | 4    | 5 ml           |
| Wash bottle    | 2    | 250 ml         |

Upon the end of the Process Proving Period, the Contractor shall replenish the consumables in the laboratory sufficient for it to be able to continue with the daily analytical works for 3 months;

The area required for each room/office shall be determined by the Contractor referring the Contractor’s proposed layout drawings. All buildings shall be supplied fully furnished. Floor to ceiling height shall be at least 3.5 m but the Contractor may allow vaults and for equipment and facilities installation and maintenance.

The offices shall be provided with telephone and LAN/WAN systems.

The administration building shall include access control systems, adequate intruder detection, fire detection, a sprinkler system and other fire-fighting requirements, air conditioning, power, lighting (including emergency lighting), water supply and sewerage systems. The building shall be connected to the emergency power supply to be provided in the Works to ensure safety and security.

#### 12.17.7 Spare Parts Storeroom

12.17.7.1 The Contractor shall design and build a spare parts storeroom with a holding capacity sufficient to accommodate all the spare parts that shall be required to be delivered under the Contract.

12.17.7.2 It shall be so provided with space saver modular galvanized steel shelves of adjustable multi-tier design, complete with signage for spare parts description. Two (2) suitable aluminum ladders shall be provided for convenient access to upper shelves. If needed by the technology to be provided, a fully air-conditioned cubicle shall be allocated for electronic parts that need to be protected from a humid environment.

#### 12.17.8 Equipment Storage Area

Equipment workshop or storage area with a minimum area of 100 m<sup>2</sup> shall be provided for the temporary storage of equipment that may be needed to replace defective ones

and of those uninstalled for repair or disposal. The storage area shall be accessible to motor vehicles and shall be provided with lifting facilities and space saver modular galvanized steel shelves of adjustable multi-tier design.

#### 12.17.9 Hazardous Waste Storage Room

12.17.9.1 Hazardous waste storage room with a holding capacity of at least thirty (30) days shall be designed and built by the Contractor for the temporary storage of hazardous waste containers in accordance with DENR requirements. It shall also comply with the Republic Act. No. 6969.

12.17.9.2 The hazardous waste room shall be provided with bund wall and applicable warning and directional signs to indicate the nearest telephone, or exit. An eyewash and emergency shower shall be provided at the main door.

12.17.9.3 Hazardous wastes shall be collected by the Employer's accredited hazardous waste hauler/treater. Treatment report copies shall be sent to the Employer for records.

#### 12.17.10 CCTV System for Plant Process Monitoring and Security Surveillance

12.17.10.1 A CCTV system shall be provided to monitor the entire plant treatment processes and security risk areas.

12.17.10.2 Process monitoring cameras shall be installed to monitor the following unit operations and processes in the WTP:

- 1 Dosing in Coagulation channels;
- 2 Flocculation and Sedimentation Basins;
- 3 Filtration Tanks and Air Blower room;
- 4 Chlorination/Oxidation rooms
- 5 Sludge dewatering operation;
- 6 Sludge cake discharge area; and
- 7 Chemical storage areas.

12.17.10.3 Security surveillance cameras shall be installed to monitor the following security strategic areas of the WTP:

- 1 Entrance gate vicinity;
- 2 Entrance door(s) of the administration building;
- 3 Guard house and its vicinity;
- 4 Control room floor of the administration building;
- 5 Ground floor of the administration building;
- 6 Entrance of the spare parts storeroom;
- 7 Entrance of the hazardous waste storage room;
- 8 Entrance of Security room/IT Room;
- 9 Entrance of Electrical Building and;



10 All corners of the perimeter walls, and at a spacing not more than 50 m.

12.17.10.4 Cameras shall be strategically located in order to maximize and have clear views of the unit operations and treatment processes taking place in the above mentioned areas as well as areas with potential security risks.

12.17.10.5 The camera types could be the outdoor or indoor type as what shall be applicable in its strategic location. For outdoor operation, camera with platform, tilt, zoom and panning operation shall be used. For indoor operation, wall or ceiling type with fixed focus shall be used.

12.17.10.6 Monitoring screen shall be installed in the guard house as captured by the security surveillance cameras. At the plant central monitoring room located at the administration building, both security surveillance and plant unit operation/process shall be shown on the monitoring screens.

12.17.10.7 Digital image recorder installed in the administration building shall be of all-in-one type.

#### 12.17.11 Others

The Contractor shall provide the following:

12.17.11.1 Suitable vehicle access roads around the premises;

12.17.11.2 Parking for plant personnel and visitors for a minimum of ten (10) cars near the administration building;

12.17.11.3 Parking for at least two (2) chemical delivery trucks;

12.17.11.4 Landscaping including tree planting along the perimeter wall inside the WTP;

12.17.11.5 Provision of all signage external of the RWTL and WTP to inform the public of the presence of the new RWTL and WTP, associated traffic routes and pedestrian routes on the public highway; and

12.17.11.6 Provision of lighting such that the WTP can be maintained during the hours of darkness. Lighting shall be controlled by pyroelectric (passive) infrared (PIR) sensors such that energy use can be minimized.

12.17.11.7 Helipad provision for any emergency or evacuation response

1 The Contractor shall provide one (1) helipad within the Site or on any of its structures, for a helicopter's arrival, departure, or hovering/taxing operations.

2 The helipad design shall comply with local safety requirements and meet specifications of the Manual of Standards for Aerodromes 2017 (and 2021 amendments) by the Civil Aviation Authority of the Philippines (CAAP) and/or other relevant standards as approved by the Engineer.

3 Helicopters using the facility will be civilian passenger-type and/or emergency services aircraft. The helipad shall be designed for single-engine helicopter with seating capacity of 2 pilots and at least 8 passengers.

- 4 The location of the helipad should be on the most accessible and obstacle free area for the approach and take off of the helicopter and shall maintain the necessary obstacle clearance. The headwinds should be well identified for the helipad location consideration and drainage should be sloped away from the helipad.
- 5 A wind direction indicator shall be provided in the form of an orange wind sock for the pilots to identify the direction of the wind. As minimum, the indicator shall be installed not less than 40m from the helipad and shall be in accordance with the Manual of Standards of Aerodrome by CAAP.
- 6 A helicopter simulation must be conducted to validate the helipad functionality. The simulation tool or software to be used, including its features and version, shall be informed to the Engineer and Employer. The simulation shall provide the following information as minimum requirement:
  - (A) Helicopter Taxiing or hovering route
  - (B) Time and distance separation between leading helicopter and following helicopter – in an instance of emergency evacuation on the area.
  - (C) Helicopter Maneuvering, with the following details:
    - (i) Hovering speed
    - (ii) Taxiing speed
    - (iii) Time needed for boarding of passenger reaching full capacity after touchdown
    - (iv) Time needed for taking off having full passenger capacity
- 7 In case the helipad will be placed on top of a covered structure, the following minimum requirements should be considered in the design:
  - (A) Weight of the helicopter with full passenger capacity;
  - (B) Any impact of the uplift force of the helicopter to the roof slab;
  - (C) Vibration due to the landing and taking off the helicopter;
  - (D) Proper access such as but not limited to, stairs with landing going to the top of the structure;
  - (E) Allowable clearance on the edges of the structure to provide adequate space for the Final Approach and Takeoff (FATO) area;
  - (F) Provision of proper markings and safety signages, and;
  - (G) Provision of lighting for the access and helipad area;
- 8 In case the helipad will be placed on ground level, the following minimum requirements should be considered in the design:
  - (A) Provision of necessary concrete pad to ensure the flat landing surface;
  - (B) Allowable clearance from other structures and linked to an access road within the Site;
  - (C) Obstacle free for the landing and take off approach;
  - (D) Provision of proper markings and safety signages, and;
  - (E) Provision of lighting for the helipad area;

- 9 The Contractor shall prepare the Aerodrome Manual in accordance with the requirements stipulated in Civil Aviation Regulations (CAR) - Aerodromes and standards in the Manual of Standards for Aerodromes by CAAP. The Aerodrome Manual shall be provided to the Employer and Engineer for acceptance prior on submitting to CAAP;
- 10 The Contractor shall prepare all documents necessary to obtain the essential permits and clearances such as but not limited to:
  - (A) Aerodrome Certificate, and;
  - (B) Permit to Operate
- 11 The Contractor shall prepare the necessary documents and accommodate the authorized third-party personnel for any safety inspection, on-site verification, and initial surveillance during the process of acquiring the essential permits and clearances.
- 12 The operation and maintenance of the helipad provision shall be included on the Construction Health and Safety Plan and Emergency Response and Evacuation Plan (see Section 3).

## **13 Mechanical Requirements**

### **13.1 General**

13.1.1 This section aims to specify and summarize the basic scope of works and requirements for the mechanical equipment and appurtenances for the Design and Construction of RWTL and WTP.

13.1.2 The mechanical requirements for this project shall include, but not limited to the following:

13.1.2.1 Design, supply and installation of all mechanical equipment and appurtenances necessary for the RWTL and WTP such as but not limited to;

- 1 Mechanical Intake Screening System;
- 2 Incline Settler and Sludge Scraper System.
- 3 Dry and Gaseous Chemical Feed Equipment, System and Appurtenances.
- 4 Recovery Water Supply System;
- 5 Potable Water Supply System;
- 6 Fire Protection and Suppression System including but not limited to standpipes, hydrants, hose reel systems, fire and jockey pumps, fire hydrant and water tanks, portable fire appliance and interfacing work with other trade services such as MVAC, FDAS, etc.;
- 7 Fuel Oil System, including but not limited to, fuel oil storage tank, fuel day tank, fuel oil piping and accessories and fuel oil system controls;
- 8 Plumbing and Drainage System for buildings including the requirement of emergency eyewash and safety shower systems in the pertinent hazardous areas in the WTP;
- 9 Mechanical Ventilation (supply and exhaust) and Airconditioning System.
- 10 Mechanical Thickening and Dewatering System;
- 11 Blowers, Mixers and Pumps;
- 12 Valves, Penstocks Sluice Gates, Pipeworks, Control points and Connections;
- 13 Required works for plant maintenance access walkways, stairways, platforms and lifting equipment/facility;

13.1.3 Mechanical equipment and appurtenances, pipes, fitting and valves material selection shall take into account the;

- 1 Characteristics of the handled media (i.e raw water, sludge, chemicals, etc.)
- 2 Potentially corrosive environment within which it operates.

- 13.1.4 Materials and equipment employed throughout the Works shall be of the highest grade, free from defects or imperfections, unused and of recent manufacture and of a classification and grade in full conformity with the Employer's Requirements. Where standard specifications do not exist, materials shall be to the highest standard currently adopted within the industry.
- 13.1.5 All mechanical equipment and appurtenances (wetted and non-wetted parts), when fabricated from ferrous metal, shall be factory coated and finished with the manufacturer's standards, and shall have a dry film thickness of at least 250 microns. Coatings shall be suitable for the process media handled and the environment where the equipment is installed.
- 13.1.6 Lay-out of mechanical equipment and appurtenances shall consider accessibility, maintenance and safety requirements.
- 13.1.7 The Contractor shall supply equipment that has been proposed during the bid. The list of preferred brands and accredited suppliers are shown in Appendix 16 Contract Specific Specifications. The Contractor's supplier shall be duly accredited by MWC Vendor Management. Vendor accreditation shall be achieved before the start of PPP. However, unless agreed between the Employer and the Contractor, the following conditions with supporting proof of evidence are considered for the replacement of the proposed equipment during the bid with an alternative brand equivalent or higher than its required Specifications, in the event that:
- 1 The Contractor's bid item for the proposed brand of equipment is not available in the market during the time of the project execution,
  - 2 The delivery of the available brand of equipment to be supplied will contribute further delays in the project execution, and;
  - 3 The Employer will have after-sales issues.
- 13.1.8 All mechanical equipment and appurtenances shall have local technical and after-sales support.
- 13.1.9 The Contractor shall submit a method statement indicating appropriate delivery, handling and storage for all mechanical equipment and appurtenances.
- 13.1.10 Data sheets of all mechanical equipment and appurtenances shall be submitted and approved prior to procurement. The document shall include but not limited to compliance list, technical brochure/product catalog, shop drawings, local support statement and service agreement of the principal and local support.
- 13.1.11 Compliance list shall compose of a checklist that the proposed material is fully compliant with the ER and SES.
- 13.1.12 All process related mechanical equipment, including blowers, pumps, and mixers, shall be equipped with online monitoring, including the working efficiency, power consumption, working frequency/ speed, vibration, pressure and temperature etc.
- 13.1.13 All mechanical equipment, valves and appurtenances shall be designed, manufactured, tested, and installed in accordance with recognized and latest local and/or international codes and standards. In the case that the standards set forth in the Contract documents have been superseded, the latest version of the standards shall be used.

- 13.1.14 Equipment efficiency selection shall achieve the best energy efficiency for all operating conditions.
- 13.1.15 The Contractor shall provide an appropriate level of redundancy and include in its design, duty and standby arrangements of all process related mechanical equipment.
- 13.1.16 The latest issue of the NEMA Premium Energy Efficiency Motor standards or IE3 Energy Efficiency Motor standards shall be the preferred energy efficiency reference for low voltage motors up to 500HP motors.

## **13.2 Process Related Equipment**

- 13.2.1 All process related mechanical equipment shall be compliant with the preferences and requirements set forth in Section 13 and SES 13.
- 13.2.2 All mechanical equipment nozzles shall be in accordance with ISO 7005. Minimum rating shall be PN 10. In the case that the required pressure rating is above PN 10, the Contractor shall provide the acceptable flange that can cater the design system pressure rating.
- 13.2.3 If no specific preference or requirement is indicated in Subsection 13 for a particular type of process equipment, the Contractor shall suffice the specifications of SES 13.

### **13.2.4 Intake Screening System.**

- 13.2.4.1 The intake screen system shall be an Automatic Trash Rack type capable of handling maximum expected screenings. The system shall be either monorail or stationary type.
- 13.2.4.2 The system shall compromise of but not limited to grab or gripper and bar screen. Both shall be made of SS316.
- 13.2.4.3 The grab or gripper shall be automatically operated (lifted and lowered). It shall be able to remove and capture the trapped screenings within the screen and between the bars of the screens. It shall also be fully capable of holding the screenings.
- 13.2.4.4 Bar Screens shall have a minimum clear opening of 40 mm. Bars shall have a flat rectangular or trapezoidal section.
- 13.2.4.5 Operation of the system shall accomodate different water levels and timer-based controls. Level Indicating transmitters shall be provided upstream and downstream of screens. Adjustable timer setpoints shall be provided.
- 13.2.4.6 Operation of the screen shall require minimum maintenance. Bars and grippers shall be easily removable.
- 13.2.4.7 For flexibility, design shall allow for manual operation of the system.
- 13.2.4.8 Installation shall provide easy access for maintenance of mechanical and electrical components and allow manual cleaning in case of excessive screenings build up.
- 13.2.4.9 A monorail type system shall be equipped with a slack rope device detection.

### **13.2.5 Inclined Settlers**

13.2.5.1 Inclined Settlers shall be either be Plate or Tube type.

13.2.5.2 Inclined settler supports assembly shall be designed capable to sustain the load of the inclined settlers, load of the sludge accumulated in the settlers, the load of the water in the clarified water launders, load of a person standing on top of the inclined settlers and other necessary loadings.

13.2.5.3 All materials of construction shall be corrosion resistant.

13.2.5.4 Materials shall meet or exceed required health and safety standards and regulations for drinking water applications set by the local government and other independent international agencies.

13.2.5.5 Supplied materials shall be certified by NSF/ANSI 61 or other equivalent Drinking Water Inspectorate.

### **13.2.6 Sludge Scraper**

13.2.6.1 Sludge Scrapers shall either be reciprocating bottom scraper or chain and flight type.

13.2.6.2 Scrapers shall be designed according to the size and level of the tanks.

13.2.6.3 All metallic components of scrapers shall be manufactured from SS 304L as minimum.

13.2.6.4 Scraper blades/flights shall run on HDPE slides or other equivalent or superior rubber material for low friction, reducing wear and tear along the line.

13.2.6.5 For reciprocating scraper blades shall be SS 316 and shall be bolt connected.

13.2.6.6 Scraper drive can either be hydraulic or electric powered. Further, the scrapers shall be provided with torque limiting switches.

13.2.6.7 In the hydraulic unit, a food grade lubricant shall be used. . It shall be equipped with hydraulic oil pressure sensors and safety interlocks in case of high pressure.

13.2.6.8 The drive mechanism shall be positioned at the most convenient end of the tank for easy access and maintenance.

13.2.6.9 Cleaning arrangement shall be provided to unclog sludge from the scrapers.

### **13.2.7 Chemical Feeder Systems**

13.2.7.1 A chemical feeder and equipment system suited for the media to be handled shall be designed and supplied by the Contractor.

13.2.7.2 The design and supply shall include but not limited to dosing pumps, suction and discharge pipework and fittings, motor and variable speed drive and controls, required instrumentations, and other necessary appurtenances.

#### 13.2.7.3 Dry Feeder System

- 1 All powdered chemicals shall be handled and processed by a fully automatic dry feeder system.
- 2 The system shall comprise but not limited to loading system, storage hopper, extension hopper, hopper covers, feeders, storage tanks equipped with mixers and heaters, dust collector, make-up and service water provision.
- 3 The hopper shall be equipped with a load cell and bin activator. The load cell shall ensure that an optimum weight of powder is stored within the hopper. Bin activators shall facilitate smooth flow of powder from the hopper to the feeders.
- 4 Dry feeders as a minimum shall be Volumetric Type equipped with torque limiters. A provision for emptying the conveyor in case of clogging shall be provided.
- 5 Storage tanks shall be provided with overflow, vent, access manhole and drain arrangement.
- 6 Additional requirements for Polymer powder feeder system shall be in accordance with SES 13.16.

#### 13.2.7.4 Gas Feeder System

- 1 Liquified chlorine gas and other chemical gases shall be handled and processed by a fully automatic chlorinator/gas feeder system.
- 2 The system shall be comprised of, but not limited to, electronic platform weighing scale, vacuum regulator and pressure gauge, changeover unit, vacuum safety valve, flow meter and regulating valves, injector non-return valve and injectors, vacuum breaker and booster pumps for water.
- 3 Each chlorine gas tank shall be equipped with a shut-off valve. Tanks shall be fixed by chains or other means.
- 4 An emergency gas scrubber system suitable for liquified chlorine gas shall be installed within the room.

### 13.2.8 Mechanical Thickening and Dewatering Equipment

13.2.8.1 The Contractor shall propose the specific thickening technology that shall meet all process requirements, subject for review and approval of the Engineer and Employer. Material of construction of metallic components shall be SS 316.

13.2.8.2 Mechanical Dewatering Equipment shall conform to SES 13.15. Other technologies such as but not limited to decanter centrifuges, multi-disc screw presses, etc. shall be allowed provided the justification from the Contractor's design and is subject for review and approval of the Engineer and Employer. Material of construction of mettalic components shall be SS 316.

#### 13.2.9 Blowers

13.2.9.1 Blowers shall be Centrifugal or Screw type with over pressure protection. Rotary lobe type air blower type shall not be used.



13.2.9.2 Centrifugal blowers shall be single or multi-stage.

13.2.9.3 Screw blowers shall be single-stage direct drive or belt driven type. Belt driven motors shall have an automatic tensioning feature and tension indicator. It shall also include a silencer or pulsation dampener feature.

13.2.9.4 Blowers shall be designed to suit the duty specified in capacity for Water Treatment Plant.

13.2.9.5 Blowers shall have the function to operate continuously at any time to provide adequate air supply for scouring.

13.2.9.6 Typical blower performance curves shall be submitted by the Contractor and appended to the completed data sheets.

13.2.9.7 Performance test shall meet the acceptance criteria in accordance with standard the blower is referenced to. In the absence of such, an alternative recognized international standard or industry practices shall be used.

13.2.9.8 Blowers shall be designed to achieve sound pressure levels below 85 dBa measured 1 meter around the blower. During normal operation, sound levels shall also not exceed 85 dBa when measured 1 meter from the outside wall of blower rooms.

#### 13.2.10 **Mixers**

13.2.10.1 Mixer shall attain highest possible mixing performance to maintain highest active volume and minimize solids build-up, crust and foam formation.

13.2.10.2 Design shall ensure that maximum thrust requirement is achieved whilst having the minimum power consumption.

13.2.10.3 Impeller type shall be selected considering the purpose or functionality and characteristics of the medium handled. It shall have a self-cleaning feature to minimize maintenance.

13.2.10.4 Installation of mixers shall be capable to sustain all necessary loads present during operation.

13.2.10.5 Mixers and its appurtenances handling sludge shall be made of SS 316.

13.2.10.6 Performance test shall meet the acceptance criteria in accordance with standard the mixer is referenced to. In the absence of such, an alternative recognized international standard or industry practices shall be used.

##### 13.2.10.7 Static Mixers

- 1 Static mixers shall either be pipe or channel type depending on the Contractor design.
- 2 Materials of construction shall be made of SS 316.
- 3 Design shall ensure that the correct dosing amount of chemical is injected proportional to the local mainstream.

- 4 Installation of pipe static mixers shall be by PN 16 flanged connection. Channel type installations shall be wall mounted.

#### 13.2.11 Pumps

- 13.2.11.1 The requirements for pump sets in this document shall be read in conjunction with SES 13.17 and SES 13.36.
- 13.2.11.2 Each pump shall fully comply with AWWA/ASTM standard. If no pertinent standard can be referenced from AWWA/ASTM, an applicable international standard shall be used as an alternative.
- 13.2.11.3 The pump-set shall accommodate the variation in the water level as required by Contractor's design and / or particular installation in the WTP.
- 13.2.11.4 Characteristics curves as per SES 13.36,1,d shall include head, flow, pump efficiency, pump power input, motor power input and pump net positive suction head required (NPSHR) versus flowrate at operating speed shall be submitted by the Contractor and appended to the completed data sheets. The net positive suction head available (NPSHA) shall be greater than the NPSHR to avoid cavitation.
- 13.2.11.5 The head-capacity curves for centrifugal pumps shall rise continuously to shutoff for all applications.
- 13.2.11.6 Performance test shall meet the acceptance criteria in accordance with standard the pump is referenced to. In the absence of such, an alternative recognized international standard or industry practices shall be used.
- 13.2.11.7 Material for body casing, suction and delivery discharge flanges as per SES 13.36,1,b shall be changed upon consideration of 13.1.3. Proposed material shall be suitable for intended media application and considering the resistance to corrosion, abrasion and mechanical shock.
- 13.2.11.8 Suction and discharge flange ratings shall be in accordance with SES 13.36,1,b. A higher or lower flange rating shall be allowed in consideration of 13.2.2. Minimum rating shall be PN 10.
- 13.2.11.9 Bearing's minimum life as per SES 13.36,1,f may be reduced in agreement with the Employer. For this, the Contractor shall provide suitable evidence that the bearings are selected to industry standards and best practices.
- 13.2.11.10 A torque limiting device shall be fitted between the gearbox and the pump.
- 13.2.11.11 Levelling screw for alignment shall be provided in addition with SES 13.36,1, e.
- 13.2.11.12 Lifting eyebolts or lugs shall be provided for lifting the pump, gearbox and motor.
- 13.2.11.13 Anchor bolts and nuts required for fixing shall be made of SS 316. If galvanic corrosion is likely to occur, insulating washers shall be used to prevent direct contact between different metals.

### 13.3 Pipework

13.3.1 The requirements for pipework in this document shall be read in conjunction with the SES 2 and 13.

13.3.2 All pipework and associated pipeline equipment and fittings shall have the appropriate temperature and pressure rating for the system in which it is operating and shall be flanged according to SES 13.

13.3.3 In force mains applications, minimum and maximum design velocities shall be maintained considering the characteristic of the handled medium and pipe material. Maximum velocity shall be designed to avoid high head loss and protect valves.

13.3.4 All process pipes shall be provided with wall thickness calculations in accordance with the applicable local or international standards. Datasheet for all process pipe material shall be submitted to the Engineer and Employer for review and acceptance.

13.3.5 Pipe diameter of  $\geq$  DN 1,000 mm for the RWTL pipe shall be made of steel.

13.3.6 WTP pipe material shall be in accordance with SES 2.80, 13.12.1 and table below:

| Medium Handled                           | Pipe Material                        |                     |
|------------------------------------------|--------------------------------------|---------------------|
|                                          | Exposed                              | Buried or Submerged |
| Raw Water, Process Water & Treated Water | SS 304                               | SS 316              |
| Sludge                                   | SS 316                               | SS 316, HDPE        |
| Air                                      | SS 304                               | SS 316              |
| Filtrate and Supernatant                 | HDPE, Galvanize Iron<br>uPVC         | HDPE, uPVC          |
| Fire Protection                          | Fire Code of the Philippines or NFPA |                     |
| Plumbing and Drainage                    | RNPCP and UPC                        |                     |

13.3.7 Pipe and fitting materials and connections for Chlorine and Dry Chlorine shall be in accordance with SES 2.78 and 13.13.

13.3.8 Ductile iron pipe material shall not be used.

13.3.9 Design and installation of plumbing and drainage piping shall be in accordance with RNPCP. In the case that there is no provision in the RNPCP, UPC shall be followed.

13.3.10 Pipe connections shall be in accordance with the following methods

| <b>Material</b>              | <b>≤ DN 65</b>     | <b>≥ DN 75</b> |
|------------------------------|--------------------|----------------|
| Galvanize Iron<br>Black Iron | Thread             | Flange         |
| Stainless Steel              | Thread or Weld     | Flange or Weld |
| Thermoplastic<br>Pipes       | Threaded or Socket | Flange or Weld |

- 13.3.11 Pipe and fitting distances from equipment suction and discharge, such as for pumps and blowers, shall be considered in accordance with best industry practices.
- 13.3.12 All exposed thermoplastic pipes shall be UV resistant coated.
- 13.3.13 Flanges shall be in accordance with SES 13.6,1. A higher or lower flange rating shall be allowed provided that it is appropriate on the operating design ranges of the Contractor. Minimum flange rating shall be PN 10.
- 13.3.14 Flange bolts shall be in accordance with the corresponding standards set forth in the standards of the selected flange.
- 13.3.15 Pipework shall be designed to accommodate and prevent failure modes by means of introducing expansion joints, seismic couplings, rocker pipes or other means accepted by the Engineer and Employer. Failure modes to be considered shall be but not limited to:
- 1 Seismic events (i.e. axial tension, local buckling due to axial compression, beam buckling, and flexural failure).
  - 2 Potential ground movement (i.e. consolidation, buoyancy due to liquefaction or lateral movement during seismic event).
  - 3 Mechanical vibrations caused by equipment.
  - 4 Thermal expansions.
- 13.3.16 Design for pipe sleeves and puddle flanges shall be in accordance with SES 13.12.2.
- 13.3.17 Pipes coupled to structures shall accommodate movement of structures and pipes. Underground pipes shall be provided with rocker pipes. Above ground pipes and pipes inside structures shall be provided with seismic couplings. Where there is risk of breakage, due to structure or pipe movements, leading to rapid drainage of process treatment tank then an automatic shutdown valve shall be installed.
- 13.3.18 General piping of process equipment shall be sufficiently flexible and adequately supported to prevent equipment nozzles from being subjected to any stresses that could disturb their alignment or internal clearances or otherwise affect the equipment. The allowable loads and moments on equipment nozzles shall be in accordance with the relevant codes and standards, and within the limits stated by the Manufacturer for the equipment.

- 13.3.19 Trenches for buried pipes shall inspected prior to any pipe laying activity. Trenches shall be in accordance with SES 3.5. Buried pipes shall be designed to accommodate all internal and external loads. External loads to consider shall be but not limited to earth load, traffic load and construction load.
- 13.3.20 All buried steel pipes shall be protected from direct contact with the backfill soils. Steel pipes shall be polyethylene encased or coated. Coating to be used shall be as per manufacturer's recommendation.
- 13.3.21 Pipelines on road crossing shall be encased to protect it from external loads. Casing pipe material shall be concrete or steel. Minimum size and installation shall be in accordance with AWWA C604. Steel casing pipes shall be in accordance with ASTM A1097.
- 13.3.22 All pipework shall be adequately supported. Pipe supports shall be designed to carry all internal and external loads that is present within the pipeline. Thrust block design for pipes shall be in accordance SES 2.32.
- 13.3.23 Pipe support material as per SES 13.6, 4 shall be changed upon consideration of 13.1.3 and is subject for review and approval of the Engineer and Employer. Pipe support in contact with raw water, process water and treated water shall be SS 316.
- 13.3.24 Leak test drain and vent connections shall be installed, without valves, at all low and high points in piping.
- 13.3.25 Piping shall not obstruct inspection covers, bearing caps, upper valves of casings or any other items which require access for operation or maintenance.
- 13.3.26 Strainer/filter selection shall reflect the nature of the fluid and the potential contaminants within the system. Strainers/filters shall be located to facilitate safe and easy access for element changing/cleaning.
- 13.3.27 Dosing lines that terminate in a pipe (main) shall be provided with a withdrawable injection fitting, capable of injecting chemical into the process fluid at the required pressure and incorporate facilities to prevent reverse flow (e.g. a non-return valve). A suitably rated flexible piping section shall be incorporated, designed to allow their safe and unhindered removal. Lines shall also have cleanout fittings to provide maintenance in the event of clogging.
- 13.3.28 Rodding and jetting points for cleaning sludge pipes shall be provided at all bends, corners and at least every 50m on straight pipes. These points shall incorporate coupling devices and isolation valve, suitable access for rodding and manual solids removal.
- 13.3.29 Pipe markings shall be in accordance with SES 2.79. Location of identification markers and sizes of legend letters shall be in accordance with ASME A13.1

#### **13.4 Valves**

- 13.4.1 The requirements for valves in this document shall be read in conjunction with SES 13.7.
- 13.4.2 All valves handling sludge shall be knife gate valves complying with AWWA C520.
- 13.4.3 Steel ball valves shall conform to AWWA C507 or BS ISO 7121.

- 13.4.4 All valves shall be suitable for bi-directional flow, unless there is a specific requirement.
- 13.4.5 All valves shall be arranged and positioned at accessible locations to ensure the safe and effective operation and maintenance. Wherever necessary, extension spindles shall be provided. All manually operated and actuated valves shall be installed with permanent hand-wheels. Clear access to the valve hand-wheels shall be provided to avoid of valve hand-wheels being tucked behind other valves or equipment.
- 13.4.6 Valves shall be provided with dismantling joint to allow for ease of disassembly.
- 13.4.7 All valves shall undergo all production test stated in the standard to which it conforms to. The Contractor is to provide certificates for all the tests conducted.

### 13.5 Lifting Facilities

- 13.5.1 Lifting facilities shall be in accordance with SES 13.21 – 13.22.
- 13.5.2 Test reports/certificates shall be provided for all new and temporary lifting appliances as part of the factory and site testing.
- 13.5.3 After the installation of the lifting appliances, examinations and tests for all the lifting appliances together with the I-beams as required under regulations under the supervision of a qualified surveyor shall be carried out. The Contractor shall submit the qualifications of the third-party surveyor to the Engineer for review and acceptance.
- 13.5.4 One original and two copies of the surveyor's test reports/certificates shall be submitted to the Engineer within two (2) weeks on completion of the official tests for record and displaying of certificates. The validity periods of the test reports/certificates shall cover the whole Defect Notification Period. All equipment, including test weights shall be supplied for the above tests.
- 13.5.5 Each item of the lifting equipment including I-beams shall bear a permanent inscription on each side clearly legible from ground floor level, stating the safe working load and the test date.

### 13.6 Mechanical Ventilation and Airconditioning System

- 13.6.1 The Contractor shall be responsible for a complete design, supply and installation of mechanical ventilation and airconditioning systems including its electrical components, connections, and other appurtenances.

#### 13.6.2 Mechanical Ventilation

- 13.6.2.1 Ventilation fans and facilities shall be provided in manned areas listed but not limited to below. Ventilation rates shall be calculated as per breathing zone requirements under ASHRAE 62.1 or air changes as per table below. Design shall be based on-the resulting greater-value.

| Location          | Type of System |                           | Air Change Rate per Hour |
|-------------------|----------------|---------------------------|--------------------------|
|                   | Exhaust        | Intake                    |                          |
| Transformer Rooms | Mechanical     | Natural via louvered door | 15                       |
| Enclosed          | Mechanical     | Natural via               | 15                       |

|                                              |            |                              |    |
|----------------------------------------------|------------|------------------------------|----|
| accessible spaces<br>in process plant        |            | louvered door                |    |
| Chlorine Storage<br>and Chlorinator<br>Rooms | Mechanical | Mechanical                   | 10 |
| Storage Rooms                                | Mechanical | Natural via<br>louvered door | 6  |
| Workshop                                     | Mechanical | Natural via<br>louvered door | 6  |
| Toilets                                      | Mechanical | Natural via<br>louvered door | 15 |

13.6.2.2 For mechanical rooms such as but not limited to blower, pump and generator set rooms, the Contractor shall submit a calculation determining the supply air intake and discharge air exhaust rates requirements. The ventilation system design shall be submitted for review and acceptance of the Engineer and Employer.

13.6.2.3 For chlorine, chlorinator room and other rooms handling chemical gases, ventilation systems shall automatically shut-off in case of gas leakage.

13.6.2.4 For MCC rooms, switchgear rooms and other rooms with total flooding system, ventilation shall be supplied to exhaust the flooding agents.

13.6.2.5 The indoor air quality in such locations shall at all times be free from toxic, harmful or disagreeable gases & flumes, shall be relatively free from odor & dust and shall conform with internationally accepted standards, e.g. ASHRAE, IME, etc.

13.6.2.6 The quality of air used to ventilate the space during the occupancy shall always be sufficient to maintain the standards of air temperature, air quality, air motion and air distribution.

13.6.2.7 Outdoor exhaust openings shall be located so as not to create nuisance. Exhaust air shall not be directed onto walkways.

13.6.2.8 Location of intakes and discharges shall ensure adequate spacing so as to avoid close circuiting, i.e. recirculation of vitiated air.

13.6.2.9 Air exhaust and intake openings that terminate outdoors shall be protected with corrosion resistant screens, louvers and grilles.

13.6.2.10 Each exhaust fan shall be capable of continuous operation.

13.6.2.11 Dampers shall be provided and installed in the proper size, type and location for optimum operation of air circulation system.

13.6.2.12 Screen and louvers shall be made of stainless steel or aluminum.

13.6.2.13 Propeller Fans

- 1 Propeller fans shall be mounted to suit particular installation. Wall mounted fans shall be supplied with wall boxes and plates suitable for removal for cleaning.

- 2 Fan and motor shall be mounted on resilient support and heavy metal frame.
- 3 Units shall have adequate wall cap and with gravity type back damper or similar shutters and wire guard.

13.6.2.14 Axial Fans

- 1 Fan shall be tube axial fan, directly driven motor.
- 2 Casing shall have flanged end connections with provision of inspection door.
- 3 Impeller shall be fastened to the hub or hub and impeller shall be as one piece.
- 4 Fans shall be complete with resilient mountings, mounting feet, connection spigot, wire guards and dampers and silencer. A silencer shall be provided if required to comply with noise restriction.



13.6.2.15 Centrifugal Fans

- 1 Fan shall be backward curved or airfoil multi-blade type with matching house.
- 2 Bearings shall be self-aligning ball type with factory sealed lubrication.
- 3 Housing shall be black mild steel sheets.

13.6.2.16 Parts of fans in contact with explosive or flammable vapors, fumes, or dusts shall be of non-ferrous or non-sparking materials or their casing shall be lined or constructed of such material.

13.6.2.17 Fans located in systems conveying corrosive vapors / gasses shall be composed of materials that are resistant to corrosion or shall be coated with corrosion resistant materials.

13.6.3 Airconditioning System

13.6.3.1 Design shall be in accordance with the following criteria in the table below and comply with ASHRAE or PSME standards.

| Ambient Temperature | Summer (°C) | Winter (°C) |
|---------------------|-------------|-------------|
| Dry Bulb            | 40          | 40          |
| Wet Bulb            | 30          | 10          |
| Daily Range         | 9.7         | 9.7         |

13.6.3.2 Design calculation for all spaces with Airconditioning system shall be submitted by the Contractor.

13.6.3.3 Airconditioning system shall be a split system or window type, both being inverter with minimum EER rating of 10.

13.6.3.4 Refrigerant shall be non-CFC type. No ozone depleting substances shall be used as refrigerant. DENR requirements on refrigerants shall be followed.

13.6.3.5 All spaces installed with airconditioning system shall be maintained at room temperature of 24 °C. Spaces such administration building, SCADA Control Room, MCC, LVSG, guard house and the like shall be airconditioned.

13.6.3.6 Minimum features shall be but not limited to motor protection, timer setting and thermostat control via remote or manual. For MCC rooms, cooling shall be supported by air flow analysis to ensure correct temperature and humidity levels.

13.6.3.7 The storage area for polymer and other powdered chemicals shall be installed with dehumidifier.

#### **13.6.3.8 Split System**

- 1 Split system shall be direct expansion type.
- 2 Split system shall consist of 2 complete packaged units consisting of a air-cooled condensing unit and a matched fan coil unit complete with all accessories and any appurtenances specified and required for the operation of the equipment.
- 3 Pipe insulation materials shall be installed in accordance with manufacturer's specification.

#### **13.6.3.9 Window Type**

- 1 The condensing of the unit shall have a blue fin protection feature.
- 2 Opening shall be tightly sealed as not to allow any leakage of air within the space.

### **13.7 Fire Protection and Suppression System**

13.7.1 Design shall be in accordance with SES 13.20

13.7.2 The Contractor shall provide fire protection and suppression systems for the whole site. The design of fire protection systems shall comply with RA 9514, Revised Fire Code of the Philippines 2019, PME Code and NFPA standards. The fire protection system shall be completed with automatic detection and alarm systems in accordance with the governing codes and standards.

13.7.3 FK-5-1-12, complying with the same standards set forth in SES 13.20,3, shall be allowed as a Total Flooding System agent in addition to HFC-227ea. Design, installation and testing of total flooding system shall be in accordance with NFPA 2001 or other equivalent standard.

13.7.4 Fire protection for genset room shall be designed, installed and tested in accordance with NFPA 37 and NFPA 820 for Sludge Treatment and Disposal Facility.

### **13.8 Fuel Storage System**

13.8.1 Design shall be in accordance with SES 13.18 – 13.19.

13.8.2 Minimum requirements for storage tank and day tanks shall be size in accordance with SES 13.18, Generator Set Accessories. Storage and day tanks capacity shall meet genset fuel consumption.

13.8.3 Fuel pipe material shall be seamless black iron, as per SES 13.19, in accordance with ASTM A53/A53M.

13.8.4 Any fuel used during the testing and commissioning period prior to process proving shall be at the Contractors expense.

## **14 Electrical Requirements**

### **14.1 General**

- 14.1.1 The Contractor shall conform to these Employer's Requirements for design and performance requirements. Should the rating of specified equipment in the Bidding documents be found to be inadequate to meet the actual loading of the Bid offer, all suitably rated equipment shall be provided that has equivalent or better performance than those proposed in the Contractor's detailed design.
- 14.1.2 Motor ratings where shown in the drawings are only for reference. The Contractor shall provide appropriate motor ratings based on the unit processes and equipment designed with sufficient design margin for safe and reliable operation and maintenance in the long term.
- 14.1.3 All electrical drawings, calculations, study and analysis reports shall be submitted with Professional Electrical Engineer (PEE) endorsement.
- 14.1.4 All electrical equipment and works shall comply with the Specifications, Philippine Electrical Code (PEC), applicable local regulations and applicable international codes.
- 14.1.5 All materials and equipment shall be based from the Employer preferred supplier list. Contractor shall provide uniformity of brands for easy maintenance and spare parts of the Employer.
- 14.1.6 All electrical equipment and appurtenances shall have local technical and after-sales support. Service agreement of the principal and local support shall be secure by the Contractor and shall submit to Employer.
- 14.1.7 All electrical equipment and appurtenances shall be capable of being isolated for maintenance without shutting down entire plant operations.
- 14.1.8 Submission by the Contractor

14.1.8.1 The submissions by the Contractor in accordance with the Specifications shall include but not be limited to the following:

#### **1 Drawings**

- (A) Electrical network single-line drawings with details of circuit breakers, busbars, cables, busways, transformers, protection, measurement, and interlocks.
- (B) Single line diagrams and schematic diagrams for all switchgears, motor control center, distribution boards and other panels for equipment package.
- (C) Detailed shop drawing for all equipment shall show relay settings to give correct discrimination to the electrical network protection system with upstream and downstream equipment.
- (D) Electrical equipment general arrangements, panel layouts, panel sections, clearances from structures and adjacent equipment.
- (E) Layout of all electrical components within each (front/rear) compartment.
- (F) Equipment installation, cable termination details.

- (G) Lighting & Small Power Layout
  - (H) Lightning Protection System Layout
  - (I) Earthing Schematics
  - (J) Auxiliary Systems and Peripherals (Fire Detection and Alarm System, CCTV System, Telephone and Data System)
  - (K) Cable route drawings including installation details and cross-sections.
  - (L) Drawings detailing the necessary cable trenches, ducts, penetrations and holes and openings and fixing holes for panels, arrangement of cable trays and their supports.
- 2 All other drawings necessary for the complete understanding of the operation, maintenance and extension of the electrical system including any required for the Owner to dismantle, repair, maintain, modify or extend the Plant shall also be provided.
  - 3 All electrical work/installation, particularly those affecting safety, operation and maintenance of the electrical equipment, including sizing of conductors, selection and setting of protection devices, layout of components within switchboards and control panels etc shall be supervised by Licensed Electrical Engineer and certified by one and same Professional Electrical Engineer appointed by the Contractor to take charge of the whole electrical work in this project.

#### 14.1.8.2 Electrical System Study

- 1 The Contractor shall conduct an electrical system study using approved Electrical design computer software for more accurate result for the entire proposed Plant to ensure that the fault current ratings as indicated in the drawings for the electrical system and equipment are in order. The Contractor shall provide electrical system and equipment to the rated fault current for the review by the Engineer. In this system study, the discrimination of protection relay settings shall be established. A technical note of the electrical design computer software shall be provided to the Engineer.
- 2 A full report with system diagrams showing the relevant study data, results and the recommended relay settings shall be submitted to the Engineer for review before submission of any proposed equipment technical drawings or documents for approval prior to equipment purchases.
- 3 The electrical system study shall include load flow analysis, short circuit and protective device coordination study and arc fault analysis

#### 14.1.8.3 Total Harmonic Distortion (THD) Study

- 1 The Contractor shall conduct a THD study for the proposed WTP to ensure that THD at the common coupling point shall comply with the requirement of IEEE 519 and the Contractor shall provide appropriate measures to reduce THD to the specified level. The methods shall be approved by the Employer.

- 2 A full report with system diagrams showing the relevant study data, results and the recommended methods shall be submitted to the Engineer for review before submission of any relevant proposed equipment technical drawings or documents for approval prior to equipment purchases.

#### 14.1.8.4 Calculations and Cable Schedules

- 1 Calculations on motor sizing, cable sizing, fuse, circuit breakers' sizing, Kaic rating, power factor correction, rating of battery chargers and battery banks for DC supplies, etc.
  - (A) Using an approved electrical design computer software to verify: compliance with PEC, correct selection of cable sizes, circuit breakers/fuses, adequate protection of cables and equipment connected to them, adequate discrimination between upstream and downstream circuit breakers.
  - (B) Cable schedules shall include all details like origin and destination equipment, cable types and sizes, cable voltage drop result, cable route and lengths, installation methods, and other information necessary for site construction works.

#### 14.1.9 Equipment Submittal

14.1.9.1 The Contractor shall submit the following information as a minimum for review of all electrical equipment prior to procurement.

- 1 Manufacturers Type Test Certificates
- 2 Equipment Catalogues
- 3 Equipment Datasheets
- 4 Compliance with Specifications
- 5 Type Test Certificates
- 6 Performance Test Certificates;
- 7 Manufacturers' Installation & Site Tests/Commissioning Instructions Manuals and Data Sheets

14.1.9.2 Manufacturers' works test certificates;

14.1.9.3 Installed equipment performance test certificates;

14.1.10 Composite manual of all manufacturers catalogues and data sheets for all equipment provided.

14.1.10.1 Manufacturers' instruction sheets for correct installation, site testing and commissioning of each equipment.

14.1.10.2 Documents necessary to fully understand the principle of operation, mechanism, correct installation, testing and commissioning of any non-standard package, system or sub-system.

14.1.10.3 Any documentation on materials which may be harmful to human health or the environment.

#### 14.2 Electrical Supply

14.2.1 The main power supply intake for the WTP shall be from Meralco at 34.5kV, three-phase, 60Hz.

- 14.2.2 The Contractor shall liaise with Meralco and comply with all their requirement including provision of space for the metering facility and required substation for 10MVA and above demand.
- 14.2.3 The Contractor shall design, supply, test and commission an emergency generator set/s to provide power supply in case of power supply failure from Meralco. The generator set/s shall be designed to keep the WTP in operation for at least 5 days, at the peak electrical loads.
- 14.2.4 The Contractor shall design the emergency generator set with consideration of spare for future expansion and propose the most beneficial number of generating units for the Plant and to the review of the Engineer.
- 14.2.5 The Employer shall be responsible for all costs associated with organizing the connection, including any costs associated with upgrading the supply if needed. The Contractor, with the Employer's assistance, shall undertake all negotiations with respect to power supplies.
- 14.2.6 Due to the uncertainties associated with the costs of providing the Electric Company's Power supply, this item for utility connections is covered by a provisional sum. The scope covered by the provisional sum shall include the following items:
- 14.2.6.1 Payment of fees including Meralco Permit Application and other associated fees related to construction and implementation
  - 14.2.6.2 Providing Meralco with a Single line Diagram with Load Schedule and vicinity map. This shall only cover any additional costs associated with the Contractor changing the format of the Load Schedule and their own plans to a form needed by Meralco, as the Contractor will be producing their own versions of these documents as part of their own design work.
  - 14.2.6.3 Securing of Certificate of Electrical Inspection and costs of attendances to support Meralco in obtaining this
  - 14.2.6.4 All other necessary works (coordination works) associated in applying for and obtaining Meralco Permanent Power Connection
  - 14.2.6.5 Costs charged by Meralco for connections and upgrades to the existing distribution network
  - 14.2.6.6 Availability (or Standing) charges that may be incurred from obtaining this increased power supply
- 14.2.7 As a note, the Employer shall be responsible for the payment of the cash advance, bill deposit and metering facility deposit. However, it is the Contractor's responsibility to advise the Employer about the magnitude of fee and timing. The Contractor shall allow sufficient time for the Employer to complete the payment.
- 14.2.8 The provisional sum shall not include the following items and these items are deemed to have been included with the Contractor's tendered price:
- 14.2.8.1 Any cabling within the WTP boundary.

- 14.2.8.2 Any delays caused by the Electric Company's power supply not being available (this shall be treated as a Contractor's risk). It is assumed that the Contractor has taken the necessary allowances to order power supplies early in the contract period and therefore does not suffer delay.
- 14.2.8.3 Any program extensions as a result of the work covered by the provisional sum.
- 14.2.8.4 Any indirect costs, such as risk allowances, overheads, and fees associated with delivering the stated work.
- 14.2.8.5 Transformers, switches or other equipment needed by the Contractors design.
- 14.2.9 The Contractor shall submit official receipts and proof of payment for all works under this item for the progress of its billing request.
- 14.2.10 Delays caused by power supply coordination
  - 14.2.10.1 Due to the uncertainties associated with the timeline of coordinating with Electric Company's Power supply, the Contractor shall be responsible for the early coordination with Meralco and Employer regarding the requirements for the construction of distribution line and determine the location of the project's substation / transformer.
  - 14.2.10.2 The Contractor shall identify the absolute maximum duration for coordinating these works with Meralco. This shall be indicated in their programme, highlighted as something critical. This duration is subject to agreement with the Engineer and Employer.
  - 14.2.10.3 Once the duration and key dates for coordination are agreed in the Contractor's programme, they shall ensure that the key dates and activities dependent on the Contractor are achieved.
  - 14.2.10.4 Once the coordination with Meralco starts, the Contractor shall demonstrate reasonable proof of coordination, with relevant milestones discussed on a monthly basis with the Engineer and Employer, or more frequently if the Contractor finds the necessity.
  - 14.2.10.5 If the Contractor fails to achieve their key dates / activities and fails to demonstrate reasonable proof of coordination, then the Contractor shall be deemed liable for these delays. Otherwise, the Contractor shall apply an EOT for the delays caused by power supply coordination.

### **14.3 Hazardous Areas and Selection of Electrical Equipment**

- 14.3.1 Hazardous areas are areas where explosive gas/air mixtures are likely to exist during normal operation.
- 14.3.2 All electrical equipment for use in these areas shall be flameproof or explosion-proof, Ex (d) as defined in IEC or equivalent internationally recognized standard.
- 14.3.3 All instrumentation for use in hazardous areas shall be intrinsically safe.



14.3.4 Cable connections to all electrical equipment in hazardous areas shall be through Ex cable glands.

14.3.5 The Contractor shall conduct the study and recommend the areas that will be classified hazardous. The report shall be submitted to the Engineer for approval prior to implementation.

#### **14.4 Scope of Electrical Works**

The Scope of Works under this Contract for the Electrical Works shall include but shall not be limited to the complete detailed design, shop drawing, supply, fabrication, delivery, storage, installation, construction, witnessed Factory Acceptance Test, site testing and commissioning and performance proving.

##### **14.4.1 Power Supply Intake**

14.4.1.1 Full evaluation of power supply requirements and co-ordination with Meralco for the intake of power supply at 34.5kV.

14.4.1.2 The Contractor shall liaise with Meralco, comply with their guidelines and requirement on provision of the feeder cables, isolations, metering and necessary civil works.

##### **14.4.2 34.5KV Drop-out Fuse Cut-outs and Load Break Switch (LBS)**

14.4.2.1 The Contractor shall design and provide 34.5KV Drop-out Fuse Cut-outs and LBS design, supply, install, test and commission.

14.4.2.2 All necessary protection, foundation and accessories to complete these systems are to be provided by the contractor in closed coordination to Meralco.

14.4.2.3 34.5KV Drop-out Fuse Cut-outs and Load Break switch shall conformed to SES 12.32 and 12.33 Electrical and Instrumentation.

##### **14.4.3 34.5kV Medium Voltage Switchgear (MVSG)**

14.4.3.1 The Contractor shall design and provide 34.5kV MVSG complete with DC supply for the power supply intake and shall be installed in a separate fire compartmentalized switch room.

14.4.3.2 All protection functions for incoming circuits as imposed by Meralco, and protections for outgoing feeder to transformer shall be provided. The Contractor shall provide any additional protection required by the MVSG and transformer manufacturer for safety of equipment and personnel, reliability of equipment, and for ease of Operation and Maintenance.

14.4.3.3 Medium Voltage Switchgears shall conform to SES 12.22 Electrical and Instrumentation.

##### **14.4.4 2.4kV Medium Voltage Switchgear**

- 14.4.4.1 The Contractor shall design and provide 2.4kV MVSG complete with DC supply and necessary accessories to complete the system. The contractor shall ensure that this equipment shall conform to latest edition of ANSI, IEC, NEC, PEC and other standard codes relative to the system.
- 14.4.4.2 The Contractor shall provide all necessary protection for incoming and outgoing feeder required by the MVSG and manufacturer.
- 14.4.4.3 The contractor shall guarantee safety, reliability and ease of Operation and Maintenance of equipment and personnel.
- 14.4.4.4 Medium Voltage Switchgear (2.4kV) shall conform to MWCI SES 12.22 Electrical and Instrumentation.
- 14.4.4.5 The Contractor shall provide a provision of power supply to treated water pumping station (scope by others) with a minimum power requirement of 10,000 kVA. The Contractor shall include main protections, power meters and other peripherals in accordance with MWCI SES 12.22 Electrical and Instrumentation. Contractor may refer to Appendix 11, SLD for preliminary information.
- 14.4.5 34.5kV/2.4kV Medium Voltage Step down Pad Mounted Substation Type Transformer
  - 14.4.5.1 Transformer insulating fluid shall be less flammable liquid insulated and environmental friendly with more than 300 degrees centigrade fire point.
  - 14.4.5.2 Pad mounted Substation type transformer shall conform to MWCI SES 12.19.2 Electrical and Instrumentation.
- 14.4.6 2.4kV/460V Medium Voltage Step Down Pad Mounted Dead Front Type Transformer
  - 14.4.6.1 The Contractor shall design, supply, install, test and commission MV Pad Mounted Dead Front Type Transformer conforming to MWCI SES 12.19.3 Electrical and Instrumentation.
- 14.4.7 460/230V Low Voltage Step Down Dry Type Transformer/s
  - 14.4.7.1 The contractor shall design, supply, install, test and commission Low Voltage Step Down Dry Type Transformer/s, conforming to MWCI SES 12.19.4.
- 14.4.8 Low Voltage Switchgear (LVSG)
  - 14.4.8.1 The contractor shall design, supply, install, test and commission Low Voltage Switchgear (LVSG), conforming to SES 12.23 & 12.24 (Low Voltage Circuit Breakers).
  - 14.4.8.2 The Contractor shall provide a power quality meter (PQM) with energy monitoring functions and connect to the SCADA. The PQM shall be at the LVSG's main incomer
- 14.4.9 Motor Control Centers (MCC)

14.4.9.1 The Contractor shall design, supply, install, test and commission at least six (6) sets of MCC for the Plant.

14.4.9.2 The Contractor shall design, supply, install, test and commission Motor Control Centers (MCC), conforming to SES 12.26 Electrical and Instrumentation.

14.4.9.3 The Contractor shall install the MCCs in a manner that long cables to motor and equipment can be minimized.

14.4.9.4 Motor control centre shall be provided with minimum one spare starter of each motor starter type and size.

#### 14.4.10 MV Variable Frequency Drives and Soft Starters

14.4.10.1 MV VFDs and MV Soft Starters shall be complete with bypass vacuum contactors, protections and other necessary accessories as per manufacturers recommendation and standards.

14.4.10.2 The contractor shall ensure that these motor starters are operating at 2.4kV system and compliant to IEC 62271-1, UL 347, UL 347B, IEEE and NEMA standard.

#### 14.4.11 LV Variable Frequency Drives and Soft Starters

14.4.11.1 The contractor shall design, supply, install, test and commission Variable Frequency Drives, conforming to SES 12.37 Electrical and Instrumentation.

14.4.11.2 The contractor shall design, supply, install, test and commission Soft Starters, conforming to SES 12.36 Electrical and Instrumentation.

#### 14.4.12 Lighting and Small Power Distribution Board

14.4.12.1 The Contractor shall design, supply, install, test and commission Distribution Boards, conforming to SES 12.27 Electrical and Instrumentation.

#### 14.4.13 Medium Voltage Automatic Transfer Switch (ATS) Panel

14.4.13.1 The Contractor shall design, supply, install, test and commission Automatic Transfer Switch (ATS), with electrical components inline with SES 12 Electrical and Instrumentation and generator set requirements inline with SES 13.25 Mechanical works.

14.4.13.2 The Contractor shall provide an MV ATS with manual bypass isolation for performing ATS maintenance.

14.4.13.3 The MV ATS shall be compliant to UL 1008A.

14.4.13.4 The MV ATS shall provide seamless transfer from emergency to normal power.

#### 14.4.14 Multi-Step Automatic Power Factor Correction or Capacitor Banks

14.4.14.1 The contractor shall design, supply, install, test and commission all provided Multi-Step Automatic Power Factor Correction or Capacitor Banks.

14.4.14.2 The Contractor shall determine the size of capacitor bank based on the total plant capacity to maintain the total power factor of the plant of 85% to 98% at all time during normal operation.

14.4.14.3 The Contractor shall provide the capacitor bank with detuned reactor to optimized low power losses and load linearity.

14.4.14.4 Power Factor Correction shall conform to SES 12.31 Electrical and Instrumentation.

14.4.15 Active Harmonics Filter Panels

14.4.15.1 The Contractor shall design, supply, install, test and commission all provided Active Harmonics Filter Panels, conforming to SES 12.31 Electrical and Instrumentation.

14.4.16 Medium Voltage Generator Set/s

14.4.16.1 The Contractor shall design, supply, install, test and commission prime type generator set/s for emergency power complete with necessary generator switchgear synchronizing panel.

14.4.16.2 The Contractor shall design the local control panel of the generator to automatically turn off the capacitor bank during emergency operation.

14.4.16.3 MV Generator set/s shall be compliant to UL, NFPA, IEC, IEEE and other international standards.

14.4.16.4 MV Generator set shall conform to SES 13 Mechanical works.

14.4.17 MV Synchronizing Panel

14.4.17.1 The Contractor shall design, supply, install, test and commission the MV synchronizing panel in line with the MV Generator set/s requirement and protection.

14.4.17.2 MV Synchronizing Panel shall be compliant to NEC, PEC, IEC, IEEE, ANSI and other international standards.

14.4.18 Neutral Grounding Resistor (NGR)

14.4.18.1 The Contractor shall design, supply, install, test and commission the required Neutral Grounding Resistor in line with the MV Generators set/s requirement and protection.

14.4.18.2 Neutral Grounding Resistor shall be compliant to latest edition of NFPA 70, UL, IEEE and other codes and standards applicable.

14.4.19 Lighting and MVAC Distribution Boards

14.4.19.1 The Contractor shall design, supply, install, test and commission Distribution Boards, conforming to SES 12.27 Electrical and Instrumentation.

14.4.19.2 Distribution Boards shall be compliant to the latest edition of NEC and PEC regarding maximum number of poles per board.

14.4.20 Local Control Panels (LCP) – Packaged Process Equipment

14.4.20.1 The Contractor shall design, supply, install, test and commission local control panels complete with isolation, protection, starter/drives, control and interface to SCADA for all packaged process equipment.

14.4.21 Valve actuators DBs & control panels, remote control units (RCU) with isolators (located close to the motors). RCU enclosures shall be made of SS 304.

14.4.22 Complete lighting and small power system for the Plant.

14.4.22.1 The contractor shall design, supply, install, test and commission all lighting and small power system necessary to complete the WTP

14.4.22.2 Lighting and small power system shall conform to SES 12.12 Electrical and Instrumentation.

14.4.22.3 Illumination levels shall be as per table below. For other areas not specified below, illumination level shall conform to SES 12.12 item 10 Electrical and Instrumentation.

| Type of Location | Area                                                 | Lux levels(Average) |
|------------------|------------------------------------------------------|---------------------|
| Indoor           | General walkway areas                                | 100                 |
| Indoor           | General staircase areas                              | 200                 |
| Indoor           | Storerooms                                           | 100                 |
| Indoor           | Bathrooms, washrooms and toilets                     | 200                 |
| Indoor           | Electrical and ICA Equipment Rooms                   | 200                 |
| Indoor           | Operating areas (Plant Areas)                        | 200                 |
| Indoor           | Control rooms                                        | 500                 |
| Indoor           | Offices and meeting rooms                            | 300                 |
| Indoor           | Laboratories                                         | 500                 |
| Outdoor          | General walkway areas (Exclusive for pedestrians)    | 30                  |
| Outdoor          | Roads, streets, loading, carparks and unloading bays | 30                  |
| Outdoor          | Operating areas                                      | 50                  |

| Type of Location | Area     | Lux levels(Average) |
|------------------|----------|---------------------|
| Outdoor          | Carparks | 10                  |

14.4.23 Complete grounding or earthing system for all proposed electrical installations and equipment under the Contract.

14.4.23.1 The Contractor shall design, supply, install, test and commission a complete grounding or earthing system, conforming to SES 12.16 and 12.18.6 Electrical and Instrumentation.

14.4.23.2 Complete equipotential bonding for all exposed metal parts under the contract in compliance with the Specifications and PEC.

14.4.24 Complete lightning protection system for all new outdoor structures and equipment under the contract.

- 1 The lightning protection systems shall conform to the requirements in SES 12.18 Electrical and Instrumentation and NPFA 780 and PEC.
- 2 Upon completion of structures, the Contractor shall proceed to install lightning protection system on the structures before any work is allowed in the Plant. If required, temporary earth points with connecting conductors shall be installed by the Contractor to achieve earth resistance which shall conform with the requirements in the Specifications and PEC. All costs in association with providing temporary earth point system and the replacement with permanent system shall deem to be included in the contract sum.
- 3 Prior to the power connection and commencement of site tests, the temporary earth point system shall be replaced by the permanent system which shall conform to the requirements in the Specifications and PEC.
- 4 Resistance value and date of test shall be indicated on a non-corrosion type label and shall be fixed next to the earth test point of the lightning protection system.

14.4.25 Fire Detection and Alarm System

14.4.25.1 The Contractor shall design, supply, install, test and commission of Fully Addressable type Fire Detection and Alarm System.

14.4.25.2 Fire Detection and Alarm System design shall be compliant to latest edition of NFPA 72, PEC, Fire Code of the Philippines and shall conform to SES 12.42 Electrical and Instrumentation

14.4.26 Cabling for the all switchgears and MCCs, LCP, DB, etc.

14.4.26.1 Power cables from VFD to motors shall be as per VFD manufacturers recommendation.

14.4.27 All cable ladders, trays, trunking, conduits, ducts, multi cable transit (MCT), supports, fixing etc. for the complete installation of the cables supplied under the Contract.

- 14.4.28 Termination of all cables supplied under the Contract including supply of cable lugs (lugs shall be compression type, screw type is no acceptable), glands, gland plates and all other material, tools and labor required to complete the installation.
- 14.4.29 All other electric cabling and cabling work necessary to complete the Works but not specifically mentioned above.
- 14.4.30 Specified or necessary factory, site tests and commissioning to verify the correct operation, performance and compliance with local regulations and Specifications and the necessary manpower (including specialists, professionals or licensed persons), tools, test equipment and materials for successful execution of the whole Works.
- 14.4.31 Fees/costs for specialists, Professional Engineers, and Registered Engineers to design, liaise and submit to authorities, supervise and conduct testing/commissioning of all electrical work necessary for completion of this Contract.
- 14.4.32 Any Mechanical and ICA equipment forming part of the equipment or system in this section shall also comply fully with the requirements described in ICA and Mechanical Specifications.
- 14.4.33 All electrical equipment not mentioned above but required to complete the Works.

## **14.5 Design and Selection Criteria for Electrical Equipment**

### **14.5.1 General**

- 14.5.1.1 The Contractor shall carry out the detailed design in compliance with the process units and equipment selection, performance requirements, segregation of equipment and loads, and other design features all necessary and in full compliance with the Specifications.
- 14.5.1.2 The Contractor shall be responsible for sizing and designing all electrical equipment in accordance with local Regulations, Standards and Codes of Practice. The design work shall follow good engineering practice and the guidelines specified in this Specification.
- 14.5.1.3 A PEE engaged by the Contractor shall endorse all the design work, in accordance with the relevant Regulations, Standards and Codes of Practices.
- 14.5.1.4 All electronic components and printed circuit boards (PCB) used in all the equipment across the entire project shall have conformal coatings in accordance with IEC 61086 - Coatings for loaded printed wire boards.
- 14.5.1.5 All electrical works shall be undertaken by suitably qualified, experienced and appropriately authorised persons. The equipment supplied, and the work carried out shall be in full compliance with all applicable regulations, local standards, International Electrotechnical Commission Standards and other standards as specified.
- 14.5.1.6 Equipment shall be of proven quality and shall be backed up with readily available local support services. Bidders are required to provide their record of supply of similar equipment in previous projects. Bidders are also required to provide details of their back up service and spare part/replacement storage capability.

### **14.5.2 Electrical Equipment Layout**

- 14.5.2.1 The Contractor shall provide floor frames for installation of all floor standing switchgears, MCC and local control panels. All associated civil works such as foundations, plinths, wall penetrations, floor openings or coring of plinths, fire proof and water proof sealing of openings, grouting, cable entry through MCT etc. shall be deemed to be included in the Contract Sum. Complete documentation of O&M manuals and training of the Owner's staff shall also be included for all the electrical equipment.
- 14.5.2.2 For 10MVA and above plant load, the contractor shall coordinate to Meralco their necessary substation requirement and standard spacing. This requirement shall be clearly shown in the drawings. Any cost relative to this work shall be scope by Contractor.
- 14.5.2.3 Layout of equipment shall allow for removal and installation of that equipment without the need to remove any other equipment.
- 14.5.2.4 The clearance behind and around the MVSG shall conform to the minimum requirements conforming to PEC



- 14.5.2.5 Fire and blast rated walls shall be provided between transformers and at the sides of the transformers. Metal gates shall be provided in front of the transformer with guide rails and shall be able to open fully for movement of transformers.
- 14.5.2.6 Provide oil containment pit filled with gravels for transformer bays on ground level. Oil pumping facility shall be provided for pumping out oil from the oil containment pit in case of oil leakages and shall conform to local regulations for disposal and transport.
- 14.5.2.7 Electrical equipment shall be located to meet all requirements of the Specification and local codes for front and rear access clearances.
- 14.5.2.8 Cabling and cable systems shall be run within the cable chambers provided below each switch room. Cable support systems within this space shall be fully co-ordinated with different voltage level cabling systems and other services within this space.
- 14.5.2.9 Exact location of equipment shall be co-ordinated with structural penetrations and other cast-in works.
- 14.5.2.10 All building penetrations including floor slab, ceiling and roof shall have fire proof and water proof sealing for those below known flood levels. Fire stop material shall comply with local Fire Code.
- 14.5.2.11 All electrical switch rooms and transformer bays shall have door locks with master keys. The Contractor shall submit sample locks for Owner's approval.
- 14.5.2.12 All switchgears shall have an appropriately rated slip proof rubber mat of minimum 1kV working voltage and 6kV di-electrical strength and at least 900mm wide placed in front and back. Rubber mat shall comply with IEC 61111, Class 0 for LV system and Class 3 for MV system.
- 14.5.2.13 All switchgears, MCC, local control panels and distribution boards shall be provided with an adequate number of padlocks (at least equal to the total number of feeders) to facilitate locking of feeders when desired for Lock-Out and Tag-Out (LOTO) procedures. A lockable key box shall also be provided in the switch room to house all the keys of the padlocks.
- 14.5.2.14 Standard danger caution notices with black letters on yellow background in local language and English shall be pasted clearly on the doors of the electrical switch rooms.
- 14.5.2.15 Cardiopulmonary resuscitation (CPR) charts, first aid box, and appropriate type of fire extinguisher shall be provided in each switch room and instrumentation room.
- 14.5.2.16 Framed as-built single line diagram (SLD) endorsed by PEE shall be provided in each switch room.

## 15 Structural Requirements

### 15.1 General

15.1.1 All structural designs for foundations, substructure, superstructures, slope protection and related support structures shall be subject to certification by the Engineer-on-Record who shall be either a member in good standing of the Association of Structural Engineers of the Philippines (ASEP), or a Structural Specialist accredited by the Philippine Institute of Civil Engineers (PICE)

15.1.2 The latest applicable codes and standards as listed in these Employer’s Requirements shall apply as the minimum requirements for all items specified herein. The Engineer-on-Record shall clearly state the standards implemented for each element of work.

#### 15.1.2.1 Software

- 1 The Contractor shall prepare and submit a 3D structural model of the structures (foundation, substructure, super-structure and others) for static and dynamic analyses. The 3D modeling shall be done in STAAD Pro.
- 2 Should the Contractor opt to use other structural applications for the mathematical modeling, the Contractor shall provide the Engineer and the Employer authorized stand-alone copies of the said program, and include training in the use of the said program for four (4) Employer’s Personnel. A technical note indicating the capability and reliability of the structural application and mathematical modelling shall be submitted by the Contractor to the Engineer and Employer for review and acceptance prior to any training. Any cost incurred for the program copies and training sessions shall be the responsibility of the Contractor. The lead time for review, acceptance, and training of the structural application shall not entail delay on the design review process of the project. The Contractor shall consider the time needed on their design programme.

#### 15.1.2.2 Seismic Design

- 1 All building structures shall be designed against seismic forces following the ASCE 7 – 10 “*ASCE Standard for Minimum Design Loads for Buildings and Structures*” procedure using the Risk-Targeted Maximum Considered Earthquake ( $MCE_R$ ) and NSCP 2015 “National Structural Code of the Philippines 7th Edition”.
- 2 All liquid-containing structures shall be designed against seismic forces following the ACI 350.3-06 “*Seismic Design of Liquid-Containing Concrete Structures and Commentary*” procedure in reference to ASCE 7-05 “*ASCE Standard for Minimum Design Loads for Buildings and Structures*” using the Maximum Considered Earthquake (MCE) and NSCP 2015 “National Structural Code of the Philippines 7<sup>th</sup> Edition” whichever generates a higher design force. The design RSA shall consider as a minimum, 100% of the NSCP 2015 RSA.
- 3 The structures shall be designated as an Essential/Hazardous Facility and qualified under Risk Category IV of ASCE 7-10.
- 4 The values of Importance Factors to be considered per structure are as follows:

| Structure | Importance Factor |
|-----------|-------------------|
|-----------|-------------------|

|                              |     |
|------------------------------|-----|
| WTP Interface Chamber        | 1.5 |
| Flow Diverting Structure     | 1.5 |
| RWTL Interface Chamber       | 1.5 |
| Coagulation/Flocculation     | 1.5 |
| Sedimentation Basins         | 1.5 |
| Filter Beds                  | 1.5 |
| Sludge Treatment and Storage | 1.5 |
| Backwash Tanks               | 1.5 |
| Contact Tank WTP             | 1.5 |
| Recovery Tank                | 1.5 |
| Tank Farm                    | 1.5 |
| Fire Hydrant                 | 1.5 |
| Fire Storage Tank            | 1.5 |
| Chlorination/Oxidation Room  | 1.5 |
| Blower Room                  | 1.5 |
| Admin Building/Laboratory    | 1.5 |
| Substation                   | 1.5 |
| Guard House                  | 1.0 |
| Perimeter Fence              | 1.0 |

- 5 Inertia forces developed by the structure and its contents during seismic excitation shall be determined based on the Site-Specific Design Response Spectra.
- 6 Effects of vertical acceleration to the structure and its contents shall be in accordance with the governing code and considered in the seismic analysis.
- 7 Dynamic earth pressures shall be calculated based on the Mononobe-Okabe Method, unless the Contractor demonstrates by calculations that developing dynamic earth pressures can be neglected. The Contractor can dispense with a seismic analysis that includes dynamic earth pressures, upon receipt of no objection from the Engineer.
- 8 Where there is liquefaction potential, a site response analysis is required to derive the site-specific amplification factor.

- 9 Reduction in soils strength shall be presented with reference to the applicable codes and standards as listed in this Employer's Requirements. All pipelines and buried chambers shall be designed to accommodate potential liquefaction.
- 10 Evaluation for liquefaction potential and soil strength loss shall be carried out following the provisions of ASCE 7-10.
- 11 Effects of liquefaction induced lateral spreading shall be determined. The soil profile, depth and thickness of liquefiable layers and proximity from a free face or waterfront should be checked to qualify the probability of lateral spreading.
- 12 When designing for structures on piles in sites classified under Site Class D, E or F, piling shall be designed and constructed to withstand deformations from earthquake ground motions and structure response. Deformations shall include both free-field soil strains (without the structure) and deformations induced by lateral pile resistance to structure seismic forces, all as modified by soil-pile interaction.
- 13 Down-drag and kinematic effects shall be investigated for deep foundations.
- 14 For the avoidance of doubt, any foundations, piles, rafts or other supporting elements shall all be designed using the same importance factor as for the superstructure.

#### 15.1.2.3 Structural Design Criteria

##### 1 Standards

- (A) For seismic analysis of the liquid containing structures, the Site-Specific Design Response Spectra for Life Safety Performance Objective (Maximum Considered Earthquake, MCE) attached from the Contractor's site specific hazard assessment (SSHA) shall be used. The design RSA shall consider as a minimum, 100% of the NSCP 2015 RSA. For non-site-specific factors, provisions of Codes cited below shall be used.
- (B) For wind analysis, the provisions of the National Structural Code of the Philippines (NSCP 2015) for wind loads shall be considered. Unless specified otherwise, MWCI structures shall be designed for an exposure category of "C". If actual site topography indicates otherwise, the more severe shall prevail.
- (C) For seismic analysis of building structures:

- (i) The seismic procedures of ASCE/SEI 7-10 (Minimum Design Loads for Buildings and Other Structures) with seismic parameters based on the Risk-Targeted Maximum Considered Earthquake ( $MCE_R$ );
  - (ii) The concrete design procedures of the more onerous between the National Structural Code of the Philippines 6th Edition (NSCP 2015) and ACI Standard on Building Code Requirements for Structural Design (ACI 318M-14); and
  - (iii) The steel design procedures of more onerous between the National Structural Code of the Philippines 6th Edition (NSCP 2015) and the AISC Standards: (1) Specification for Structural Steel Buildings (AISC 360-10) and (2) Seismic Provisions for Structural Steel Buildings (AISC 341-10).
- (D) For design of liquid containing structures, the seismic procedures of ACI 350.3-06 and the concrete design procedures of ACI 350-06 *"Code Requirements for Environmental Engineering Concrete Structures"* shall be used.

#### 15.1.2.4 Materials

##### 1 Concrete

- (A) For structural concrete, the 28-day compressive strength shall not be less than 28 MPa for general structures, and 35 MPa for water-retaining structures.
- (B) Cement shall conform to the requirements of ASTM Type I for general structures and Type II MS (moderate sulfate-resistant) for water-retaining structures in accordance with ASTM C150 requirements or approved equivalent. Properties of cement shown in Table 4 of ASTM C150 shall also be considered.

##### 2 Steel Reinforcement

- (A) Bar reinforcing steel shall be deformed steel bars conforming to ASTM A706, Grade 40 or its equivalent under PNS-49 for bar sizes 10mm and lower, and Grade 60 or its equivalent under PNS-49 for bar sizes 12mm and higher.
- (B) Steel reinforcement shall be free from loose mill and rust scale and from coatings that may destroy or reduce the bond.
- (C) Steel mats or fabric shall comply with ASTM A185, ASTM A497 or ASTM A704M.
- (D) Steel reinforcement shall bear mill identification symbols and shall be tagged with the size and mark number so that different types may be identified. It shall be stored off the ground.
- (E) Every batch of steel reinforcement delivered to site shall be tested to verify mass and tensile properties for every shipment of 5,000kg or a fraction thereof.
- (F) The test shall consist of 5 specimens. Abbreviated testing may be considered on a particular batch at the discretion of the Engineer through a written report indicating the number of specimens to be tested.

3 Structural Steel

- (A) Structural steel sections shall comply with the relevant provisions of ASTM A36.

15.1.2.5 Design Loading Considerations

- 1 All dead loads and superimposed dead loads shall be considered in the design of the structures.
- 2 Equipment weights where applicable shall be included. Should this information be not available at the time of the analysis, the designer shall conservatively assume the weight of the equipment.
- 3 All live loads, i.e. occupancy loads, maintenance loads, movable objects and all other loads that change over time shall be included in the analysis.
- 4 Soil and traffic surcharge load where applicable and as per recommended by the AASHTO code shall be considered.
- 5 Wind loads shall be considered using the provision of NSCP 2015.
- 6 Earthquake loads shall be considered using the provision of applicable codes and standards specified in these Employer’s Requirements.
- 7 Hydrostatic and hydrodynamic loads shall be considered using the provision of NSCP 2015 and ACI 350.3-06 for liquid retaining structures.
- 8 Earth pressure loads and dynamic soil loads shall be using the provisions of NSCP 2015 and ACI 350.3-06 for liquid retaining structure, and NSCP 2015 for building structures.
- 9 Impact loads shall be considered in the design by increasing equipment loads as recommended by NSCP 2015.
- 10 Increase in equipment weights due to induced vibration shall be applied.
- 11 Load combinations without the negating effects of static earth pressures to the hydrostatic and hydrodynamic forces shall be considered.
- 12 Surcharge loads and any other actions of adjacent structures which may cause adverse effects in the construction works of the facilities shall be considered. Appropriate mitigating measures such as but not limited to shore/slope protection shall be implemented if needed.
- 13 All structures shall be designed against both normal and critical operating sewer levels. The sewer level shall be defined as “critical” if the level condition will potentially cause flooding in the plant considering all risks defined in the HAZOP.
- 14 Embedded structure walls and all appurtenant structures around it shall be designed to sustain a minimum pressure due to HS-20 traffic load.

15.1.2.6 Additional Design Loads

- 1 Tank structures exposed to weather shall be designed considering ambient temperatures and temperature load effects, in accordance with AASHTO 2007 “American Association of State Highway and Transportation Officials”.

15.1.2.7 Design Basis Requirements

- 1 Foundation

- (A) The choice of the foundation scheme shall mainly depend on the magnitude of structural loads transmitted to the foundation and underlying ground.
- (B) Settlements shall be considered to establish the allowable bearing capacities.
- (C) Reduction to the allowable soil bearing capacity and liquefaction induced settlement shall be considered where there is liquefaction potential.
- (D) Sizing of the foundation system(s) (i.e. area of footing against bearing capacity or number and arrangement of piles) shall be checked under ultimate level forces against allowable soil bearing pressure or allowable pile capacity.
- (E) Combination of inertial and kinematic loads shall be considered in the design of piled foundations.
- (F) Relevant testing such as pile load test, integrity test, plate load test and similar tests shall be conducted on all foundation solution to verify actual capacity.

## 2 Tank Structures

- (A) Design for concrete sections shall be performed at Ultimate Strength level.
  - (i) Wood-Armer Method shall be used to determine the moment demand forces for the flexural design of concrete liquid-retaining structural walls, mat foundations and slabs.
  - (ii) Floor slabs and walls shall be designed to sustain shear stresses by concrete capacity alone.
- (B) All tanks that are designed to be covered or with a roof slab shall have a minimum 300mm sloshing wave height.
- (C) Design of the structural steel shall be by Load Resistance Factor Design (LRFD). Material strength increase is not allowed. The effect of vertical acceleration shall be considered.
- (D) Stability Requirements
  - (i) Sliding
    - (1) Throughout the construction and overall life of the structure, discrete elements and complete structures shall have a factor of safety at least 1.5 against sliding effect of applied forces.
  - (ii) Overturning
    - (1) Throughout the construction and overall life of the structure, discrete elements and complete structures must have a factor of safety at least 1.5 against overturning effect of applied forces.

(iii) Uplift/Flotation

- (1) Throughout the construction and overall life of the structure, elements and complete pipe works, discrete elements and completed structures shall have a factor of safety at least 1.1 against uplift forces caused by displacement of ground water or inundation from flood water considering operation of works (i.e. tanks empty). The ground water level to be used for the design purpose shall be based from the Ground Investigation results at Design Flood Elevation.
- (2) A permanent anti-flotation solution shall be provided that does not rely on any operational requirement or provision of temporary equipment or materials. Pressure relief valves shall not be used as a permanent anti-flotation design method.

(E) Serviceability Requirements

- (i) Throughout the construction and overall life of the structure, settlement of the structure shall not cause cracks wider than the design crack width and shall not cause the structure unserviceable. Settlement limits shall be obtained from specific equipment suppliers and shall be included in the design.
- (ii) Settlement and crack widths shall be checked against the requirements of any applicable codes and standards.

3 Building Structures

- (A) Design for concrete sections shall be performed at Ultimate Strength level.
- (B) Design of the structural steel shall be by Load Resistance Factor Design (LRFD). Material strength increase is not allowed. The effect of vertical acceleration shall be considered
- (C) Use of steel structure such as trusses for support facilities shall be limited, deck type roof structures shall be adopted.
- (D) Deflection Criteria
  - (i) Deflection limits shall be checked against the requirements of any applicable codes and standards.
- (E) Seismic Drift
  - (i) Seismic Drift limits shall be checked against the requirements of any applicable codes and standards.
- (F) Wind Drift
  - (i) Wind Drift limits shall be checked against the requirements of any applicable codes and standards.
- (G) Minimum Design Requirements



- (i) Minimum concrete cover of structural elements shall conform to ACI 318M-14 standards.
  - (ii) Minimum amount of reinforcement of structural elements shall conform to ACI 318M-14 standards.
- 4 Modelling Requirements
  - (A) For concrete building elements, cracked section properties shall be considered.
- 5 Structural Design Calculation Package
  - (A) A searchable soft copy of structural design calculations (input and output) for all structures and foundations in its original electronic file format, along with a hard copy signed and sealed by the Engineer-of-Record, shall comprise the structural calculation package, and shall be submitted to the Engineer
  - (B) The calculation package shall at least contain the following:
    - (i) Technical Narrative
    - (ii) References
    - (iii) Design Criteria
    - (iv) Load Derivations
    - (v) Structural Modeling and Load Application
    - (vi) Analysis Results and Interpretation
    - (vii) Component Design
    - (viii) Plans and Spot Details in A3
    - (ix) Photocopy of License of Structural Design Software
    - (x) Photocopy of Professional License and Current Professional Tax Receipt of Engineer-of-Record
    - (xi) Photocopy of ASEP ID and/or PICE (Specialist) ID
- 6 Submission packages
  - (A) The contents of each submission package will be agreed with the Employer. Generally, submissions shall be complete per structure, or other functional grouping of process treatment equipment. Therefore, a package shall contain foundation and superstructure calculation and drawings details together.

## **16 Geotechnical Requirements**

### **16.1 General**

The Contractor shall refer to the Appendices to these Employer's Requirements for the Geotechnical Investigations, Shear Wave Velocity Profile and Appendix 3 Table and Graph of Response Spectra for the Site. The Contractor shall make their own assessment on the completeness of the information; and shall carry out more investigations should they need more information to make determination of the foundation design.

Claims due to lack of knowledge of site conditions will be rejected.

The design and construction for the pipelines, tunnels, and ancillaries shall be in accordance with MWCI SES 5.

### **16.2 Design Criteria for Foundation Design**

#### **16.2.1 Soil strength, compressibility and deformation parameters**

16.2.1.1 The parameters shall be calculated from the soil investigation data using published correlation equations.

16.2.1.2 The correlation equations shall be indicated in the geotechnical assessment report.

#### **16.2.2 Liquefaction analysis**

16.2.2.1 The factor of safety against liquefaction shall be calculated using either the Japan Road Association method or the Idriss and Boulanger (2014) method.

16.2.2.2 The liquefaction potential of the area shall be calculated using the Liquefaction Potential Index procedure developed by Iwasaki (1982).

16.2.2.3 The peak ground acceleration values shall be taken from the site-specific response spectrum and shall conform to the ASCE 7-10 guidelines for analyzing liquefaction.

16.2.2.4 Liquefaction induced settlement shall be calculated using either, Ishihara and Yoshimine method, or Tokimatsu and Seed method.

#### **16.2.3 Foundation solutions**

This section provides the minimum requirements for the foundation solutions. The critical structures referred in this section are all water and liquid retaining structures, tanks, electrical and controls structure, chlorine preparation area, sludge treatment facility, chemical storage, and building services.

16.2.3.1 A structure classified as critical shall be supported by a foundation system that would prevent liquefaction from affecting the structures, and limit settlement to 25mm or less. All the interconnecting hydraulic structures including pipework and channels, shall be designed for the same amount of settlement. The Contractor shall design the flexibility in the connections to account for any differential settlement, while ensuring the structural and hydraulic integrity of the structures.

16.2.3.2 A structure classified as non-critical may be supported by a foundation system that can be susceptible to liquefaction provided the limit to total settlement is 50mm or less.

16.2.3.3 Shallow foundation system

- 1 Strength parameters used in the bearing capacity calculations shall be indicated in the geotechnical assessment report.
- 2 Settlement calculations shall be presented in the geotechnical assessment report to illustrate that the recommended bearing capacity values will limit settlement to within the tolerable limits.
- 3 The Contractor shall verify that the soil conditions at the founding level of each structure conforms to the recommended bearing capacity values.
- 4 In the event that changes to the foundation design are necessary due to the variations in the actual soil conditions, the Contractor shall make the necessary changes at no cost to the Employer.

### **16.3 Excavation**

#### **16.3.1 General**

16.3.1.1 The Contractor shall provide, but not limited to, the excavation methodology, list of equipment with respective calibration certificate and with validity of at least one (1) year, safety procedures to be utilized, and risks or hazards associated to the works. The document shall be for review and acceptance of the Engineer.

16.3.1.2 When excavating to final levels for the foundations of structures or for pipes or to the limits for the face of any structure requires to abut undisturbed soil, the Contractor shall not excavate the last 150 mm until immediately before commencing the constructional work, except where the Engineer shall permit otherwise. If the final levels for the foundations of structures or for pipes requires to abut on hard rock, the Contractor shall excavate until the required depth.

16.3.1.3 An independent Geologist or Geotechnical Engineer, approved by the Engineer, shall examine the formation level of major structures determined by the Engineer. The expert shall approve the soil conditions as suitable for the construction of the said structures. In case that the expert instructs or recommends any additional foundation measures the Contractor shall act accordingly. The costs of this expert shall be borne by the Contractor.

- 16.3.1.4 Should the material forming the bottom of any excavation, while acceptable to the Engineer at the time of his inspection, subsequently become unacceptable to him due to exposure to weather conditions or have become puddle, soft, loose during the course of the works, the Contractor shall remove such unsound material by hand.
- 16.3.1.5 Care shall be taken in design and construction to keep the soil structure intact. If the soil beneath formation level has been disturbed, it should be well compacted or replaced by lean concrete or other material approved by the Engineer.
- 16.3.1.6 No water should reach the formation level between excavation and placing of the foundations. To this end, the interval of time should be kept to minimum. If necessary, formation levels should be protected by a blinding of lean concrete immediately after excavation. If water has reached the formation level, the soaked soil shall be replaced by lean concrete or other material approved by the Engineer. After construction of the foundations and walls, backfill shall be placed as soon as feasible.

#### 16.3.2 Supporting of Excavation

- 16.3.2.1 The Contractor shall ensure that temporary support structures must be designed to withstand all external forces that may be caused by soil pressures, water pressures, nearby structures, additional loadings and vibrations.
- 16.3.2.2 The design of the support to all excavations including supporting calculations shall be submitted to the Engineer. No excavation work may commence until the Engineer has approved the Contractor's proposals for supports of all excavations. The Contractor shall not remove any temporary supports from the excavations until, in the opinion of the Engineer, the permanent work is sufficiently advanced to permit removal. As shoring is removed any voids left by its removal shall be filled and compacted as specified.
- 16.3.2.3 The Contractor shall ensure that safe access is available in the excavation.
- 16.3.2.4 The Contractor shall be responsible to provide and maintain the slope surface protection works during construction.
- 16.3.2.5 The Contractor shall be responsible for the design and implementation of temporary drainage works and dewatering procedures especially if excavation is required below the water table in cohesionless soils.
- 16.3.2.6 The Contractor shall report to the Engineer immediately if any adverse geological or groundwater condition is revealed during the construction works.
- 16.3.2.7 Water that is discharged from the site due to construction activities must be passed through a sand trap or settlement tank prior to discharging into permanent drainage system.

16.3.2.8 The Contractor shall maintain all excavations or trenches free from water, including ground water and surface water infiltration, surface water run-off or sewage and the like, regardless of the source and shall be responsible for all costs incurred. Water collected from entering excavations by the Contractor shall be disposed in a manner approved by the Engineer. The Contractor shall take account of the groundwater levels and the seasonal variation in the levels and shall be deemed to have carried out all investigations were necessary, during the pricing of his Tender, to assess the impacts and include the costs in dealing with such groundwater levels during the works. The Contractor shall further consider the pressures imposed and any supports if necessary, to ensure that the sides of the excavation and the base shall remain stable at all times during operation of the Contractor's dewatering methods.

### 16.3.3 Trench Excavation and Bottom/Bedding

16.3.3.1 "Trench Excavation" means excavation of trenches into which pipes, fittings, cables, ducts are to be laid. Trenches shall be dug to the line gradient as indicated on the drawings or in the specification or as agreed with the Engineer. Safety procedures shall be adhered to and if required the trench shall be supported and braced. The trench width shall allow for safe working alongside the pipeline and shall permit proper compaction of the side backfill. When necessary, due to poor soil conditions upon inspection of the Engineer, trenches deeper than 1m shall have slope protection.

16.3.3.2 The depth of the trench shall be such that the required depth of the bedding can be placed under the pipeline and trimming and grading of the bottom of the trench. It shall also consider that the barrel of each length of pipe can be uniformly supported over its full length, free at the joints and to the correct grades and levels. The bedding material for pipes and ducts shall generally be clean hard coarse sand, or gravel. The proposed material for bedding and surround all different pipe and duct materials shall be submitted to the Engineer for review and approval.

16.3.3.3 For the RWTL, open trench excavation as the pipelaying methodology shall only be allowed starting from the Water Portal stub out towards the Raw Water Interface Chamber inlet. Refer to Section 16.5 onwards for the acceptable pipelaying methodologies for the remaining components of the raw water transmission line alignment.

## 16.4 Backfilling

### 16.4.1 General

16.4.1.1 The Contractor shall provide, but not limited to, the backfilling methodology, list of equipment and materials, and safety procedures to be utilized. The document shall be for review and acceptance of the Engineer.

16.4.1.2 Backfilling shall not be carried out without the consent of the Engineer. Material shall be placed in horizontal layers, thickness not to exceed 200 mm and compacted thoroughly with suitable mechanical equipment. Compaction for general backfilling and backfilling trenches shall be carried out to produce a dry density not less than 95% of the maximum dry density determined in accordance with BS1377 (Test 13) or DIN 18126. The soil is to be protected from any kind of ground or surface water.

16.4.1.3 Backfill material around pipes (and the bedding) shall conform to the pipe manufacturer's recommendations and international standards. Suitable material for backfilling shall be deposited and compacted in layers not exceeding 150 mm thickness if rammed by hand and 200 mm thickness if mechanically rammed (measured after compaction). Backfilling of pipe trenches shall be carried out in two stages: Initial backfilling is sufficient to anchor the pipes adequately during the pressure and/or water-tightness tests of the pipeline. It shall leave all joints completely uncovered for inspection during the test. Final backfilling is the completion of backfilling after the tests have been carried out successfully.

16.4.1.4 The backfilling material shall not be of "unsuitable material", such as: Materials from swamps, marshes and bogs; Vegetable matter, timber or similar material liable to decomposition; Materials susceptible to spontaneous combustion; Clay or earth having excess liquid content; Rock over 100 mm in any dimension.

16.4.1.5 Supports to the excavation shall be carefully removed according to the backfilling progress, but the removal of such supports shall not relieve the Contractor of his responsibility for the safety and stability of the Works. Surface drainage shall ensure that no rain water can collect and infiltrate the soil near the backfilled structures.

#### 16.4.2 Backfill settlement

16.4.2.1 Ground settlement due to the weight of backfill placed over the site shall be calculated by the Contractor for both elastic compression (for sand layers) and consolidation settlement (for clay layers) and shall be submitted to the Engineer for approval.

16.4.2.2 For time-delayed consolidation settlement, the estimated time rate of settlement and time to 95% primary consolidation shall be submitted to the Engineer for approval.

#### 16.4.3 Backfill settlement monitoring program

16.4.3.1 A settlement monitoring program shall be established to ascertain the rate and magnitude of ground settlement. As a minimum, backfilled area shall undergo verification density test. The contractor shall submit an acceptance criteria that shall comply with relevant Philippine Standards, DPWH Standards, etc.

16.4.3.2 The compaction tests on site such as Field Density Test shall be carried out by an independent Geologist or Geotechnical Engineer approved by the Engineer. Compaction tests shall be carried as follows:

- 1 One (1) test for each 50 m of trench for each pipeline;
- 2 One (1) test for each 500 cubic meter compacted earth material;
- 3 For the backfill of each structure (not including small manholes and chambers, unless specifically requested by the Engineer)
- 4 A minimum of two (2) tests and more tests if required to comply with the proceeding sentence. The type, number and location of all tests shall be approved by the Engineer.

16.4.3.3 The construction of structures built on fill shall only commence after it is been shown that consolidation settlement has attained at least 95% of the total settlement.

16.4.3.4 The settlement monitoring program shall consist of settlement plates with vertical markers. The settlement shall be recorded at least twice a week using a leveling instrument. The settlement values shall be referenced against a fixed datum to provide consistency of the measurements. The results shall be submitted to the Engineer for acceptance.

## **16.5 Mined Tunnel Construction for RWTL**

### **16.5.1 General**

16.5.1.1 This Section applies to all tunneling work carried out using tunnel mining techniques by means of mechanical excavation. It defines the requirements for excavation and initial and permanent supports of those sections of the Work.

16.5.1.2 The excavation will be supported by Initial Support, which shall not form part of the permanent lining.

16.5.1.3 Scope of Work includes Construction of the Aqueduct Tunnel to suit the Contractor's design and method of construction in accordance with the following:

- 1 Conventional means used to excavate the tunnel (mechanical excavation).
- 2 Installation of the Initial Support (as defined below) as required.
- 3 Installation of permanent tunnel lining.
- 4 Installation of any necessary temporary bulkhead and for shaft breakout.

16.5.1.4 Conduct a thorough assessment into all the utility crossings along the pipe alignment to be constructed and identify all suspected underground obstructions along the pipe alignment. The Contractor shall demonstrate that the pipe alignment to be constructed by mined tunneling techniques has adequate clearance from all such utilities and obstructions.

16.5.1.5 Reference Specifications, Codes, and Standards

- 1 National Codes of Philippines
  - (A) NSCP, National Structural Code of the Philippines
- 2 American Concrete Institute
  - (A) ACI 318M, Building Code Requirements for Structural Concrete and Commentary
  - (B) ACI 350M, Code Requirements for Environmental Engineering Concrete Structures and Commentary
  - (C) ACI 544.4R Design Considerations for Steel Fiber Reinforced Concrete ASTM A185 Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement
  - (D) American Society for Testing and Materials (ASTM)

- (E) ASTM A572, Standard Specification for High-Strength Low-Alloy Columbium- Vanadium Structural Steel
  - (F) ASTM A615, Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
  - (G) ASTM A820, Standard Specifications for Steel Fibers for Fiber-Reinforced Concrete
  - (H) ASTM C150, Standard Specification for Portland Cement
  - (I) ASTM C1609, Standard test method for flexural performance of fiber reinforced concrete using beam with third point loading
- 3 US Army Corps of Engineers
- (A) CRD-C611, Flow of Grout for Preplaced Aggregate Concrete
- 4 Other references:
- (A) Barton, N.R., Lien R. and Lunde (1974). "Engineering classification of rock masses for the design of tunnel support", Rock Mechanics, 6(4), pp.189-239
  - (B) Chang, Y. and Stille, H. (1993). "Influence of early age properties of shotcrete on tunnel construction sequences". Shotcrete for Underground Support VI, Proceedings of the Engineering Foundation Conference, Niagara-on-the-Lake, Canada
  - (C) Grimstad, E. & Barton, N. (1993). "Updating of the Q system for NMT". Proceedings of the International Symposium on Sprayed Concrete – Modern Use of Wet Mix Sprayed Concrete for Underground Support, Fagernes, 1993
  - (D) Hoek, Carranza-Torres and Corkum (2002). "Hoek Brown failure criterion – 2002 edition". 5th North American Rock Mechanics Symposium and the 17th Tunnelling Association of Canada Conference, Toronto, Ontario, Canada, 2002
  - (E) Hong Kong Code of Practice for Structural Uses of Steel in Hong Kong
  - (F) Hong Kong Code of Practice for Structural Use of Concrete
  - (G) EN-14488-5 'Determination of energy absorption capacity of fibre reinforced slab specimens

## 16.5.2 Definitions

- 16.5.2.1 Mined excavation shall refer only to mechanically excavated tunnel and shaft construction including but not limited to the use of pneumatic hammer, scrapers, picks, roadheader or excavator.
- 16.5.2.2 Initial Support – Temporary ground support that is installed to provide a stable tunnel opening. This includes the Initial Support as designed and shown on the Contractor's Drawings, and any additional support measures installed during excavation to address local stability.
- 16.5.2.3 Permanent Support - A support system that is designed to accommodate all long-term loads for the final lining system



16.5.2.4 Rock Bolts - Bolts generally consist of post-tensioned deformed fiberglass or steel rods with a mechanical or chemical anchor at one end and a face plate and nut at the other end. Rock bolts are typically tensioned after installation. The space between the bolt and the rock shall be filled with cement or resin grout for permanent support applications.

16.5.2.5 Rock Dowels - Rock Dowels consist of untensioned deformed steel bars, which are grouted into the rock. Tensioning is not possible and the load in the dowels is generated by movements in the rock mass.

16.5.2.6 Steel Supports – Lattice Arches or Steel sets

### 16.5.3 Submittals

#### 16.5.3.1 Prior to construction

This Specification requires, as a minimum, the following submissions to the Engineer for approval before construction commences:

- 1 Drawings and calculations for all Temporary Works and Initial Support/safety measures;
- 2 The Contractor's geological interpretation of the ground conditions;
- 3 The Contractor's permanent lining design;
- 4 Details of the methods, materials and equipment for installation and testing of initial supports, excavation, and construction of permanent lining;
- 5 Results of all pull testing and production testing of rockbolts, and grout testing;
- 6 Method statements for all construction stage monitoring, including installation and reading procedures, certification and calibration of instruments, presentation of result and emergency response.
- 7 Results of all monitoring undertaken for the tunnel.
- 8 Safety procedures and access provision. Tunneling works are considered as work in confined spaces and adequate safety measures shall be implemented and provided.

#### 16.5.3.2 During Construction

This Specification requires, as a minimum, the following submissions to the Engineer for approval during construction:

- 1 Records of installed Initial Support as stated in Section 16.5.6.;
- 2 Survey of the excavation profile after installation of Initial Support;
- 3 Shotcrete testing results

#### 16.5.3.3 Provide the following Sections related to Mined Tunnel in the Construction Method Reports (Detailed Work Plans) for the Tunnel Construction Access Shaft:

- 1 Details of breakouts from the Tunnel Construction Access Shaft.
- 2 Excavation and Support of Mined Tunnel.

- 3 Construction of the Permanent Lining.
- 4 Submit the materials testing certification/information for review and comment for rock bolts/dowels and shotcrete if there are any differences from submittals made for the construction of shaft.

16.5.3.4 Submit the following certification/records during operations:

- 1 Tunnel Excavation Reports: Daily reports for each manned shift shall be prepared and completed within 24 hours after each shift. At a minimum, the reports shall include the following information.
  - (A) Date.
  - (B) Manpower records providing numbers of persons and trades.
  - (C) Comments on equipment used.
  - (D) Start and end stationing of each excavation round.
  - (E) Weather.
  - (F) Shaft atmosphere monitoring results and records of gas monitoring and other atmospheric impurities in the working environment.
  - (G) Ground conditions. After mucking and scaling, produce a geological map of the face and side walls for each excavation round and include a description of the observed ground conditions and photographs of the shaft bottom or tunnel face after each round.
  - (H) Details of all initial tunnel support installed per excavation round. Illustrate locations using sketches of shaft cross sections and a face view of shaft walls. Details shall including the following information:
    - (i) Installation of rock bolts / dowels. Provide daily rock bolt tensioning records within one day of each day's rock bolt operations. Records shall include date of tensioning, temperature, test jack identification number, name of person who tested the rock bolt, rock bolt location, rock bolt number, rock bolt length, resin or grout details, and tensioning test details.
    - (ii) Area, thickness, and location of shotcrete, including details of any reinforcement; e.g., welded wire fabric and fibers
    - (iii) Details concerning any other support installed.
    - (iv) Explanation of any changes to the Designed Initial Support.
  - (I) Readings observed over the previous 24 hours from all geotechnical instrumentation.
  - (J) Details of planned stoppages for maintenance works.
  - (K) Details of unplanned stoppages for maintenance works.
- 2 Shaft Design Engineer's Representative (SDER) Observations: During installation of the Initial Support, the Contractor shall require the SDER to observe and monitor work and provide to the Engineer, by the fifth day of each month, a separate, signed and sealed form that the work during the previous month was performed in general accordance with the Contractor's Design concepts.

- 3 The Tunnel Design Engineer's Representative (TDER) shall prepare and submit a Required Excavation and Support Sheet (RESS) prior to the excavation of each advance. The RESS shall include, at a minimum, the beginning and end station, the support class, and the range of the average Geological Strength Index (GSI) of the face appropriate for the support class.
- 4 Tunnel Design Engineer's Representative Observations: During installation of the Initial Support, the Contractor shall require the TDER to observe and monitor work and provide to the Engineer, by the second (2nd) day of each week, a separate signed and sealed form that the work during the previous week was performed in general accordance with the Contractor's Design concepts.

16.5.3.5 Submit as-built survey of the excavated profile every seven (7) days during excavation of the tunnel or shaft.

16.5.3.6 Immediately notify the Engineer of any tunnel or shaft misalignments.

#### 16.5.4 Products

##### 16.5.4.1 Shotcrete

- 1 Permanent shotcrete, with the exception of the plain shotcrete finishing layer where applicable, shall contain steel fiber reinforcement conforming to ACI 544.4R and ASTM A 820.

16.5.4.2 Excavation equipment in accordance with Section 16.5.6.

16.5.4.3 Grouting equipment in accordance with Section 16.5.7.

#### 16.5.5 Execution Requirements

16.5.5.1 Determine the excavation sequences and establish initial tunnel support categories to maintain a safe excavation in all ground conditions. The length of unsupported sections and time for application of support elements shall be as shown on the Contractor's Drawings and as determined by the TDE and/or the TDER in consultation with the Superintendent based on the actual conditions encountered.

16.5.5.2 Tunnel setting out allowance and tolerances shall include the following:

- 1 Survey and setting out allowance:  $\pm 50\text{mm}$
- 2 Permanent Lining: minimum thickness shall comply with that shown on Drawings
- 3 Smoothing layer and waterproofing membrane allowance: 20mm
- 4 Overspray allowance: 25mm
- 5 Temporary Lining: minimum thickness shall comply with that shown on Drawings
- 6 Convergence allowance: 50mm
- 7 Construction tolerances: 50mm

16.5.5.3 Repair support not located within specified tolerances or damaged during the Work.

16.5.6 Excavation and Initial Support

16.5.6.1 Survey and mapping

- 1 Geological mapping of all exposed surfaces in the tunnel shall be undertaken by an experienced geologist. Geological mapping shall be undertaken prior to the covering of the exposed surfaces by shotcrete. Geological mapping records shall be submitted to the Engineer.
- 2 Records shall be kept of all Initial Support installed in the tunnel. The records shall identify, but not limited to, the numbers and types of rock bolts, the thickness of shotcrete, and the location of steel supports installed in each section of tunnel. Records of Initial Support shall be submitted to the Engineer.
- 3 During excavation of the tunnels chainage markers shall be installed on the sides of the tunnel at regular intervals to allow geologists and others responsible for mapping and recording information to reference their location. Chainage markers shall be installed as soon as practicable, and shall be replaced if covered over by shotcrete or obscured by tunnel services.
- 4 Behind tunnel excavation and installation of Initial Support, the internal surface of the tunnels shall be surveyed at intervals of not greater than five (5) meters, to verify that the exposed surface and Initial Support does not encroach on the design thickness of the concrete lining. The survey shall comprise no less than ten (10) points normal to the tunnel axis at each 5 meter interval. Where the survey shows a section of tunnel to encroach within the specified dimensions, additional surveys shall be undertaken at two (2) meter intervals within that section, and over a length of twenty (20) meters on each side of the section. The results of the survey shall be submitted to the Engineer.

16.5.6.2 Probe drilling

- 1 Where required, the Contractor shall be responsible for probing ahead of the tunnel face in order to prove or investigate the ground.
- 2 The selection of plant for probing shall be agreed with the Engineer and shall take into account the probable nature of the ground ahead and its water-bearing capacity.
- 3 Probing shall be carried out such that at all times the distance of probed ground ahead of the face is sufficient to allow modification of the method of working ahead of any change in ground conditions. The number of probes, their positions in the face and angles with respect to the tunnel drive shall be governed by the actual ground conditions encountered and the machinery in use subject to minimum requirements specified on the contract drawings.
- 4 The maximum probed distance ahead of the face shall be governed by the ground conditions and the degree of uncertainty with distance, subject to minimum requirements specified on the contract drawings.

- 5 Should the information obtained from probing indicate that forward ground conditions will require a modification of the method of working, the Contractor shall prepare proposals for the Engineer's agreement.
- 6 The diameter of probe holes shall be not less than 38 mm.
- 7 The flush used shall be suitable for the type of ground conditions anticipated and the machinery in use.
- 8 A trial shall be carried out in advance of tunnelling activities in order to identify the optimum drill bit, drill diameter, flush and percussion rate. These parameters shall be kept constant during drilling to allow direct comparison between probe holes.
- 9 An accurate and systematic record of probe hole positions (positions in the face and angles with respect to tunnel drives), drill penetration rate, drill parameters (percussion, torque, thrust), flush (colour, percentage return), drilling sounds (loud, quiet, intermittent), water strikes and interpretation of the nature of the ground ahead shall be noted at the time the holes are bored and a copy provided to the Engineer.
- 10 Full facilities shall be provided for the Engineer to inspect probing work in progress.

#### 16.5.6.3 Underground Excavation

- 1 Excavation for tunnels shall be carried out to the lines and levels shown on the Contractor's Drawings. Excavation shall be carried out so that no material shall protrude into the design lining thickness.
- 2 Excavation for tunnels shall be carried out in a careful manner to ensure that the exposed surfaces are as stable as the nature of the material permits and that overbreak is kept to a minimum.
- 3 The tunnel excavation shall advance in suitable increments of length, width and depth to prevent deterioration of unsupported surfaces through exposure. The unsupported advance of tunnel shall not exceed the limits calculated by the Contractor to ensure safety of personnel. The Contractor is responsible for excavation support and lining sequencing.
- 4 An adequate stock of support materials, and suitable equipment for their installation, including rock bolts, steel supports, and shotcrete, shall be maintained on site for the duration of the tunnel excavation such that the stability of the tunnel may be properly maintained at all times.
- 5 Exposed faces shall be examined as soon as possible after excavation by mechanical means, and all loose pieces of rock shall be removed using remotely operated mechanical plant as far as practical. Faces that are to be supported by shotcreting are to be mapped and shotcreted as soon as practicable after excavation. Rock faces shall be maintained in a safe condition. Scaling of any rock surfaces to be left in an exposed condition shall be carried out with hand tools and surfaces shall be thoroughly cleaned using high pressure air and water as appropriate to the rock conditions.
- 6 Adequate Initial Support shall be provided for the tunnel and headings. The Initial Support shall be left in place permanently provided they do not encroach within the design thickness of the concrete lining.

- 7 The Engineer shall be informed without delay of any permeable strata, fault, shear zone or weak geological feature encountered during excavation. When excavating in loose or soft ground care shall be taken to ensure that ground loss outside the excavation line is minimized.
- 8 Before tunnel excavation is halted for a period exceeding 12 hours, by either a planned or unplanned stoppage, the face of the tunnel or heading shall be inspected and assessed by the Contractor and the level of face support required determined and installed. Any soft ground or weak rock shall be secured by shotcrete and rockbolts as necessary.
- 9 Deterioration, over excavation or damage to the tunnel invert or to support footings at the heading or invert, through exposure, lack of water control or construction traffic shall be prevented. Any damage caused to the invert shall be made good.
- 10 The Contractor shall monitor conditions that might threaten the stability of the excavation whenever the excavations are suspended or shutdown.

16.5.6.4 The TDE or TDER shall be responsible for the determination of the Initial Support requirements and shall visit the site whenever major decisions affecting either the execution of approved support designs plans or any alterations in Initial Support designs need to be made.

16.5.6.5 SDER and Superintendent(s) shall assess the ground conditions at shaft break-out and provide ground improvement or other acceptable means to prevent instability of the ground as necessary.

16.5.6.6 Shotcrete shall be applied to the exposed excavated surfaces as shown on the Contractor's Drawings, in accordance with Section 16.5.8. All ground shall be fully supported during the last work shift prior to weekends, holidays not worked and any shutdowns. During any shutdown time, the tunnel face shall also be positively secured. The Contractor shall be responsible in ensuring the stability and safety of the pending works during shutdown time.

16.5.6.7 Other Support Systems:

- 1 Install all support members in tight contact with the surface being supported, as shown on the Contractor's Drawings and/or as determined by the ER and Superintendent.
- 2 Install rock bolts/dowels as soon as possible after exposing the ground by excavation.

16.5.7 Permanent Lining and Back Grouting

16.5.7.1 The permanent concrete lining shall not be installed without approval of the SDE and Engineer.

16.5.7.2 Design and execution of the permanent concrete lining shall conformed to DPWH.

16.5.7.3 The concrete forms shall be erected and supported in accordance with the Contractor's form designs and shop drawings.

16.5.7.4 Forms shall not be stripped until concrete strength has reached the stripping strength specified for that element of the work. Forms shall be removed in accordance with ACI 347 without damage to concrete and in manner to ensure complete safety to the structure. Concrete test cylinders in accordance with relevant standard, shall be tested to verify concrete strength prior to stripping.

16.5.7.5 Joints shall be grouted.

16.5.7.6 Joints shall be clean and smooth.

16.5.7.7 Install and monitor survey points on the final lining as shown on the Contractor's Drawing. The survey accuracy shall be +/- 3mm.

16.5.7.8 Waterproofing for the permanent lining shall be done.

#### 16.5.8 Shotcreting

##### 16.5.8.1 General

- 1 For application as permanent ground support, apply the shotcrete using the wet mix process only.

##### 16.5.8.2 Proportioning and Mixing

- 1 General:
  - (A) Weight measuring equipment and tolerances in accordance with ASTM C94.
- 2 Dry Mix Process:
  - (A) Pre-bagged dry mix shotcrete shall be mixed in accordance with manufacturer's recommendation.
- 3 Wet Mix Process:
  - (A) Design mix in accordance with ACI 506.2 with aggregate content correction for pumped concrete.
  - (B) Mix shotcrete in stationary plant, portable batch type, or truck mixers in accordance with ASTM C685. Calibrate batching equipment in accordance with ASTM C685 at the start of each shift.
  - (C) Addition of the steel fibers shall be at the site.
  - (D) Dosing of admixtures by hand is not permitted.

##### 16.5.8.3 Surface Preparation

- 1 Excavate rock surface to line and grade. Scale loose rock from rock surface. Clean surface with air/water jet. Rock surface should be damp immediately prior to placing shotcrete.
- 2 Remove all deteriorated, loose, unsound material or contaminants from concrete or previously placed shotcrete that might inhibit bonding. Chip areas to be repaired to remove offsets causing abrupt changes in thickness. Taper edges to approximately 45 degrees to eliminate square shoulders at the perimeter of a cavity. Surface shall be saturated surface dry immediately prior to placing shotcrete.

- 3 The surface of structural reinforcement shall be free of deleterious materials that inhibit bonding. Reinforcement laps shall be separated with a clearance of at least three times the diameter of the largest aggregate size. Reinforcement shall be secured to prevent movement.
- 4 Secure forms to minimize the effects of vibration. Construct forms to allow escape of placement air and rebound.
- 5 Securely fix drainage pipes, channels, and panning prior to and during shotcrete placement.

#### 16.5.8.4 Application

- 1 General:
  - (A) Use equipment capable of discharging mixed material into the hose under close control, and that is able to deliver a continuous smooth stream of uniformly mixed material at the proper velocity to the discharge nozzle, free from slugs of any kind.
  - (B) Apply shotcrete from the bottom and continue upwards to avoid the inclusion of rebound. Velocity and spraying distance shall be optimum for maximum adherence and compaction.
  - (C) Place shotcrete first in corners, recesses, and other areas where rebound or overspray cannot escape easily. In corners, direct nozzle at approximately 45 degree angle or bisect the corner angle.
  - (D) Thoroughly clean delivery equipment at the end of each shift.
  - (E) Regularly inspect and replace equipment parts as required.
- 2 Provide a stable working platform that provides nozzleman and assistant with access to the receiving surface.
- 3 Alignment control.
  - (A) Install taut ground wires or other means to establish thickness and plane of required surface.
  - (B) Install taut ground wires or other means at corners or offsets not established by forms.
- 4 For invert lining, use separately controlled air blowpipe during spraying to remove rebound from the lining.
- 5 Spraying shotcrete through more than one layer or reinforcement or mesh is not permitted.
- 6 Do not reuse rebound, sprayed fibers, or overspray.
- 7 Do not apply shotcrete on surfaces with standing water or running water.
- 8 Place shotcrete to completely encase reinforcing steel. Encase reinforcement by shooting with sufficient velocity and plasticity so material flow around and behind reinforcement.
- 9 Shotcreting More Than One Layer:
  - (A) Allow sufficient time for each layer of shotcrete to set up, so that it may take the next layer without sagging. Where movement of shotcrete has occurred adjacent to slough-off, the shotcrete in question shall be removed.



- (B) Roughen shotcrete layers after initial set, if required, to increase bond of next shotcrete coat. Methods that can be used for surface preparation include pneumatic chipping hammer, sandblasting, high-pressure water blasting and combination of these methods. If mechanical methods such as a chipping hammer are used, the procedure must be followed by sandblasting or high-pressure water blasting to remove the bruised surface material.
- (C) Wash surface with fresh, clean water to remove dust or any other contaminants to achieve a good bond and pre-saturate concrete. Allow concrete to dry back to a saturated surface dry condition or use air blowing to remove excess water on the surface immediately prior to shotcrete application.
- (D) Before applying any new layer of shotcrete on previously applied shotcrete coatings, thoroughly sound the surface with a hammer for hollow areas. Remove and replace any voids before additional shotcrete coatings are applied.
- (E) Before installing permanent shotcrete, thoroughly inspect the initial tunnel support/ and/or previous layers of permanent shotcrete for defects or damage caused from blasting, construction activities or ground deformation. Repair previously installed support as required.
- (F) For permanent shotcrete, apply shotcrete in continuous layer thickness between 76 and 152 mm per pass.

#### 16.5.8.5 Finishing

- 1 Initial and Permanent Shotcrete: Natural finish.

#### 16.5.8.6 Curing

- 1 Temporary Shotcrete: Natural curing is permitted.
- 2 Permanent Shotcrete: Immediately after finishing, cure shotcrete continuously by maintaining in a moist condition for 7 days or until specified strength is attained or until succeeding shotcrete layers are placed. Cure by one of the following methods:
  - (A) Ponding or continuous sprinkling.
  - (B) Covering with absorptive mat that is kept continuously wet.
  - (C) Covering with impervious sheet material.
  - (D) Curing compounds that impair bonds shall not be used where a further layer of shotcrete is applied.

#### 16.5.8.7 Protection

- 1 Protect surfaces not intended for shotcrete placement from deposit of rebound and overspray or impact from nozzle stream.
- 2 Remove rebound or hardened overspray from final shotcrete surfaces and from areas not intended for shotcrete placement.

#### 16.5.9 Field Quality Control

##### 16.5.9.1 Test Panels and acceptance tests

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- 1 The performance requirements shall be set by the Designer.
- 2 The site trials shall employ the equipment which will be used in the Works and the constituent materials shall be fully representative of those to be used in the Works.
- 3 For each type of sprayed concrete to be used a trial mix shall be designed by the Contractor and prepared with the constituent materials in the proportion proposed. Target workability values shall be determined for the wet mix process. Sampling and testing procedures shall be in accordance with BS EN 12350. A clean, dry mixer shall be used and the first batch discarded.
- 4 The equipment proposed for the application of concrete in the Works shall be used for the trial. The trial will establish whether the selected equipment is capable of efficiently mixing concrete, accelerator and air at the nozzle, and be capable of positioning the nozzle at a suitable distance and orientation to the surface geometry of the structure to which the concrete is to be applied.
- 5 During the trials the Contractor will establish the volume of air required to give adequate compaction of the material using the nozzle and conveyance lines selected for the Works. If the delivery equipment or nozzles are to be changed during the course of the works the volume of air required will need to be verified again. The equipment will be maintained adequately, to ensure that the required volume of air can be maintained while spraying. Air pressure can only be used as a control if the air delivery system is not altered from the original verification trial. No additional taps or restrictions will be permitted to be added into the system without repeating the verification trials.
- 6 If a particular quality of finish is required other than as sprayed, the trials will evaluate the methods and tools to be used to achieve the required finish and the Engineer will approve the method and quality of finish achieved.
- 7 From the trial mix an experienced nozzleman shall prepare sufficient test panels as per BS EN 14488-1 Clauses 4.3 and 5.4. The sprayed concrete in the panels shall adhere well to the backform, be properly compacted and exhibit no sagging.
- 8 The panels shall not be moved for 18 hours after spraying and shall be stored without disturbance at a temperature of 15 to 25 degree Celsius and covered by polythene sheet until the time of coring.
- 9 Cores for strength tests shall be obtained from the panels at 1 day in accordance with BS EN 14487-1. The cores will be visually inspected and the dimensions and comments regarding the quality of the cores will be recorded as required in BS EN 12504-1. The cores will be free from lamination. The cores for strength tests shall be stored in water.
- 10 No sets of cores to be tested at any given age shall come from the same panel. Sets of cores to be tested at different ages (i.e. 1 day and 28 days) may come from the same panel. For each test at least one spare specimen shall be provided. The testing requirements shall be: compressive strength in spray direction after 1 day and 28 days on a set of five cores each as per BS EN 14487-1. The correction for in situ compressive strengths is defined in BS EN 13791.

- 11 The Contractor shall carry out other tests and trials during the period of the site trials as specified in BS EN 14487-1 Clause 7.3, to confirm that the proposed mixes and methods meet the minimum performance requirements, unless otherwise agreed with the Engineer.
- 12 If required by the Engineer, the trial shall include the construction of the proposed joints including layer joints and advance joints. Samples taken from across the joints will then be taken and the results reported.
- 13 The site trials shall be repeated if the source or quality of any of the materials, mix proportions or placing equipment is to be changed during the course of the Works.
- 14 Should any mix fail to produce satisfactory sprayed concrete, the Contractor shall repeat the construction of test panels and test either the same mix, plant, and labour or make such adjustments as he considers necessary.

#### 16.5.9.2 Production Tests

- 1 Tests shall be carried out on a routine basis on cores or other samples taken from sprayed concrete placed in the Works. The location of the cores shall be determined to give even distribution around the entire lining (i.e. samples from crown, axis and invert).
- 2 Where the nominal required sprayed concrete thickness is less than 100 mm, the cores for the compressive strength testing shall be taken from areas where the actual thickness is greater than 100 mm. Alternatively additional sprayed concrete thickness shall be applied in selected areas agreed by the Engineer for subsequent coring of test specimens.
- 3 Compressive strength tests shall be carried out on prepared test cores in accordance with BS EN 14487-1 and BS EN 14488-2. The time of coring shall be as close as possible to 24 hours after placing. Cores required for 28-day strength tests shall be obtained at the same time as those for 1-day tests and stored in the laboratory in accordance with BS EN 12504-1 and BS EN 12390-2.
- 4 The frequency of coring shall be in accordance with BS EN 14487-1. The minimum sampling frequencies are valid for production volumes or areas as indicated in the table below. For volumes or areas smaller than those in the table below, at least one test sample shall be taken.

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Method No.                   | Type of test                                                   | Inspection/test according to     | Minimum sampling frequency                   |                                             |                                             |
|------------------------------|----------------------------------------------------------------|----------------------------------|----------------------------------------------|---------------------------------------------|---------------------------------------------|
|                              |                                                                |                                  | Strengthening of ground                      |                                             |                                             |
|                              |                                                                |                                  | Category 1                                   | Category 2                                  | Category 3                                  |
| Control of fresh concrete    |                                                                |                                  |                                              |                                             |                                             |
| 1                            | Water/cement ratio of fresh concrete when using wet mix method | By calculation or by test method |                                              |                                             | Daily                                       |
| 2                            | Accelerator                                                    | From record of quantity added    |                                              |                                             | Daily                                       |
| 3                            | Fibre content in the fresh concrete                            | According to BS EN 14488-7       | Min 1                                        | 1/200m <sup>3</sup> or 1/1000m <sup>2</sup> | 1/100m <sup>3</sup> or 1/500m <sup>2</sup>  |
| Control of hardened concrete |                                                                |                                  |                                              |                                             |                                             |
| 4                            | Strength test of young sprayed concrete                        | BS EN 14488-2                    | 1/5000m <sup>2</sup> or 1/2 months           | 1/2500m <sup>2</sup> or 1/month             | 1/250m <sup>2</sup> or 2/months             |
| 5                            | Compressive strength                                           | BS EN 12504-1                    | 1/1000m <sup>3</sup> or 1/5000m <sup>2</sup> | 1/500m <sup>3</sup> or 1/2500m <sup>2</sup> | 1/250m <sup>3</sup> or 1/1250m <sup>2</sup> |
| 6                            | Density of hardened concrete                                   | BS EN 12390-7                    | When testing compressive strength            |                                             |                                             |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Method No.                                   | Type of test                                                                                                                                                          | Inspection/test according to                                                                                     | Minimum sampling frequency                                   |                      |                      |
|----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|----------------------|----------------------|
|                                              |                                                                                                                                                                       |                                                                                                                  | Strengthening of ground                                      |                      |                      |
|                                              |                                                                                                                                                                       |                                                                                                                  | Category 1                                                   | Category 2           | Category 3           |
| 7                                            | Resistance to water penetration                                                                                                                                       | BS EN 12390-8                                                                                                    | 1                                                            | 1/6 months           | 1/month              |
| 8                                            | Freeze–thaw resistance                                                                                                                                                | As no European Standard on this issue is available at the publication of this document, National Standards apply | 1                                                            | 1/6 months           | 1/month              |
| 9                                            | Bond strength                                                                                                                                                         | BS EN 14488-4                                                                                                    |                                                              | 1/2500m <sup>2</sup> | 1/1250m <sup>2</sup> |
| Control of fibre-reinforced sprayed concrete |                                                                                                                                                                       |                                                                                                                  |                                                              |                      |                      |
| 10                                           | Fibre content of hardened concrete (this test is alternative to method No. 3 when it is not practical to determine the fibre content from the fresh sprayed concrete) | BS EN 14488-7                                                                                                    | When testing residual strength or energy absorption capacity |                      |                      |

| Method No. | Type of test                                    | Inspection/test according to   | Minimum sampling frequency                     |                                             |                                            |
|------------|-------------------------------------------------|--------------------------------|------------------------------------------------|---------------------------------------------|--------------------------------------------|
|            |                                                 |                                | Strengthening of ground                        |                                             |                                            |
|            |                                                 |                                | Category 1                                     | Category 2                                  | Category 3                                 |
| 11         | Residual strength or energy absorption capacity | BS EN 14488-3 or BS EN 14488-5 | 1/2000m <sup>3</sup> or 1/10 000m <sup>2</sup> | 1/400m <sup>3</sup> or 1/2000m <sup>2</sup> | 1/100m <sup>3</sup> or 1/500m <sup>2</sup> |
| 12         | Ultimate flexural strength                      | BS EN 14488-3                  | When testing residual strength                 |                                             |                                            |

- 5 Mechanical rebound hammers shall not be used to obtain indirect compressive strength of sprayed concrete.
- 6 If the results of any production test do not comply with the evaluation criteria, the results and tests procedures shall first be checked and confirmed. The Engineer may require that additional tests be carried out by the Contractor to determine the extent of the non-compliance and/or new mix proportions or methods determined to avoid further failures.
- 7 Where sprayed concrete does not comply with the required strength, the Contractor shall execute remedial work which may involve additional sprayed concrete or replacement in sections where it is safe to do so. The Contractor shall take into account any limits placed on the tunnel profile dimensions resulting from the Specification. The Contractor shall submit to the Engineer for agreement, a method statement, specification and calculations for remedial work.
- 8 The Engineer shall, in the event of repeated failure in Quality Control, require the Contractor to adjust the mix to achieve the required strength.
- 9 The Contractor shall keep a record in a form to be agreed with the Engineer of all tests on sprayed concrete, which shall be kept on site identifying the tests with the section of work to which they relate.
- 10 Site-specific calibration is required for the strength tests of young sprayed concrete as specified in BS EN 14488-2.
- 11 For permanent linings, test panels sprayed in the tunnel can be used instead of taking samples from the lining.
- 12 All core holes in the lining should be backfilled with non-shrink mortar of an equivalent strength unless otherwise specified.

16.5.9.3 Immediately after removing tunnel lining forms for each segment of tunnel lining perform a survey of the tunnel to determine as-built conditions and locate any locations not complying with the required tolerances. Correct concrete lining as required to construct tunnel structure within specified tolerances and provide minimum required clearances.

#### 16.5.10 Inspection And Maintenance Of Initial And Permanent Tunnel Support

##### 16.5.10.1 Inspect support elements:

- 1 Daily for all tunnel excavations until conclusion of all work applicable to this Section, unless otherwise agreed with the Engineer.

##### 16.5.10.2 Repair or replace support elements:

- 1 Improperly installed.
- 2 Exhibiting evidence of structural distress.
- 3 Damaged for any reason.

### 16.6 Excavation Using Pre-support System for RWTL

#### 16.6.1 General

16.6.1.1 This Section applies to all tunneling work within the Tunnel performed with the use of a pre-support (pipe or pile) canopy. This applies to all tunneling work carried out using mechanical means (i.e. pneumatic hammer, scrapers, picks, roadheader or excavator).

- 1 The requirements included in this section shall be in addition to those set forth in Section 16.5.
- 2 The canopy shall be used as initial ground pre-support until the permanent lining is installed.

16.6.1.2 The tunnel excavation will be supported by Initial Support, which shall not form part or all of the permanent tunnel support.

16.6.1.3 The scope of work shall include the following:

- 1 Pre-excavation grouting as necessary,
- 2 Installation of groundwater drainage pipes (as applicable),
- 3 Installation and grouting of a pipe or pile canopy system for ground pre-support,
- 4 Excavation and installation of shotcrete and steel set supports in predetermined round lengths,
- 5 Installation of shotcrete and verification of required strength gain prior to subsequent advance.
- 6 Safety procedures appropriate for the excavation works such as, but not limited to, access provision, proper ventilation, gas detection during excavation.

16.6.1.4 Conduct a thorough assessment into all the utility crossings along the pipe alignment to be constructed and identify all suspected underground obstructions along the pipe alignment. The Contractor shall demonstrate that the pipe alignment to be constructed by pipe jacking has adequate clearance from all such utilities and obstructions.

## 16.6.2 Definitions

16.6.2.1 Cased-Drilled Method – A single-step method for the installation of a pipe casing involving advancing the pipe directly behind the drill bit during drilling. The bit and pipe casing stay in place after completing the drilling process.

16.6.2.2 Canopy Tube – A length of pipe casing, installed as part of a pipe canopy.

16.6.2.3 Drainage Tube – A hole drilled into the surrounding ground using a perforated casing to relieve groundwater pressure. Also referred to as Drainage Holes.

16.6.2.4 Excavation Round – The excavation length required to install the subsequent steel support(s).

16.6.2.5 Excavation Advance – The total excavation length performed under one pipe canopy prior to installation of the next pipe canopy.

16.6.2.6 Face Tubes – PVC or fiberglass tubes installed into the face for the purpose of drainage, grouting, or bolting.



- 16.6.2.7 Face Bolts – Fiberglass tubes drilled and grouted into the tunnel face.
- 16.6.2.8 Face Drainage – Perforated PVC tubes drilled into the tunnel face to relieve water pressure acting on the tunnel face.
- 16.6.2.9 Initial Support and Permanent Tunnel Support - systems composed of materials and structural elements combined together in a construction technique so as to provide support and face stability prior and during the excavation underground. These include steel arches, sprayed concrete, ribbed systems, rock bolts, etc.
- 16.6.2.10 Lattice girder - Initial Support elements consisting of three or four steel reinforcing bars interconnected with steel stiffening elements used to directly support rock loads by forming in conjunction with shotcrete a structural arch with or without associated wall plates, foot blocks, tie rods, spreaders, lagging, blocking, reinforcement anchorage for post, and other material to brace and fix the lattice girders. They are for use on underground excavations including but not limited to tunnels and shafts.
- 16.6.2.11 Pipe canopy – Also known as Pipe Umbrella or Pipe Arch. A pre-support system formed by the installation of pipe casings around the tunnel perimeter prior to excavation of the tunnel. The pipe casings are grouted in place after installation.
- 16.6.2.12 Pre-Drilling Method – A two-step installation procedure for a pipe casing where a hole is drilled first and then the pipe casing is pushed into the pre-drilled hole.
- 16.6.2.13 Probe Holes - Holes drilled from the excavation face as exploratory holes for locating potential groundwater inflow zones.
- 16.6.2.14 Spile – A steel bar installed as pre-support element around the tunnel perimeter prior to excavation of the tunnel. The spiles are typically grouted in place after installation
- 16.6.2.15 Steel sets – Also known as Steel Arch Supports or Steel Ribs. Steel arches consisting of steel beams that conform to the shape of the tunnel erected under the pipe canopy, installed in position, and encased with shotcrete to support the pipe canopy.
- 16.6.2.16 Steel supports – Steel lattice girder or steel set.
- 16.6.2.17 Threaded-Nipple Couplings – A system used to join the individual sections of pipe casing using a tapering thread body that when joined provides a constant outside diameter along the pipe.
- 16.6.2.18 Threaded Couplers – A system used to join the individual sections of pipe casing using a thread body that when joined has a larger outside diameter than that of the pipe casing.
- 16.6.2.19 Weep holes – Holes drilled through the temporary lining and into the ground that allow the dissipation of groundwater pressure on the lining.

### 16.6.3 Submittals

16.6.3.1 Prior to construction, the Contractor shall submit a supplement to the Construction Method Report(s) to cover excavation support using the pipe canopy system. The plan shall include:

- 1 Excavation and Support of Tunnel using Pipe canopy. This section shall include the following:
  - (A) Details of support arrangements and excavation procedures to suit the anticipated ground conditions. This may include, but is not limited to detailed methods for drilling, installing, and grouting of the pipe canopy, erection of steel sets, and application of shotcrete.
  - (B) Organizational chart indicating lines of authority and communication. Provide narrative or matrix indicating responsibilities and qualifications for key personnel.
  - (C) Procedures for performing geological mapping of the tunnel face and sidewalls exposed by the latest excavation round.
  - (D) Procedures to assess and evaluate the performance of the installed support and excavation procedure, by means of appropriate observations and/or instrumentation.
  - (E) Procedures for notifying the TDER and the Engineer if observations/instrumentation monitoring reveals that ground conditions are not adequately addressed by the existing design.
- 2 Handling and Disposal of Groundwater
- 3 Probe Drilling, Dewatering Holes, and Measurement of Groundwater Inflow
- 4 Drilling and Grouting
- 5 Instrumentation and Monitoring, including the frequency of readings, trigger levels, and review and action procedures for dealing with readings approaching or exceeding trigger levels.
- 6 Spoil Removal and Disposal

16.6.3.2 Submit the materials testing certification/information for the pipe canopy tubes including testing of couplers and steel sets and shotcrete for review and approval of the Engineer.

16.6.3.3 Submit the following certification/records during operations at the conclusion of each canopy advance:

- 1 Records of groundwater inflow through drainage tubes.
- 2 Records of amount of grout volumes and pressures injected through the pipe canopy tubes.
- 3 Records of amount of grout volumes and pressures injected for pre-excavation grouting operations.
- 4 Records of lining monitoring.

16.6.3.4 For lattice girders, submit the following to the Engineer for information, as part of the design submission:

- 1 Manufacturers product data
- 2 Material qualification data

- 3 Fabrication and installation tolerances
- 4 Three 600mm long samples of the lattice girder with accessories for each lattice girder type
- 5 Certifications that materials meet specification requirements
- 6 Qualified welding procedures
- 7 Welder certifications/qualifications
- 8 Fabricator's shop drawings for lattice girders prior to use.

#### 16.6.4 Worksite Conditions

- 16.6.4.1 The Contractor shall transport, handle, and install pipe canopy and steel sets using appropriate means to avoid damage. Do not attempt to install pipe canopy tubes that are bent, dented, or that have damage to the nipple threads.
- 16.6.4.2 Protect pipe canopy tubes, steel sets, and appurtenances from impact loads and chemicals in the tunnel environment. Materials exhibiting severe corrosion or oxidation that has pitted the surface of the materials and compromises the structural integrity of the pipes shall not be incorporated into the work.
- 16.6.4.3 Water from drainage tubes shall be collected in a conduit (e.g. PVC pipe) and channeled to the sumps or established drainage channels.

#### 16.6.5 Products

##### 16.6.5.1 Pipe Canopy

- 1 Pipe canopy tubes shall be provided by a manufacturer approved by the Engineer. Pipe wall thickness shall be a minimum of 6mm.
- 2 The pipe canopy tubes shall include threaded-nipple couplings capable of developing the full bending capacity of the pipe section without failure.
- 3 The pipe canopy tubes shall include perforations in the pipe wall to allow grouting of the annular space between the pipe canopy and drilled ground surface.
- 4 The pipe canopy tubes shall have a minimum yield strength of 460MPa
- 5 If systematic grouting through the pipe canopies is used to consolidate/improve the ground, additional perforations of 10mm minimum diameter shall be added to the tubes such that there is ten (10) perforation per one (1) square meter surface area along the pipe. Perforations shall be staggered and/or offset such that they do not diminish the bending moment capacity of the tube section.

##### 16.6.5.2 Spiles

- 1 Spiles shall be either:
  - (A) steel bars or tubes with wall thicknesses not less than that specified and constructed from steel to ASTM A615, or
  - (B) glass-reinforced plastic (GRP) bars or tubes with wall thicknesses not less than that specified.

- 2 The pile diameter shall not be less than that specified.
- 3 Pre-drilled and self-drilled piles shall be grouted. If grout is to be used for pile installation it shall be commensurate with the ground conditions and angle of pile inclination.

#### 16.6.5.3 Grout

- 1 Grout mix for pipe canopy tubes shall use a cement grout designed such that it can penetrate through the pipe canopy perforations and fill the annular space.

#### 16.6.5.4 Steel Sets

- 1 Unless otherwise agreed with the Engineer:
  - (A) Steel members shall be ASTM A992 Steel
  - (B) Butt plates shall be ASTM A36 Steel.
  - (C) Bolts for connecting butt plates of steel sets shall be A325 Type 1.
  - (D) Nuts for connecting butt plates of steel sets shall be A563 Gr. 3.

#### 16.6.5.5 Lattice Girders

- 1 Materials:
  - (A) Each of the primary retaining bars of a lattice girder segment shall be composed of only one piece of high strength steel having a yield strength of 460MPa or more.
- 2 Fabrication:
  - (A) The connection elements at the end of lattice girder segments shall be constructed of angled structural steel having yield strength of 250Mpa or more, or of welded flat steel ensuring similar strength characteristics.

#### 16.6.5.6 Drainage Tubes

- 1 Drainage tubes shall be provided by a manufacturer approved by the Engineer. Drainage tubes shall include threaded-nipple couplings and be installed using the cased-drilled method.

#### 16.6.5.7 Shotcrete

- 1 Shotcrete shall contain steel fiber reinforcement conforming to ACI 544.4R and ASTM A 820.

### 16.6.6 Execution Requirements

- 16.6.6.1 Unless otherwise agreed with the Engineer, the general construction sequence for installation of grouting, drainage tubes, pre-support canopy, steel supports, and shotcrete would be as follows.

- 16.6.6.2 Perform probe holes and measure water inflow. Monitor and record drill speed, torque, and resistance pressure required to advance each probe hole. The inflow limits shall be set by the Contract and shall be approved by the Engineer. If the inflow limits has been exceeded, drill grout holes and perform systematic grouting according to the Contractor's Design.
- 16.6.6.3 If grouting is performed, drill 15m long verification holes in the excavation face at four (4) locations to be determined in the field by Construction Superintendent and TDER.
- 16.6.6.4 If total combined flows from verification holes exceed that approved by the Engineer, grout verification holes and perform secondary grouting as previously described. Drill verification holes as in accordance with the Contractor's Design and approved by the Engineer at completion of secondary grouting and monitor groundwater. Continue sequence using tertiary grouting if combined flows from verification holes continue to exceed the approved value at the direction of the TDER, Superintendent, and Construction Manager.
- 16.6.6.5 Where required under the Design, drainage tubes shall be installed using the cased-drilled method. Water shall be used to flush the cuttings from the drill hole while installing casing. Bentonite shall not be used to advance the casing or flush the cuttings. Monitor and record drill speed, torque, and resistance pressure required to advance each drainage tube. Develop the drainage tubes by flushing with clean water to increase their effectiveness, as necessary.
- 16.6.6.6 Install the canopy tubes required for the advance and grout all of the pipe canopy tubes. Grouting of the pipe canopy shall be performed in a systematic 'bottom-up' manner. Inject canopy tube until a minimum pressure of 3 bar above back pressure is reached at a flow rate of less than 3l/min for a minimum of 10 minutes. If additional pipe canopy tubes are installed, follow a similar sequence for grouting.
- 16.6.6.7 The following excavation sequence shall be followed, unless otherwise agreed with the Engineer:
- 1 Excavation shall expose the underside of the pipe canopy tubes.
  - 2 Excavate in adequately short rounds. In no instance shall excavation face exceed 1.5m beyond the previously erected steel support.
  - 3 Upon completion of the excavation round, allow TDER access to face to record face condition and perform mapping and ground characterization. In the event the ground characterization indicates a change in ground support, TDER shall consult with Superintendent to verify and implement the change in support class.
  - 4 Apply a sealing layer of shotcrete having a minimum thickness of 50mm to the excavation surface and face. Install face tubes as necessary and as directed by the TDER and Superintendent. Erect steel support and apply shotcrete to completely fill any gaps between the shotcrete sealing layer and steel support. Build up shotcrete to the minimum design thickness as indicated on the Contractor's Drawings.

- 5 Continue excavation of next round once previously placed shotcrete has achieved the minimum compressive strength as described and at the locations indicated on the Contractor's Drawings.
- 6 Upon reaching end of the pipe canopy excavation advance where subsequent pre- support system components are to be installed, place a shotcrete with min thickness as specified on the Contractor's Drawings on the excavation face. Install face tubes as necessary and as directed by the TDER and Superintendent.
- 7 If, at any time during the excavation, work is stopped or delayed for more than 48 hours, apply shotcrete to the face (with designed thickness ) and build up shotcrete to the full design thickness within 1.5m of the face.

#### 16.6.7 Lattice Girders

##### 16.6.7.1 Design:

- 1 Design lattice girders for the Initial Support of tunnels, shafts, and other underground excavations to support the ground safely and maintain the shape of the tunnel without encroaching beyond the tolerances stated herein; and maintain until the final lining is complete and ready to accept loading.
- 2 Design lattice girders to facilitate shotcrete penetration into and behind the girder to minimize the creation of spray shadows.
- 3 Design lattice girders to have good quality bonding between the steel and shotcrete to form a composite structure and a continuous concrete lining.
- 4 Design all lattice girders to be fully encased in shotcrete or concrete.
- 5 Design lattice girders to contribute at a minimum, 5 percent of the total moment of inertia of the combined shotcrete/lattice girder arch.
- 6 The maximum spacing between stiffening elements shall be less than three times the cross sectional height of the lattice girder to ensure against buckling.
- 7 Design lattice girders with a maximum spacing of five feet from the centerline of each lattice girder to the centerline of each adjacent lattice girder.
- 8 Design all lattice girders to fully enclose the approved space requirements, with due consideration of construction tolerances and deformations due to rock loading.

##### 16.6.7.2 Preparation:

- 1 Prevent bending, scraping, and overstressing members when handling and shipping lattice girders.
- 2 Properly block projecting parts during handling to prevent damage.
- 3 Replace bent and damaged lattice girders.
- 4 Keep a reserve of all materials required for lattice girder installation ready for use when needed and in an amount sufficient to avoid delays

##### 16.6.7.3 Installation:

- 1 Provide lattice girders consisting of three or four primary retaining bars connected by steel stiffening elements of the manufacturer's design that are dimensioned, arranged, and installed as shown in the approved Initial Support Design Drawings. Install additional lattice girders as necessary to preserve the safety of the work.
- 2 Install lattice girders after each round, as soon as practicable after exposing ground by excavation, and as close to the heading as the Work will permit. Install lattice girders to within 1m of the exposed tunnel face at the point where excavation is full width, before stopping Work for prolonged periods of time, such as shifts not worked, weekends and holidays.
- 3 Secure lattice girder segments to maintain position during shotcrete application.
- 4 Provide steel footplates bearing on a smooth surface formed by pre-cast concrete or cast-in-place concrete. If precast concrete foot blocks are used, place foot blocks on a pad of low slump, dry packed concrete, completely filling any space between foot block and foundation surface, providing a level bearing surface.
- 5 Install lattice girders, tie rods, stiffeners, or other restraint to maintain the lattice girder in the proper configuration without buckling or deformation.
- 6 Lattice girder placing tolerances are as follows:
  - (A) Longitudinal: + 50mm
  - (B) Transverse: + 15mm
  - (C) Vertical: +15mm
  - (D) Plumbness: +25mm in 3m

#### 16.6.7.4 Field Quality Control:

- 1 The Contractor is solely responsible, during the course of construction, for the adequacy of lattice girders to ensure the safety of personnel and construction operations and to carry the actual loads without deflecting more than limits specified in the Contractor's Design.

### 16.6.8 Spiles

#### 16.6.8.1 Installation:

- 1 Where spiling is employed to provide support for advancing the excavation, spiles shall be driven into the ground or placed in predrilled and grouted holes as specified on the Contractor's Drawings.
- 2 The embedded length shall be not less than that specified by the Temporary Works Designer (typically 1 m beyond the proposed advance of the excavation).
- 3 The accuracy of installation shall be better than  $\pm 5^\circ$  away from the alignment specified.
- 4 The number, location, overlap and angle of spiles shall be commensurate with the ground conditions and methodology specified on the Temporary Works drawings.

- 5 Spiles shall be installed such that a tensile bond is formed between the spile, the ground ahead of the proposed excavation, and the sprayed concrete lining. Typically this may involve grouting the spile into the hole for pre-drilled and self-drilling spiles or hammering the spile in.
- 6 Care shall be taken during installation of spiles to ensure minimum disturbance of the ground due to the installation process.

## **16.7 Microtunnelling and Pipe Jacking Construction for RWTL**

### **16.7.1 Definitions**

- 16.7.1.1 Jacking Pipe - Pipe specifically designed and manufactured for the purpose of being jacked into its final position.
- 16.7.1.2 Launch pit or shaft - An excavation at the commencement point of a jacked section of pipeline, in which the jacking structure and other equipment is installed and from which the microtunnelling operations are carried out.
- 16.7.1.3 Lift (shaft / pit) - The incremental construction height completed as the shaft / pit progresses downward.
- 16.7.1.4 Microtunnelling - Method for installing an underground service pipe (pipeline) to a high accuracy using a microtunnel boring machine (MTBM) without disturbing the surface. The pipeline is installed behind the MTBM via a pipe jacking operation.
- 16.7.1.5 Open Shield System - A mechanised tunnelling system having no capacity to create a pressurised area forward of the machine for ground support or groundwater control.
- 16.7.1.6 Operator - Suitably trained or qualified person who operates machinery, an instrument or other equipment.
- 16.7.1.7 Safe Work Method Statement - A document summarising the work required for an activity. This document summarises the hazards and the required measures to control and minimise safety risks.
- 16.7.1.8 Shield - A tunnelling machine comprising a cylinder of metal at the leading edge of a pipe jack that is driven forward through the ground and which protects those staff working within it.
- 16.7.1.9 Trenchless Construction - Installation of new, or replacement of, underground infrastructure with minimal disruption to surface environment, traffic, business and other activities.

### **16.7.2 General**

- 16.7.2.1 Tunnel construction by one-pass methods with or without human interference. The construction method involve jacking pipe following a microtunneling boring machine, with the pipe serving as both the tunnel liner during construction and the water conveyance pipe after completion of construction.
- 16.7.2.2 Microtunnelling/Pipe Jacking shall, for the purpose of this document, be defined as a trenchless construction method for installing pipelines which is:



- 1 Controlled: The microtunnel boring machine (MTBM) is typically operated from a control panel at the surface; The system will generally install pipe simultaneously as spoil is excavated and removed;
- 2 Guided: The guidance system shall reference fixed points in the MTBM and shall be capable of installing the pipes to the required tolerance for line and level;
- 3 Jacked: The process of constructing the pipeline shall be by consecutively pushing pipes and the MTBM through the ground using a jacking system for thrust; Alternatively, the pipe can be pushed/jacked into the ground after the hole is excavated provided that the drive is in competent ground able to selfsupport until the pipe is installed;
- 4 Supported: Most microtunnelling/pipe jacking drives are able to provide continuous pressure to the face of the excavation to balance ground, groundwater and earth pressures; However, in some instances with competent dry ground full face support is not required and the Contractor will employ a machine unable to provide pressure to the face.

16.7.2.3 To avoid confusion within this Specification the term 'microtunnelling' will be used to describe any works that include the use of a microtunnel boring machine and/or pipe jacking system for the installation of a pipeline with minimal surface disruption.

16.7.2.4 Microtunnelling can be divided into two categories defined by the excavation technique and the material handling systems on the MTBM. The Contractor is responsible in identifying which type of microtunneling equipment is the most efficient for this Project. The categories are listed and defined below:

- 1 Slurry Microtunnelling
- 2 Earth Pressure Balance Microtunnelling

16.7.2.5 The Drawings and Specification define the basic requirements for finished pipe laying by MTBM pipe jacking work, and cover appropriate techniques that may be applicable to the works to be undertaken by the Contractor.

16.7.2.6 The Contractor shall be responsible for inspecting the location and familiarising himself with the conditions under which the work will be performed and with all necessary details as to the orderly execution of the work. The omission of any details shall not relieve the Contractor's responsibility for the satisfactory installation of the work in its entirety. No monetary or other claims made by the Contractor on the grounds of want of knowledge will be entertained by the Engineer.

16.7.2.7 All excavations shall be carried out to the required lengths, depths, inclinations and curvatures as may be necessary for the construction of the works or as shown in the Drawings, in whatever material that may be found. All excavated materials shall be disposed off to the appropriate dumping sites.

16.7.2.8 It shall be the responsibility of the Contractor to maintain stable soil conditions at the jacking face to prevent loss of ground during pipe jacking operation. Methods which require dewatering of the ground will not be accepted, nor will methods which may lead to significant ground loss.

- 16.7.2.9 All tools on the cutter head including gauge cutters shall be of robust and durable for construction to minimize the need for replacement during the pipe jacking. Any proposed method by the Contractor that requires the use of compressed air to perform inspection and maintenance is subject to approval by the Engineer.
- 16.7.2.10 The Contractor shall be responsible for design and approval of all temporary works for pipe jack. The design of all temporary works for pipe jack shall be independently checked and submitted to the Engineer for review. The designs shall be submitted to the Engineer a minimum of 30 working days before the commencement of construction of the works which are the subject of the design. The certified designs shall include geotechnical and structural design for the pipe jack, the method of protecting the excavation from traffic, slopes, structures and utilities, and the method of dealing with groundwater.
- 16.7.2.11 The Contractor shall be responsible for ensuring that sufficient time is allowed for submission and acceptance of his proposal and for the manufacture and delivery of the necessary material to avoid delaying of the works.
- 16.7.2.12 During construction of pipe jack exceeding 50m in length they shall, until substantially complete, be equipped with a telephone providing communication between the work below ground and an approved location at the surface. Except with the Engineer's permission, all such telephones shall be equipped with coloured light signalling systems and shall not be equipped with or connected to bells.
- 16.7.2.13 Arrangement for the location and guarding of plant, equipment, materials, accommodation, etc. required or to be used at each working shaft shall be subject to approval by the Engineer. All shafts shall be equipped with guard railing at least 1.2m high or other approved equivalent.
- 16.7.2.14 The approved working area for each shaft shall be enclosed by a secure fence or hoarding which shall be close boarded and not less than 2.3m high and shall, where appropriate, be equipped with warning lights. Watchmen shall be present at shafts at all times when work is in progress.
- 16.7.2.15 Smoking and naked lights shall be prohibited in pipe jack, and shafts and on the surface within 5m of any working shaft and of the outlet of any exhaust fan in use for the ventilation of such works.
- 16.7.2.16 Jacked pipes shall be kept clear of water and excavated material, and shall not be used for storage of plant or equipment nor for holding plant or equipment which is temporarily unused except where this cannot reasonably be removed elsewhere.
- 16.7.2.17 All personnel employed by the Contractor in the execution of pipe jack including the sinking of and attendance at shafts shall be experienced and competent in their respective tasks and shall work only under the direct control of a suitable supervisor. Operators shall be fully aware of all specified tolerances and maximum allowable jacking loads.

- 16.7.2.18 The Contractor shall submit to the Engineer the preliminary mapping report of the underground utility services survey at least 1 month prior to the commencement of works on site. A minimum 3.5m band width along the pipe alignment shown on the Drawings and 2m from the edges of working shafts shall be surveyed. If a utility was identified in the area during the survey, Contractor shall notify the engineer and will be responsible in the coordination with the utility company.
- 16.7.2.19 Annular grout shall be placed to fill up the void between the jacking pipe and the ground. The annular grout shall be non-shrink type to protect the jacking pipe. The design of annulus grout shall be submitted to the Engineer for approval. The Contractor shall demonstrate the annular grout has filled up the whole void fully after setting. In case any voids still exist after the first grouting, the Contractor shall carry out the grouting work again.
- 16.7.2.20 For all sections of jacking pipe shown on the Drawings to be constructed by the MTBM pipe jacking method, access will not normally be permitted from the surface to allow the removal of obstructions, e.g. boulders, timber, artificial material or any other material which obstructs normal pipe jacking operation. The Contractor shall use suitable MTBM and adopt appropriate construction methods to minimise, as reasonably possible, the risk of pipe jacking and tunnelling being stopped. The Contractor shall submit the contingency plans to the Engineer four (4) weeks prior to the commencement of any pipe jacking and tunnelling drive detailing the Contractor's proposals for dealing with any obstructions which may interrupt progress. These contingency plans shall be agreed in principle with the Engineer and Employer and any relevant authorities. It shall be noted that excavation from the road surface, when permitted, may be restricted to non-peak hours, including night-time and may have to be temporarily decked over at other times. Appropriate approvals and permits from relevant authorities shall be required.
- 16.7.2.21 The finished diameters of jacking pipe shown on the Drawings are the minimum hydraulic diameters required.
- 16.7.2.22 Pipe laying by the MTBM pipe jacking method shall be selected to control ground and water table movements to prevent damage to adjacent roads, utilities and structures.
- 16.7.2.23 All machinery, including hoists, locomotives and track shall be suitable for quiet and efficient operation and shall be installed and maintained to a high standard of reliability and safety to the satisfaction of the Engineer.
- 16.7.2.24 The Contractor shall comply with and make due allowance for this site access restriction in his method of construction.
- 16.7.2.25 Standards and Regulations
- 1 The Contractor shall undertake his own assessment as to the type of material to be excavated and sub-surface conditions and shall allow for any dewatering, timber shuttering and shoring that may be required.

- 2 Where local or international standards do not exist, the manufacture and installation of equipment shall be in full compliance with the manufacturer's own recognized standards. Manufacturer's standards, where used, shall be submitted to the Superintendent by the Contractor for review and acceptance shall be obtained by the Contractor from the Superintendent prior to commencement of manufacture.
- 3 The Contractor shall have in place a dedicated quality system that conforms to ISO 9001.
- 4 Quality control procedures for management, inspection, review and evaluation of all materials, manufacture, workmanship and testing of all products shall be planned and implemented by appropriately skilled and qualified persons to ensure that requirements of the quality procedures are met and that high quality is maintained.
- 5 The Contractor shall ensure that all equipment supplied/installed under this Specification is the product of a manufacturer who is fully experienced, reputable, qualified and regularly engaged for at least five years in the manufacture of the equipment to be supplied/installed. A technical note of the proposed equipment supplier shall be submitted by the Contractor to the Engineer and Employer for acceptance.

#### 16.7.2.26 Approved Sub-contractor

- 1 The specialist sub-contractor to carry out pipe jacking shall be approved by the Engineer prior to the commencement of work on site.
- 2 Should the Contractor intend to carry out the pipe jack himself, this must also be approved by the Engineer.
- 3 The Contractor shall engage skilled pipe jacking operators with a minimum relevant experience of at least 5 years to carry out the pipe jacking work in similar ground conditions.
- 4 The Contractor shall ensure that all key personnel who are responsible for driving, maintenance and controlling the machine for the pipe jacking work have received the necessary training in the duties that they are required to perform. Such training shall include emergency procedures.
- 5 The Contractor shall submit the staff qualifications, training and experience records for key operational and managerial staff, and past job reference of the sub-contractor or the contractor to the Engineer for approval.

#### 16.7.3 Submittals

##### 16.7.3.1 Method statements

- 1 The Contractor shall submit to the Engineer at least 4 weeks prior to construction of each section of pipe jack, a detailed method statement covering all the pipe laying by MTBM pipe jacking method for that section of pipe jack. The method statement shall be fully documented with calculations and working drawings. The method statement must cover all the operations required to install the jacking pipe with particular reference being made to the following:

- (A) Type of tunnelling machine and method of construction including proposals for controlling ground movements and groundwater drawdown; these shall be such as to prevent damage to existing roads, utilities and structures;
- (B) Installation of pipes;
- (C) Details of pipe joints and methods of transferring thrust;
- (D) Method of maintaining water tightness around the shield and pipes at the shafts with particular reference to the breakaway from the shaft;
- (E) Spoil removal system;
- (F) Safety requirements;
- (G) Grouting proposals;
- (H) Personnel details;
- (I) All supporting calculations and working drawings;
- (J) Contingency plans for removal of obstructions, recovery of pipe jacking machine; and
- (K) Ground investigations.

#### 16.7.3.2 Daily report

- 1 The Contractor shall submit to the Engineer a daily report on the progress of the pipe-jacking activities and any unusual occurrence in a form approved by the Engineer. The report will include, but will not be limited to, daily survey results, line and level, pressure and distance.

#### 16.7.4 Products

##### 16.7.4.1 Pipe Jacking Machine

- 1 The tunnel shall be constructed by pipe jacking techniques using purpose made MTBM for excavation. The MTBM shall have a pressurized closed face slurry tunnelling system offering controlled support pressure to the tunnel face. The MTBM shall have a provision to deal with ground water in case the access door must be opened in an area where ground water is present.
- 2 The Contractor shall be fully responsible for the selection, design and supply of the machines, shields and ancillary equipment. The complete system shall be purposely designed for the project while being compatible with the anticipated soil and geotechnical conditions. The system shall include MTBM, slurry circuit, pressure bulkhead, main jacking station, interjack stations and automatic bentonite injection system for lubrication of the pipe annulus.
- 3 All tunnelling machines shall be robust with adequate safety margins for the anticipated duty, designed and manufactured to comply with all relevant safety standards.

- 4 The cutter face shall at all times be able to support the full excavated area without the use of ground stabilisation and have the capability of measuring the earth pressure at the face and setting a calculated earth balancing pressure. The MTBM shall control groundwater during excavation without the use of external dewatering equipment. The measuring and balancing of earth and groundwater pressure shall be achieved by use of slurry. A slurry bypass method shall be included to allow for change in direction of flow to be made or isolated. The system shall be capable of increment adjustment to maintain face stability for soil conditions encountered.
- 5 The pressure control system shall automatically maintain the required pressure on the face at all periods when the machine is advancing, and when standing. Control shall be such that the pressure can be adjusted to suit changing face conditions and can be maintained at all times within  $\pm 10\%$  of the required pressure.
- 6 Pressure sensors capable of working in air, liquid, spoil/liquid and spoil media shall be mounted on the pressure bulkhead or slurry pipework with pressure gauges in the control cabin reading the pressure in the chamber.
- 7 Access shall be provided from inside the machine to the front of the shield by means of an access door in order to replace disc cutters which are worn during pipe jacking. The access can also be used to deal with unforeseen obstructions which may block the advance of the MTBM. All tools on the cutter head including the gauge cutters shall be of robust and durable construction in order to minimise the need for replacement during the drive. The MTBM must have a provision to deal with ground water in case the access door must be opened in an area where ground water is present.
- 8 The MTBM shall be equipped with an airlock system. Where the machine uses low pressure compressed air system to gain access to the pressure chamber, this shall comply with the provisions of BS EN 12110:2014 and all relevant safety standards.
- 9 The external diameter of the MTBM or shield shall be designed to produce minimum overcut and the least necessary clearance for the proper construction of the Works. Design shall take into account the horizontal and vertical alignment to be negotiated. Provision shall be made to limit and correct roll of the machine.
- 10 All operating functions of MTBM or shield, including rate of advancement, shall be in the control or direction of the MTBM or shield driver. The MTBM shall be capable of controlling shield rotation by means of bi-directional drive on the cutter head. The MTBM shall be mechanically articulated to enable remotely controlled steer of the shield.
- 11 There shall be adequate access to all areas of the MTBM where work, including maintenance, may be carried out. A clear means of egress in an emergency shall be provided and maintained at all times. Minimum dimensions shall conform to the appropriate safety standard.

- 12 The machine and MTBM shall be guided by a laser guidance system, which is acceptable to the Engineer to ensure that the specific alignment is achieved during advance. A guidance system, with the ability to predict ahead of the face, installed on pipe jacking machines with a display to show the position and altitude of the machine is recommended. Line and grade shall be controlled by the guidance system that relates the actual position of the MTBM design reference. The display should be positioned to enable the machine driver to have a clear view at all times.
- 13 MTBMs shall be furnished with a means of controlling orientation. Steering information shall be monitored and transmitted and saved to the operator console. The MTBM display shall continuously show and automatically record the position of the shield relative to the design reference, roll, inclination, altitude, rate of advance, installed pipe length, thrust force, cutter head torque, slurry pressure, slurry flow and slurry valve positions. Lasers or other means are to be provided to determine the line, level and square of the shield. Detailed guidance information shall be checked against the tunnel alignment control at regular intervals as agreed with the Engineer.
- 14 The MTBM shall have suitable features to ensure that the shield shall maintain line and level and shall be able to make the required adjustments to recover the line and level if necessary. Such features may include an articulated cutter head, programmable gauge cutters, etc.
- 15 The MTBM shall be capable of bi-directional drive on the cutter head wheel to minimise drift and rotation or roll of the pipe during pipe jacking operation.
- 16 The Contractor shall demonstrate that the equipment and installation methods shall not damage the pipes.
- 17 A lubrication system that injects an accepted lubricant to lower the friction developed on the sides of the pipe during jacking shall be provided.

#### 16.7.4.2 Jacking Pipe

- 1 Pipe units to be installed by pipe jack shall be suitable for the intended use, and for the forces to be generated during installation.
- 2 Where external collars are used for jointing they shall be constructed of corrosion-resistant materials such as stainless steel or shall be protected against corrosion by an approved coating system.
- 3 Gasket for pipejack joints
  - (A) Gaskets for pipejack joints shall provide a seal against the ingress of groundwater during jacking and in the permanent condition. Gasket material shall comply with the requirements of BS EN 681-2, including resistance to chemical attack and microbiological degradation.
  - (B) The gasket shall be lubricated with a product recommended by the manufacturer and agreed with the Engineer.
- 4 Provision shall be made for the injection of lubricating fluid or grout through pre-formed holes in the pipe walls. Lubrication holes shall be fitted with non-return valves.

- 5 The manufacturer's premises and methods shall be open to inspection by the Engineer for the purpose of checking the quality of manufacture. The Contractor shall ensure that all necessary assistance is provided to the Engineer on each visit.

#### 16.7.5 Execution Requirement

##### 16.7.5.1 Surveying and Setting-Out

###### 1 Preliminary Survey

- (A) Before commencing the pipe jacking work, the Contractor shall without prejudice to any other requirement of the Contract and to the satisfaction of the Engineer.
- (B) It shall be the responsibility of the Contractor to satisfy himself as to the ground conditions along the pipe jacking route and if he judges it to be necessary, he shall carry out additional ground investigations at his own cost.
- (C) Conduct a thorough assessment into all the utility crossings along the pipe alignment to be constructed by pipe jacking method and identify all suspected underground obstructions along the pipe alignment. The Contractor shall demonstrate that the pipe alignment to be constructed by pipe jacking has adequate clearance from all such utilities and obstructions.
- (D) Establish reliable temporary bench marks (above ground) at both ends of each pipe jack to be driven from the shaft.
- (E) Establish at least four reliable survey stations adjacent to the shaft to facilitate the setting out of the underground works and checking of the setting out.
- (F) Prior to the commencement of pipe jacking operations the Contractor shall install the settlement monitoring points generally at 5m intervals along the ground surface directly above the centreline of the pipe to be jacked and at offsets from that line of 5m interval up to 10m but not less than the depth from ground level to the bottom of the pipe where possible, unless otherwise directed by the Engineer to suit site condition. In roads these cross sections shall extend the full width of the road corridor. Settlement monitoring points shall also be installed at the corner of each building or other structures within 20m of the centreline of the pipe jack. Additional settlement monitoring points shall be identified as required by the Contractor as part of his design submission and installed as directed by the Engineer.
- (G) The Contractor shall conduct the conditional survey with supporting photographs the condition of all roads, footpaths, buildings and structures over and alongside each pipe jack route. The records shall be submitted to the Engineer as a record of reference in checking for subsequent settlement during excavation.
- (H) Prediction of ground, building and structure movements as a consequence of the pipe jacking work and at each stage of construction shall be provided by the Contractor as part of his design submission for each element of the works to be designed.

###### 2 Setting out of the works



- (A) The Contractor shall provide the Engineer with details of his proposed method of setting out pipe jacking.
- (B) The Contractor shall, given reasonable notice, allow access for the Engineer and his staff to all pipe jacking sections at any time for the checking of the lines and levels, and for measurement and logging of progress. The frequency of checking and logging shall be agreed with the Engineer on site.

3 Surveys during construction

- (A) During the jacking operation between any two working shafts the Contractor shall make daily observations, or at the numbers of survey monitoring per day as directed by the Engineer, of surface levels on the previously agreed cross section points to detect subsidence (if any). Such daily observations should be recorded in forms of agreed with the Engineer, the records should be submitted to the Engineer daily.
- (B) Upon completion of a pipe jack between any two working shafts the Contractor shall, without prejudice to any other requirement of the Contract and to the satisfaction of the Engineer.
- (C) Repeat the level survey of the ground surface above the pipe jack.
- (D) Record and report with supporting photographs for changes in the condition of roads, footpaths, buildings and structures over and alongside the pipe jack.
- (E) If at any location or time, actual movements recorded exceed 90% of the predicted movements at that stage and 75% of the total predicted movement, the Contractor shall review his predictions and resubmit his predictions to completion of the works where directed by the Engineer.
- (F) If at any location or time, actual movements recorded exceed the predicted movements at that stage and 85% of the total predicted movement, the Contractor shall be required to stop work and take any necessary remedial measures to protect the adjacent building, structure and road. Work shall only recommence once the Contractor has resubmitted his revised predictions, revised his construction method and sequence as required and measures are in place to protect the adjacent building, structure, road and facility at risk.
- (G) Shortly prior to the substantial completion of the works and again prior to the end of the maintenance period, the Contractor shall repeat the surveys and inspection as described above for the pipe jacking.

16.7.5.2 Safety

1 General

- (A) Where work is carried out in pipe jack, the Contractor shall comply with the following local safety requirements and all relevant safety standards, as well as obtaining necessary permits needed to operate the works.

2 Lighting and other electrical equipment

- (A) Lighting and other electrical equipment for use within or adjacent to jacking sections and shafts shall be either intrinsically safe or flameproof of an approved type. Where considered appropriate for man access and for essential services. Whenever work is in progress underground the workings shall be illuminated adequately. A minimum light of 100 watts per 10m length of pipe jack or such higher level that may be required by the Engineer for safe working, access and inspection shall be installed and maintained unless otherwise consented to by the Engineer. Naked lights shall not be used.

### 3 Ventilation

- (A) The Contractor shall maintain a fresh air supply by approved means to all places underground and to all chambers wherein work is being undertaken. The use of compressed air for ventilation purposes will not be permitted.
- (B) Each shaft and jacking section shall be ventilated by a fan which shall be suitably situated and connected by ventilation ducting to within 5 metres of the working face.
- (C) The fan shall be capable of delivering or exchanging at the end of the ducting at least 15 cubic metres of air per minute per square metre of area of the face to be ventilated.
- (D) Approval to the use of diesel power will not be given.
- (E) Ventilation shall not be considered satisfactory unless:-
  - (i) The amount of carbon dioxide in the general body of the air is not more than 0.5 per cent by volume;
  - (ii) The amount of oxygen in the general body of the air is not less than 20 per cent by volume;
  - (iii) The amount of respirable dust and quartz in the general body of the air is not more than 0.25 milligrams per cubic metre;
  - (iv) The amount of any other substance is within safe working limits. The total concentration of inflammable gas shall not exceed 25 per cent of the lower explosive limit of the mixture by volume in air.
- (F) The Contractor shall ensure that no person is allowed to enter any pipe jack for any purpose whatsoever except with adequate attendance, life lines and breathing apparatus, or unless the pipe jack is being ventilated as described above and has been so ventilated continuously for at least one hour up to the time of entry. Safety procedure under 'working in confined space' shall be implemented by the Contractor.
- (G) Each shaft sinking and pipe jack shall be provided with at least two (2) approved automatic gas detector. Continuous monitoring for toxic and inflammable gases oxygen content shall be instituted with monitors set as near as possible to the most hazardous areas. Regular tests shall also be taken for carbon dioxide content.
- (H) All gas detectors shall be expertly and regularly maintained.

- (I) If gas detection equipment indicates the presence of toxic or inflammable gases approaching hazardous concentrations, all work in the danger area shall cease and all personnel shall immediately vacate the workings, and the condition of the workings shall be reported to the Engineer immediately. The activity will be considered as a hazardous activity and any succeeding procedure shall be in accordance to Section 3.

#### 16.7.6 Excavation in Pipe Jacks

##### 16.7.6.1 General

- 1 The Contractor shall plan, programme and execute the excavation of jacking works in accordance with the Specification and Drawings. Before commencing work the Contractor shall submit and have approved his method statement by the Engineer.
- 2 Excavation of jacking work that carried out in any material encountered, shall be true to line and level. The Contractor shall provide such continuous superintendence as is necessary to maintain line and level during jacking of the pipe.
- 3 The position of the internal face of any pipe shall not deviate, at any time during the pipe jacking procedure, from that detailed in the Contract by more than the following permissible deviations or any other reduced deviation necessary to prevent distress to the pipe.

| Work Category | Dimension or Alignment | Permissible Deviation |
|---------------|------------------------|-----------------------|
| Pipe jacking  | Horizontal Alignment   | 50 to 75mm            |

- 4 The gradient shall not deviate more than 0.5% from the design gradient. There shall also be no backfall at any point of the pipeline. Any misalignment shall be made good to the satisfaction of the Engineer at the Contractor's expense.
- 5 The Contractor shall assess the anticipated localised settlement at any jacking pipe section to ensure that the pipe joints and watertightness systems proposed is not compromised and incorporate any necessary strengthening of the pipe and pipe joints and ground improvement measures into his design.
- 6 The manner in which the excavation is carried out shall be such as to minimise the extent of any loosening of the ground beyond the limits of the excavation and to ensure that the ground is fully supported at all times. The Contractor shall take immediate action to secure any loose material in the excavated face so as to minimise risk of loss of ground and consequent settlement of properties and services above and adjacent to the works.
- 7 In the absence of other requirements or limitations in this Specification, or subsequent instructions, the Contractor will be a liberty to propose and adopt, subject to the Engineer's approval, any of the normal methods of excavation in jacking.

- 8 Any significant subsidence of the ground, if noticed, shall be immediately brought to the notice of Engineer and all excavation operations shall be stopped.

#### 16.7.6.2 Working Shafts

- 1 The Contractor shall construct working shafts at locations shown in the drawings and exact location to be approved by the Engineer.

#### 16.7.6.3 Excavation in jacking

- 1 The Contractor shall ensure the compatibility of the excavation methods adopted with the method for dealing with water in jacking. In the event of ground or water conditions varying to such an extent as to require an alteration to the method of working then the Contractor will be required to submit to the Engineer without delay his proposals for dealing with the new conditions.
- 2 Excavation shall not be carried out ahead of the leading edge of the shield except for the purposes of removing obstructions or making clay pockets.
- 3 The Contractor shall conduct regular checks to compare the volume of material removed with the calculated volume of the jacking to provide a safeguard against excessive loosening or loss of material beyond the pipe dimension. Allowance shall be made for any material removed with the water from the jacking operation.

#### 16.7.6.4 Grouting of Cavities

- 1 The Contractor shall submit the grouting proposal and grout mix and obtain the consent of the Engineer before any cavity grouting is carried out. The proposed grouting method shall be compatible with the proposed pipe jacking method.
- 2 The minimum compressive strength of hardened grout shall be 5MPa. The Engineer may consent to the use of an accelerator in the grout mix or the use of other additives. The injection grout shall be thoroughly mixed in plant which shall be positioned as near to the point of injection as practicable.
- 3 The Contractor shall keep a detailed record for the grouting work at least containing the following information:
  - (A) Time and duration of grouting work;
  - (B) Details of grout mix;
  - (C) Point of injection and depth of the hole; and
  - (D) Quantity of grout and pressure applied.
- 4 The grouting record shall be kept on Site by the Contractor and be available for inspection by the Engineer at all times and shall be the property of the Employer on completion of the Contract.
- 5 All lifting holes and grouting holes shall be sealed with approved mortar.

#### 16.7.6.5 Grouting to facilitate excavation

- 1 Grouting techniques may also be required or applied to control groundwater flows or pressures or to consolidate weak or fissured ground.
- 2 The Contractor shall provide suitably qualified and experienced staff to supervise these operations, and shall obtain the approval of the Engineer to the proposed personnel before commencing such work.

#### 16.7.6.6 Grouting ahead of pipe jacks

- 1 Grouting from pipe jacks to reduce water inflows or to stabilise ground prior to excavation shall comply with the general requirements of this Clause and procedures shall be agreed to verify the cost-effectiveness of the procedures and to facilitate measurement.
- 2 Where forward probing is being employed the grout shall be injected via the probe holes, and the drilling and grouting plant provided by the Contractor shall be compatible with this objective.
- 3 Grouting shall not be carried out at pressures higher than that exerted by the overburden to the jacking pipe, and shall normally be carried out until the acceptance drops below 2 litres per minute per metre length of hole being grouted.

### 16.7.7 Pipe Jacking

#### 16.7.7.1 General

- 1 Before commencing any pipe jack, the Contractor shall submit for approval by the Engineer full details of the proposed pipes to be installed, the equipment and method to be used and the personnel. Each crew to be employed on pipe jacking work shall include a reasonable proportion of suitably experienced personnel. An engineer or foreman experienced in the pipe jacking technique shall be present at all times to supervise the work.

#### 16.7.7.2 Thrust pits

- 1 The Contractor shall be responsible for the design, safe and efficient operation and supervision of the jacking equipment, thrust blocks and ancillaries. For the purpose of pipe jacking work, thrust pits shall be deemed to be working shafts.
- 2 Thrust walls shall be designed to transfer jacking forces to the ground without visible settlement or deflection and shall be adequate for installation of the pipeline. Each thrust wall shall be constructed normal to the proposed line of thrust. The Contractor shall be solely responsible for the design and construction of the thrust walls and any associated works.
- 3 Rails for pipes supports shall be continuous over the full length of the pit. No joints in the rails will be allowed within the pit.

#### 16.7.7.3 Reception pits

- 1 For drives requiring a reception pit to receive the shield and leading pipe of a pipe jack, the Contractor will generally not be permitted to commence driving the pipe jack until the reception pit construction has been completed unless otherwise approved by the Engineer.

#### 16.7.7.4 Shields for pipe jacking

- 1 Excavation of pipe jacks shall be undertaken within a shield suitable for the ground conditions to be encountered which shall be kept close to the working face of the drive at all times. Where the size of the jack permits the shield shall be equipped with steering jacks. Details of each shield for use on a pipe jack shall be submitted to the Engineer for approval as early as possible.
- 2 The Contractor shall give the Engineer 72 hours notice before mobilising a shield in any thrust pit and shall carry out such tests as the Engineer deems necessary to prove the shield is in good working order.
- 3 The Contractor shall ensure that an adequate supply of spare parts is available locally to allow foreseeable maintenance and repair activities to shields to be carried out without undue delay to the progress of the works.

#### 16.7.7.5 Execution of pipe jacking

- 1 The pipe jack load shall be transmitted to the pipe or performed units through a suitable thrust ring which shall be sufficiently rigid to ensure even distribution of the thrust. Resilient packing material shall be provided between the thrust ring and the end of the pipe or performed unit.
- 2 A purpose made compressible packer of hardboard or other approved material shall be included between the thrusting surfaces at each joint. The packer shall be placed in position and securely attached to each pipe or unit before the pipe or unit is transferred into the thrust pit.
- 3 Thrusting shall not be commenced until the sliding ring has been checked for damage.
- 4 Pushing blocks shall not be in direct contact with the pipe or performed unit, which shall be protected by means of a steel ring, template or other approved method. Damaged pushing blocks shall not be used.
- 5 The arrangement of thrust blocks, jacking system and pushing blocks shall be square to the line of the bore to ensure the whole is evenly loaded.
- 6 Interjack stations may be used at the discretion of the Contractor, where frictional resistance or other causes might otherwise necessitate unreasonably high jacking forces.
- 7 The Contractor shall take all reasonable precautions to prevent damage to the ground surface, utilities and structures above or adjacent to the line of pipe jack. The Contractor shall board off the entire face of any drive in soft ground at the end of each shift and at any other time when driving is discontinued.

#### 16.7.7.6 Checking and Control

- 1 The Contractor shall submit to the Engineer daily reports of the thrusting pressures and the line and level measurements and shall maintain a graphical plot of the records which shall be updated not less than once each day and be available for inspection by the Engineer at any time.
- 2 Checks on divergence shall be carried out at intervals not exceeding 300mm, and more frequently if required by the Engineer by means of laser beam and target or other approved technique. Any divergence from the required line shall be rectified without delay. However, adjustment of line and level shall be gradual and take account of the maximum recommended angular deflection of the pipe or performed unit joints. If the divergence exceeds the specified tolerances the drive shall cease and shall not recommence until the Contractor has instituted adequate remedial action to the satisfaction of the Engineer.

#### 16.7.7.7 Cleaning and inspection of completed works

- 1 Upon completion of pipe jacking of each pipe length, the Contractor shall flush the line and undertake a closed circuit television survey and provide the original video tape recording to the Engineer.
- 2 If necessary the Contractor shall remove any debris and/or carry out any remedial work identified. Upon completion of remedial work and/or removal of debris the section shall be re-surveyed and the Engineer provided with the latest original video tape recording. Further additional CCTV surveys resulting from the need to again clean or carry out further remedial work shall be at the Contractor's cost.
- 3 The pipeline shall only be commissioned after approval by the Engineer and receipt of the final inspection original video tape recording. Tape recordings of previous inspections will then be returned to the Contractor for re-use.
- 4 The Contractor shall submit to the Engineer within 30 days of completion of the pipe jacking, the as-constructed drawings in which all information and details for the complete construction of the pipe jacking shall be given.

### 16.8 In-tunnel pipeline option for RWTL

#### 16.8.1 General

- 16.8.1.1 When RWTL pipeline is constructed as in-tunnel pipeline, the Contractor may select tunnelling option for the carrying tunnel of the pipeline such that sufficient workspace can be established to layout the RWTL pipeline inside without compromising the economic and practical side of the construction from the viewpoint of material cost, local availability of equipment supplier, etc.

#### 16.8.2 Constructability

- 16.8.2.1 Carrying tunnel can be advanced through mined tunnelling technique, pipe jacking technique or any other options that the Contractor may deem to be efficient and economical.

16.8.2.2 To keep the volume of the empty space between the in-tunnel pipes and the carrying tunnel at a minimum, which can be backfilled by concrete after the pipeline construction, a minimum horizontal clearance of 500mm must be established between the individual RWTL pipes, and from the pipes to the carrying tunnel sidewall. This can establish a minimum 4.5m wide (i.e., base length) horse-shoe mined tunnel or a maximum 4-m pipe-jacked tunnel for the carrying tunnel. Should any construction methodology create tunnel dimensions outside of such criteria, direct tunnelling of the RWTL into the ground is recommended.

16.8.2.3 After the construction of the RWTL pipes, the carrying tunnel may be backfilled with concrete, otherwise, the tunnel lining for the carrying tunnel shall be structurally designed to sustain the design life of the RWTL pipes as stipulated in Section 10.3.

## **16.9 Slope Protection for WTP**

### **16.9.1 General**

1.6.8.1.1 The different elevation levels in the WTP area shall be supported by slope protection schemes to be selected and designed by the Contractor such that global stability, member adequacy, constructibility and non-disturbance to nearby and adjacent structures, properties, and/or public domains such as roads, bridges, etc. are satisfied

1.6.8.1.2 In the design of the slope protections schemes, both the stability during construction and the stability in the long-term conditions shall be considered. In the temporary condition, temporary construction loads and restrictions imposed on the construction in terms of land use shall be considered in the slope stability checking.

1.6.8.1.3 Critical sections for stability analysis shall be selected and analyzed using limit equilibrium method or numerical analysis. Stabilization works shall be proposed where necessary subject to the result of the stability analysis to achieve the required minimum factor of safety.

1.6.8.1.4 The stability of slope protection schemes under seismic loadings in terms of critical acceleration which corresponds to the design seismic action shall be considered. In identifying the critical acceleration and other related parameters, information from the Site-specific Seismic Hazard Assessment shall be utilised. Retaining walls and embedded type of retaining walls shall be designed with increases in active earth pressures and water pressures and reduction in passive pressures resulting from the design earthquake. Over-turning, sliding and bearing capacity of the retaining structures shall be assessed under the additional seismic loading to check the overall stability of retaining wall under earthquake loadings.

### **16.9.2 Constructability**

16.9.2.1 The Contractor shall employ only plant and working methods which are suited to the materials to be handled and traversed.



- 16.9.2.2 Temporary supports or other methods shall be used to maintain excavations in a stable condition and to prevent settlement of structures or utilities due to excavation or dewatering.
- 16.9.2.3 Construction plant or other vehicles shall not be operated or parked adjacent to excavations and earthworks material or other materials shall not be placed adjacent to excavations unless this has been allowed for in the design of the temporary works for the support of the excavation.
- 16.9.2.4 Equipment for the construction of the slope protection has to be mobile under the electrical posts and lines and other similar utilities found on site, otherwise construction and diversion plans for such existing utilities has to be provided by the Contractor.
- 16.9.2.5 The junction of slope protection structure and cast-in-place tanks must be designed to prevent loss of engineered fill material and must allow differential settlement between the two entities. Contractor shall identify the appropriate materials that should be used behind the joint to contain the soil from eroding.
- 16.9.2.6 Structural backfill and ordinary backfill material shall be compacted as stipulated in Section 16.4. Furthermore, both shall consist of free draining granular materials free from excess moisture, muck, frozen lumps and roots, sod or other deleterious materials. When structural backfill is used as part of the retaining earth structure, it must have at least 34 degrees of angle of internal friction, while at least 30 degrees would suffice for ordinary backfill. Gradation requirements for both shall be in accordance with published standards such as AASHTO T 27 and T 11, DPWH Standard Specification for Highway Bridges and Airports, or any other equivalent published standards.
- 16.9.2.7 Earthwork final surfaces and formations shall be maintained in a stable condition and shall be protected from damage due to water or other causes and from exposure to conditions which may adversely affect the surface.
- 16.9.2.8 Earthwork final surfaces shall be completed to a stable condition as soon as practicable after excavation has been completed. The subsequent permanent work or surface protection shall be carried out as soon as practicable after the earthworks final surface has been completed.
- 16.9.2.9 The impact of handling and storing of materials on site prior to their placement/installation which may affect the integrity of the materials due to degradation, damage, etc. before installation shall be taken into account by the Contractor.

### 16.9.3 Slope protection drainage

- 16.9.3.1 Drainage channels shall be provided at the crest and toe of slopes and retaining walls to intercept surface runoff and drain to an approved disposal point.

- 16.9.3.2 In order to avoid the excessive build up of porewater pressure in the backfill materials of the slopes and retaining walls during torrential rains, internal drainage systems such as weepholes, and/or other methodologies appropriate may be employed by the Contractor.

16.9.4 Construction monitoring

- 16.9.4.1 The Contractor shall provide appropriate methodologies in monitoring the water table level, movement and settlement of the backfill and engineered fills, inclination of slopes, etc. during the construction of the slope protection scheme. Methodology such as (but not limited to) utilisation of piezometer, tiltmeter, inclinometers, etc. may be employed on site.

**16.10 Site Monitoring**

16.10.1 General

- 16.10.1.1 This Section of the Specification defines the requirements for project-wide geotechnical instrumentation and monitoring.

- 16.10.1.2 To ensure the safety and stability of the Work, the Contractor shall monitor the ground support, the stability of the excavation and the surrounding ground, and compare results with estimated values. The monitoring systems shall measure movements of the ground, surrounding structures, and deformation of support system within the excavations.

- 16.10.1.3 Instrumentation is required for the measurement of:

- 1 Deformations or strains;
- 2 Movements / settlements of the ground, buildings, structures or utilities;
- 3 Groundwater levels or pressures;
- 4 Groundwater ingress into excavations.

- 16.10.1.4 The purpose of the instrumentation is to:

- 1 Enable the Engineer to be satisfied that the geotechnical models adopted are representative, and that the behavior of the ground and supports are as anticipated;
- 2 Allow re-evaluation of the ground strength and design parameters to confirm the adequacy of the support systems;
- 3 Assist with the identification and location of any high in-situ stresses;
- 4 Enable routine performance monitoring of excavation stability during excavation and support installation;
- 5 Provide advance warning to ensure safety.

- 16.10.1.5 The location, type and extent of monitoring required shall be determined by the Contractor and approved by the Engineer.

- 16.10.1.6 Environmental instrumentation and monitoring is outside of the scope of this section, and shall be carried out in accordance with the ECC requirements.

16.10.2 Submittals

16.10.2.1 This Specification requires, as a minimum, the following submissions to the Engineer:

- 1 Proposals to adopt alternative materials, equipment or methodology;
- 2 Method statements for all construction stage monitoring, including the types of equipment to be used, details of certification and calibration of instruments with a validity of at least one (1) year, installation and reading procedures, presentation of results, trigger levels, presentation of results, and actions proposed if the trigger levels are exceeded, including any emergency response;
- 3 Safety procedure to be implemented at Site which includes, but not limited to, identified risks and hazards of any activities involved in the Work, protective equipment to be used, provision of safety signages and warning devices, and mitigation and preventive measures.
- 4 The Contractor shall provide the data sheet of the geotechnical instrumentation to be utilized with the following information, but not limited to, information of the equipment, certificate associated for calibration and accuracy, local support, and other supporting details. The document shall be provided for review and acceptance of the Engineer.

16.10.2.2 Results of all monitoring undertaken for the Work.

16.10.3 Worksite Conditions

16.10.3.1 Instrumentation and monitoring shall be carried out within the Designated Work Areas and as well as in areas that may be accessible to the general public, along the RWTL alignment, as necessary.

16.10.3.2 Where necessary due to the nature of the ground conditions or where adverse water conditions are anticipated then the requirements for the use of special grouts for pre-excavation grouting shall be employed. Details of which are described below.

16.10.3.3 Pre-excavation grouting

1 Primary grouting

- (A) Primary grouting shall be undertaken at a pressure sufficient to place the grout properly but not greater than 1 bar above the prevailing hydrostatic pressure at the location of grouting unless the lining and equipment have been designed for higher pressures, and agreed with the Engineer.
- (B) Primary grouting shall be timed so as to minimise ground movement.
- (C) Any sealing material or device installed at the leading edge of the ring to prevent grout loss shall be removed upon completion
- (D) The Contractor shall ensure that grouting pressures do not result in ground heave or overstress or distortion of lining or distortion or damage to gaskets or damage to other structures.

(E) Grouting equipment shall be fitted with a pressure gauge and automatic pressure release valves capable of being preset to a specific pressure. Grout pressure is to be measured at the nozzle with a suitable gauge.

(F) Grouting shall be carried out at pressures to completely fill the cavity with grout.

## 2 Secondary grouting

(A) Secondary grouting is the regrouting of lining and shall be completed as soon as practicable but within 14 days of the primary grouting or when the face has advanced 50m from the location of primary grouting whichever first occurs. Secondary grouting shall be at a pressure consistent with filling all voids but shall not exceed the design pressures stated in the Section 16.9.3.3. (1)A.

16.10.3.4 Upon completion of grouting, threaded grout plugs shall be fully tightened into the lining.

## 16.10.4 Manufacture And Storage

16.10.4.1 All measuring devices used shall be manufactured by companies with proven experience in the field of geotechnical instrumentation and with a minimum of two (2) years implementation in a similar project. All materials, designs and construction shall be of a suitable quality to provide robust, corrosion and, where appropriate, vibration resistant instruments. The accuracy and dependability of the equipment shall not be significantly affected by changes in temperature, humidity, stray currents or other appropriate adverse conditions that may be encountered. A certified testing company shall provide calibration certification for each device with a validity of at least one (1) year.

16.10.4.2 The instrument manufacturer(s) shall provide drawings and data describing the principal features, mode of operation, the measuring range and the degree of accuracy, including repeatability of readings, of the equipment. The manufacture of all items shall be in accordance with the Drawings provided, and with this Specification, and shall comply with any relevant Standards. All instrumentation used shall be new at the time of installation.

16.10.4.3 All equipment and installation accessories required for the operation of the instrumentation system and recording of measurements shall be securely stored where they will not suffer physical damage or damage arising from excessive moisture, extremes of temperature or other adverse conditions, or from vandalism.

## 16.10.5 Multiple Points Borehole Extensometers

16.10.5.1 Extensometers shall be the steel rod or glass fibre reinforced plastic type and capable of establishing three anchor points at different depths in the hole.

16.10.5.2 The anchor points shall be deformed mild steel bar 22mm diameter and 500mm long, or other suitable configuration. Each anchor shall be secured to a measuring rod that is individually protected by a plastic sleeve that allows the measuring rod to move freely.

16.10.5.3 Relative movement between the anchors and the reference collar shall be measured with an electric transducer, or other equivalent sensor. The accuracy of the extensometer readings shall be  $\pm 0.1\text{mm}$  and be unaffected by cable length and stable under the prevailing conditions. The anchor at the longest depth shall be regarded as the fixed datum.

16.10.5.4 The extensometer system shall have remote readout capabilities based upon vibrating wire technology or potentiometers. The electric cable from the transducers shall be up to 20m long and connect to a compatible readout terminal box or data logger.

#### 16.10.6 Groundwater Monitoring Devices

16.10.6.1 Vibrating wire piezometers shall be capable of reading up to 70m pressure head with an accuracy of  $\pm 1\%$ .

16.10.6.2 Vibrating wire piezometers shall have a readout facility with cable connection to a data logger. All instrument components shall be protected against corrosion and provided with suitable protective covers

#### 16.10.7 Execution Monitoring Procedures

##### 16.10.7.1 Arrangements for monitoring

- 1 Suitable allowance shall be made in the programme of work for the installation, testing, calibration, reading, and maintenance of the instrumentation, and for interpretation of the field readings and implementation of any corrective measures.
- 2 Instrumentation personnel shall be provided with all necessary equipment and access to carry out their work in a safe and proper manner at appropriate time intervals.

##### 16.10.7.2 Installation

- 1 Equipment shall be installed according to the manufacturer's recommendations. Testing shall be undertaken as necessary to ensure satisfactory functioning of the equipment at each stage of the installation. In particular, adequate precautions shall be taken to protect the instruments and any found to be malfunctioning at any time shall be replaced at the earliest opportunity.
- 2 All instruments shall be securely fixed, and their terminations (including any attendant wiring and terminal panels) shall be recessed and adequately protected against mechanical damage and ingress of water and dirt. The equipment shall be fixed such that it is capable of resisting air movement and pressure changes underground, and adverse climatic conditions at surface locations.

- 3 The instrumentation shall be installed as soon as practicable in the cycle of excavation and erection of ground support. Those parts of the instrumentation that are not embedded in the ground must be adequately protected against mechanical and environmental damage. They shall be accessible at all times for survey purposes. Defective or damaged measuring devices shall be replaced at the earliest opportunity to enable recording of measurements to continue. The costs incurred on replacing the defective and damaged devices shall be under the responsibility of the Contractor.
- 4 Every practical measure shall be taken to prevent damage to the instruments and ancillary equipment during handling, installation and subsequent operation. All the instruments required for long term monitoring shall be maintained in a satisfactory working order for the duration of the monitoring programme.
- 5 All the instrumentation in use shall be correctly calibrated. Periodic checks to confirm the validity of calibration shall be carried out by an accredited third party. Re-calibration of all instrumentation shall be done at least once a year. Records shall be kept of all calibration certificates and for sending equipment off site for recalibration by certified testing laboratories.

#### 16.10.7.3 Measurement

- 1 A suitable reference system for all the instrumentation equipment shall be established so that records for any particular location can be easily recovered for interpretation or review.
- 2 Measurements frequency requirements shall be as follows:
  - (A) Instruments shall be read as soon as possible after installation to establish datum readings, which shall be established from a minimum of two independent reading operations giving consistent results. Datum readings and reading frequencies specific to a particular instrument are to be determined by the Contractor and approved by the Engineer.
  - (B) Readings shall continue to be taken once each day until the rate of change in the readings falls off sufficiently to allow a lower frequency to be adopted with confidence that the safety of the Work is not in doubt and such that the amount of data retrieved will allow trends with time to be clearly identified and evaluated. The frequency of readings shall be not less than that listed below, and shall be increased should the need arise:

- (i) Baseline readings (zero readings) shall be made immediately after installation, and established from a minimum of two independent readings that give consistent results;
  - (ii) 1 reading per day during the first two weeks or at any period when the tunnel, shaft or other excavation is within 20m of the instrumentation location; followed by
  - (iii) 2 readings per week up to the end of the first month; followed by
  - (iv) 1 reading per week up to the end of the second month; followed by
  - (v) 1 reading per month up to the end of the sixth month; followed by
  - (vi) 1 reading every two months until completion of the element of the Work being monitored.
- (C) In the event of any change in circumstances, for example a change in ground conditions of influence from adjacent works, the programme of readings shall recommence. The reading frequency may be adjusted to take account of the advance rate of the tunnel, shaft or excavation.

### 3 Data collection and evaluation

- (A) Instrument readings shall be recorded on record sheets designed for the purpose or recorded electronically for subsequent analysis by computer and be made readily available for inspection of the Employer or Engineer. Corrections shall be made for temperature difference or other factors as appropriate. Plots of deformation against time shall be produced together with plots of temperature and humidity when relevant.
- (B) Instrumentation personnel shall be responsible for taking all measurements and their proper recording. There shall be site-based staff available at all times during the construction who are capable of analysing the data in terms of the adequacy or otherwise of the ground support provided. The results shall be entered into time-measurement diagrams. The deformation diagrams shall be updated as soon as each set of measurements has been taken so that the Contractor can make an evaluation of the stability of the excavation.
- (C) Deformation results shall be assessed in conjunction with a visual examination of the excavation surfaces to record signs of distress such as cracks and sections of splitting and falling rock or a loosening of ground support.
- (D) Subject to the findings of both the measurements and any signs of distress in the ground/excavation, any adjustment to the existing level of support shall be determined by the Contractor in consultation with the Engineer.
- (E) All details of the instrumentation shall be recorded including the length and orientation of the drillhole(s), ground / groundwater conditions and installed support (if any). The record shall be made available for the inspection of Employer and Engineer in any given time.

- (F) Monitoring shall continue until the Engineer confirms that monitoring at a particular location may cease. Generally this shall be when readings have stabilised, or when subsequent construction works require the monitoring points to be destroyed or buried.

#### 16.10.8 Specific Monitoring Procedures

##### 16.10.8.1 Convergence measurement

- 1 Convergence measurement shall be undertaken by optical deformation monitoring, using a three dimensional coordinate system, of measuring bolts firmly embedded in the ground.
- 2 The measuring bolt shall be steel threaded bar fitted with a reflective target. The embedded length of the measuring bolt shall be at least 300mm. Appropriate measures shall be taken to protect the measuring bolts from damage.
- 3 Measurements shall be carried out with a free-standing high precision optoelectronic theodolite with integrated coaxial electronic distance meter. The accuracy of the convergence readings shall be  $\pm 2.0\text{mm}$ .

##### 16.10.8.2 The frequency of readings shall comply with the requirements of Sub-Clause 16.9.7.3. A software package shall be used which allows a direct data flow and enables the quickest possible processing of information between reading and interpretation of the data. The software shall comply with the following requirements:

- 1 Free stationing of theodolite and calculation of standard deviation in all three coordinate directions.
- 2 Automatic target identification and recognition of new zero readings.
- 3 Calculation of three-dimensional coordinates and displacements of any desired point, and calculation of its normal distance to the theoretical excavation profile.
- 4 Automatic processing of measurement data to produce printouts from the readings.
- 5 Compensation for refraction anomalies and other measurement errors.

##### 16.10.8.3 Multiple point borehole extensometers

- 1 Multiple point borehole extensometers shall be used in the tunnel or shaft to measure displacement of the surrounding ground at distances of up to 6m from the excavation. The accuracy of drilling shall be such that the drill hole shall be straight and shall not deviate from its intended orientation by more than four degrees.
- 2 The measuring rods with the protective plastic sleeves from each anchor point shall be bundled together and fixed to a reference collar at the open end of the hole. A robust removable protective cover shall be provided to encompass all rods from the one drill hole and provide protection to the reference collar.
- 3 The complete assembly shall be grouted in place fixing the anchors to the ground but allowing free movement of each rod within its sleeve. The grouting shall protect the instrument from groundwater.



- 4 Extensometer reference collars shall be incorporated in the Initial Support / lining and recessed behind the surface of the lining in areas where they might otherwise be prone to damage.
- 5 In addition to the deformation readings, optical survey readings of the collar of the extensometer shall be taken at each instrumentation reading. A software package shall be used which allows a direct data flow and enables the quickest possible processing of information between reading and interpretation of the data.

#### 16.10.8.4 Surface settlement

- 1 Points for monitoring surface settlement shall be established at accessible locations above the Tunnel, or near the excavation work, at not less than 50m centres for the MTBM Tunnel, 25m centres for the Mined Tunnel, and 10m for other excavation works.
- 2 Settlement measurement shall be undertaken by optical deformation monitoring, using a three dimensional coordinate system.
- 3 Settlement monitoring points shall consist of a reflective target fixed to an existing structure, or to a threaded steel bar measuring bolt embedded at least 300mm into the ground below the ground surface. The top of all measuring bolts shall be protected with a suitable cover.
- 4 Measurements shall be carried out with a free-standing high precision optoelectronic theodolite with integrated coaxial electronic distance meter. The accuracy of settlement readings shall be  $\pm 2.0\text{mm}$ .
- 5 A software package shall be used which allows a direct data flow and enables the quickest possible processing of information between reading and interpretation of the data. The software shall comply with the following requirements:
  - (A) Free stationing of theodolite and calculation of standard deviation in all three coordinate directions;
  - (B) Automatic target identification and recognition of new zero readings;
  - (C) Calculation of three-dimensional coordinates and displacements of any desired point, and calculation of its normal distance to the theoretical excavation profile;
  - (D) Automatic processing of measurement data to produce printouts from the readings;
  - (E) Compensation for refraction anomalies and other measurement errors.

#### 16.10.8.5 Groundwater levels

- 1 Monitoring of groundwater levels in the area around the tunnel or shaft shall be undertaken for the duration of the construction period. The purpose of the monitoring is to observe and record the impact of the Work on the groundwater table, and to allow comparison between the actual and estimated drawdown of the groundwater table.

- 2 Monitoring of groundwater levels shall be undertaken in a select number of existing boreholes as approved by the Engineer. The holes selected shall cover the full area likely to be affected by drawdown of the groundwater table. Monitoring of groundwater levels shall be undertaken with either vibrating wire or standpipe piezometers, or a combination of both.
- 3 Vibrating wire and standpipe piezometers shall be installed in accordance with the manufacturer's instructions.
- 4 Weekly readings shall continue for the duration of the excavation stage. Readings shall continue to be taken until the drawdown/recovery of groundwater table has stabilised, even if this stabilisation does not occur until well after completion of the excavation.

#### 16.10.8.6 Groundwater ingress

- 1 For mined tunnel, refer to Section 16.9.3.3 for the details on how to control groundwater ingress.
- 2 Measurements shall be taken of water inflows into the tunnel or shaft. A weir arrangement located across the tunnel excavation drain, or near the shaft sump, at an appropriate location is a suitable option for this purpose.
- 3 Flow readings shall be taken at a minimum of weekly intervals when construction activities are not occurring in the excavation to avoid erroneous results through the presence of process water flows.

#### 16.10.9 Recording Equipment And Ancillaries

##### 16.10.9.1 Instrumentation cabling

- 1 Cabling for instrumentation shall be neatly and securely fixed to appropriate cable trays or conduits which in turn shall be securely fixed to the ground or / shaft tunnel lining.
- 2 Cabling for instrumentation shall be segregated from other power cabling, and be at least 300mm away from other cables. Instrumentation cabling shall be twisted pair cable with a suitably earthed overall screen.
- 3 All electrical fittings for instrumentation shall be of robust and water resistant construction, and shall not corrode in the tunnel or shaft environment.

##### 16.10.9.2 Readout boxes and connection points

- 1 At instrumented cross-sections, boxes shall collect the cabling from the various remotely read instruments and from local terminal boxes, such as those attached to the ground, so that monitoring can be conveniently carried out from a single position close to an instrumented section.
- 2 Readout boxes shall be positioned for ease of access and shall be protected from damage during construction.
- 3 The terminals in readout boxes are to be clearly marked with the relevant instrument reference number on engraved plastic laminate name plates.

- 4 Readout connection points shall be contained in readout boxes of robust water tight metal construction. All cable entries to boxes shall be through watertight glands. Readout boxes shall have lockable waterproof sealed doors.

16.10.9.3 Remote readout facilities

- 1 Unless otherwise agreed with the Engineer, all electrical measuring devices shall be capable of being read remotely from portable remote readout units. Readout units shall be supplied together with leads for plugging into the measuring devices and readout boxes.
- 2 Readout devices shall have facilities for recording monitoring data directly onto tape or magnetic disc for subsequent computer processing.
- 3 Readout devices shall have the appropriate circuitry to minimise electrical interference and shall be suitable for the accuracies of measurement specified under individual items of instrumentation.

16.10.10 Reporting Of Results

- 16.10.10.1 The results of all monitoring carried out in accordance with this Specification shall be submitted to the Engineer within 48 hours of the readings being taken.

## **17 Operation and Maintenance Requirements**

### **17.1 Provisional Operation and Maintenance Manuals**

- 17.1.1 Within 28 days prior to the start of the Tests on Completion, the Contractor shall submit to the Engineer, the provisional Operation and Maintenance (O&M) Manuals, in sufficient detail in relation to the operation, maintenance, process equipment troubleshooting, dismantling, reassembling, adjusting and repair of the Facility.
- 17.1.2 The Contractor shall provide an electronic copy of the O&M Manual to the Engineer and Employer for review. Once accepted, the Contractor shall provide five (5) hard bound paper copies and electronic copies of the sets of the provisional O&M Manuals

### **17.2 Final Operation and Maintenance Manuals**

Within 28 days prior to the issuance of the Taking Over Certificate, the Contractor shall submit to the Engineer the Final O&M Manuals.

The Engineer and Employer shall review and accept the Final O&M Manuals of the Contractor prior on providing ten (10) hard bound paper copies and electronic copies of the sets of the Final O&M Manuals

#### **17.2.1 Presentation of the O&M Manual shall be as follows:**

Format shall be patterned after the recently reviewed manual by the Engineer on which the Contractor has received the Notice of No Objection;

17.2.1.1 The English Language shall be used throughout;

17.2.1.2 Electronic (or Web-Based) copies of all drawings and documents shall also be provided on Compact Disc(s). The electronic copy shall be latest MS word for all text; AutoCAD for all drawings, and Adobe Acrobat PDF for the entire document inclusive of all appendices and sections;

17.2.1.3 Manuals shall be assembled in metric, A4, metric paper. Each volume shall not be more than 50 mm thick and shall be bound by 4 sets of brass binding screws/posts/studs with durable hard covers of adequate size for the information contained;

17.2.1.4 Drawings shall be assembled between metric A3, size covers and held together using 4 sets of brass binding screws/posts/studs. All drawings shall be reduced to A3 size and suitably fixed in the binder. As-built drawings shall be in Intergraph PDF format;

17.2.1.5 Binders shall be suitable on the front and down the spine as follows: Contractor's name, address and telephone number, Contract number, Job name;

17.2.1.6 Each set of pages shall be stapled and the spine cloth bound to form a booklet to strengthen the individual pages. Individual pages with reinforced holes will not be acceptable. The manual shall be arranged in series of volumes each relating to specific equipment system or facility. All volumes shall be compiled in generally the same logical sequence as the process flow through the plant; and

17.2.1.7 Photographs showing: 1) individual equipment; and 2) all nameplates found at the equipment shall be added, with complete description, to the appendices of the manual.

17.2.2 The data shall include, where relevant, the following:

17.2.2.1 Full instructions on the operation of the plant to ensure the satisfactory performance of the plant, including the following:

- 1 Communications plan;
- 2 Start up and shut down procedures;
- 3 Emergency response
- 4 Standby facilities operating procedures;
- 5 Fault diagnosis procedure and warning systems;
- 6 Periodic maintenance procedures;
- 7 Testing procedures for equipment and devices; and
- 8 Installation and dismantling procedures.

17.2.2.2 Full instructions regarding routine maintenance – daily, weekly, monthly and annually. These shall include recommended lubrication protective treatment, checking, testing, replacement procedures, additives and dos and don'ts for all parts of the equipment.

17.2.2.3 Fault finding guidelines described in detail with reference to associated drawings and diagrams, typical faults that may occur and how to diagnose them. Where applicable, fault location charts shall be included to facilitate tracing the cause of malfunction or breakdown.

17.2.2.4 A complete listing of all programs and application software including source code, copies of all graphical layouts, details of all communication protocols and printouts of all database or point information.

17.2.2.5 Schedules and lists of manufacturers and suppliers (including local support in the Philippines) of equipment and components, including contact telephone numbers, addresses, and make and model numbers.

17.2.2.6 Comprehensive equipment data schedules summarizing information required for maintenance, repair, adjustment and replacement. Data schedules to include items such as engines, alternators, radiators, filters, pumps, fans, motors, instruments and the like.

17.2.2.7 A list of all recommended spares with full details of all spares required for each component. A separate section of the manuals shall be devoted to each size and type of equipment and to each item of plant. It shall contain a detailed description of its construction and operation and shall include all relevant pamphlets, and a list of parts with the procedure for ordering spares. The detailed sections of the manual, if necessary, shall contain further maintenance instructions and fault location charts.

- 17.2.2.8 The O&M manuals shall describe the installation as a whole and shall give a step-by-step procedure with assembly drawings for any operation likely to be carried out during the life of each item of plant, including its erection, commissioning, testing, operation, maintenance, dismantling and repair. Manuals shall identify and cover aspects liable to affect other installations and shall include all health and safety precautions to be taken.
- 17.2.2.9 Preventive maintenance schedule which shall include equipment, type of maintenance to be done, schedule, reference manual and page number; trouble shooting guide; and a listing of defects and what to do citing references.
- 17.2.2.10 Drawings, actual photographs and illustrations showing the plant and equipment, position and types of individual components, circuit diagrams and wiring diagrams, test points and sensor locations and dismantling and reassembly drawings and instructions.
- 17.2.2.11 Process Operation Guideline shall include the following:
- 1 An overview of the treatment process including objectives / function of unit operations;
  - 2 A guide to optimize the treatment plant operations;
  - 3 A tabulation of performance issues and accompanying troubleshooting guide;
  - 4 Recommended correction procedures for performance issues and particular scenarios identified during HAZOP; and
  - 5 Process operation guideline.
- 17.2.2.12 Administration, organization and allocation of human resources.
- 17.2.2.13 Accident prevention, occupational safety, and hygiene.
- 17.2.2.14 Treatment of waste and disposal of residues.
- 17.2.2.15 Operational monitoring.
- 17.2.2.16 Process design (e.g. basis of design and operating envelope) of all treatment stages of WTP shall be added as an appendix to the O&M Manual.
- 17.2.3 Any additions, alterations or deletions which shall be required by the Engineer following the experience gained during the periods of Testing and Commissioning, trial operations and process proving shall be incorporated in these copies in the form of additional or complete replacement pages and the cost of these amendments shall be deemed to be included in the Contract Price.
- 17.2.4 The Contractor's attention is drawn to the need to ensure that the following items, as minimum, are included in the O&M manuals:
- 17.2.4.1 All health and safety instructions for chemicals and any precautionary measures necessary for ensuring health and safety and avoidance of misuse.

- 17.2.4.2 General description of the scope, purpose and manner of working of each system or apparatus forming part of the Works, and the final functional design specification (FDS).
- 17.2.4.3 Schedule of equipment supplied giving manufacturers' name and appropriate make, model/catalogue number, description of unit and component parts identified on drawings.
- 17.2.4.4 Maintenance procedures for regular maintenance and preventative maintenance, including frequencies of routine operations, guide to fault diagnosis, fault finding charts, step-by-step procedures for dismantling, cleaning, servicing, part replacement and reassembling, including recommended clearances and tolerances.
- 17.2.4.5 Maintenance procedures for the flushing of chemical tanks, pumps and dosing lines and procedures for dealing with leakages and spillages including neutralization.
- 17.2.4.6 Schedule of spare parts with ordering reference numbers and parts identified on equipment drawings.
- 17.2.4.7 Schedule of tools.
- 17.2.4.8 Schedule of changeover frequencies for duty / standby equipment.
- 17.2.4.9 Sectional arrangement drawings of major items of plant with dismantling instructions.
- 17.2.4.10 Plant layout drawings showing the "as-built" installation.
- 17.2.4.11 P&ID for "as installed" processes.
- 17.2.4.12 Schedules for "as installed" instrumentation.
- 17.2.4.13 Electrical system single line diagrams.
- 17.2.4.14 Electrical system protection grading characteristics and setting data.
- 17.2.4.15 General arrangement and circuit diagrams for switchboards and control panels "as installed".
- 17.2.4.16 Diagrams of all "as installed" connections between electrical plant and instrumentation systems.
- 17.2.4.17 Operating procedures including step by step instructions for pre-start, starting up, including start up following emergency shutdown, normal operation and normal and emergency shutting down of the plant.
- 17.2.4.18 "Do's" and "Don'ts" in plant operation with attention drawn to all operations considered to be hazardous to personnel or likely to damage plant.
- 17.2.4.19 Data on general setting of controls associated with controlling design conditions, monitoring instruments and switchgear, together with the details of initial settings of all adjustable items.

- 17.2.4.20 Test certificates for works and site tests carried out on plant, for site tests carried out on pipework, electrical and instrumentation installations and other items where appropriate.
  - 17.2.4.21 Pump performance and calibration characteristics as tested and system characteristics.
  - 17.2.4.22 Manufacturers' printed operating and maintenance instructions.
  - 17.2.4.23 Lubrication instructions including frequency of application and schedule of recommended lubricants and their equivalents, which shall be readily obtainable.
  - 17.2.4.24 Typical log sheets for recording plant operating information for each process and chemical plant with instructions from identifying departures for normal behavior.
  - 17.2.4.25 Typical log sheets on which operating staff can record their service / maintenance checks on essential equipment and at periods recommended by the Contractor.
  - 17.2.4.26 Instrumentation, control and automation equipment operating instructions for normal procedures in a step by step format including flow charts, control operations, requests for display or printing of data, performance monitoring, response to alarms or failures, changing of operation parameters, and manual data entry.
  - 17.2.4.27 Description of the WTP control philosophy (a layman's guide) including plant trips and interlocks.
  - 17.2.4.28 A schedule of alarms, giving cause and action to be taken.
  - 17.2.4.29 Procedures for calibration of instruments, dosing pumps etc.
  - 17.2.4.30 Data sheets for process and chemical plant giving design parameters.
  - 17.2.4.31 Data sheets for all equipment such as pumps, compressors and etc., and shall include, but not limited to the following, process data, design operating conditions, equipment data, materials, motor information.
- 17.2.5 The Works shall not be considered as completed until the Engineer has reviewed and issued Notice of No Objection.
- 17.2.6 Spares and Tools
- 17.2.6.1 A list of plant spares and tools for operation of the RWTL and WTP for up to five (5) years from successful commissioning shall be included in the bid submittals. This list shall be reviewed and agreed with the Engineer for any omissions and exclusions. The list shall distinguish critical spares from the general spares.
  - 17.2.6.2 Critical spares are items with long lead-time and the deployment of which is likely to occur during the life of the WTP.



- 17.2.6.3 The agreed list of Plant Spares and Tools shall be finalized after the Process Proving Period and shall be a pre-requisite for the issuance of the Taking-Over Certificate. The Contractor shall supply all finalized spare parts, or their equivalent as recommended and advised by the manufacturer.
- 17.2.6.4 Spare parts shall be handed over to Manila Water only at the end of the Contract. The warranty for these spare parts shall only commence upon the handover of these spare parts. All costs are deemed to be included in the tender sum. No claims for extra by the Contractor shall be entertained by the Engineer and/or Manila Water.
- 17.2.6.5 The Contractor shall supply all replacement parts of all equipment during the maintenance period and Defects Notification Period (DNP). The Contractor shall submit the schedule of unit rates for all spares supplied under this Contract, one month before end of Contract period.
- 17.2.6.6 The Contractor is required, prior to acceptance by the Engineer, to provide evidence that any unit supplied as part of the works will have a service center, either within Metro Manila or the Southeast Asia region, to provide the spare parts (especially the critical items) and competent service.
- 17.2.6.7 Mandatory spare parts are to be listed in the Contractor's Bid under Section 2 of the bidding documents.
- 17.2.6.8 For critical spares, the quantity of spares shall be sufficient for a duration of two (2) years from start of the Process Proving Period to the end of the Defects Notification Period.
- 17.2.6.9 The critical spares shall be delivered and stored at the Site, and shall become the property of the Employer. The Contractor may use these parts and replace them at their own expense during and up until the end of Tests on Completion. The replacement of the used parts shall be within the 28 days after completion of Test on Completion.

### **17.3 Special Tools**

- 17.3.1 A list of Special Tools for operation of the RWTL and WTP for up to five (5) years shall be included in the bid submittals.
- 17.3.2 For each type of equipment furnished by him, the Contractor shall provide a complete set of all special tools (including grease guns or other lubricating devices) which may be necessary for the adjustment, operation, maintenance, and disassembly of such equipment. Tools shall be high-grade, smooth, forged, alloy, tool steel or material recommended by equipment suppliers and agreed by the Engineer. Grease guns shall be lever type. Special tools are considered to be those tools which, because of their limited use, are not normally available but are necessary for the particular equipment. These maintenance tools shall be handed over to the Employer at the end of the Contract.
- 17.3.3 Special tools shall be delivered at the same time as the equipment they pertain to. The Contractor shall properly store and safeguard such special tools until completion of the work, at which time they shall be delivered to the Employer. All spare parts and special tools whether or not specified but required for the maintenance of the plant equipment shall be deemed to be provided for all plant equipment offered.

## **18 Tests on Completion – Construction Tests**

### **18.1 General**

#### **18.1.1 Resources and materials for inspection and testing**

- 18.1.1.1 After the Contract has been awarded, the Contractor shall submit to the Employer for approval a list of their proposed suppliers and sources of materials required for inspection and testing.
- 18.1.1.2 The materials subsequently supplied shall conform to the quality of samples, which have been approved by the Employer.
- 18.1.1.3 The Contractor shall submit names of additional suppliers and sources of materials during the inspection and testing, but no supplier and source shall be changed without the approval of the Employer.
- 18.1.1.4 The Contractor may submit for the Employer's approval an equivalent or better alternative material than those specified in this specification.
- 18.1.1.5 Unless otherwise specified, at least three (3) samples of each materials shall be submitted a minimum of fourteen (14) working days prior to ordering such materials or equipment. Submission shall be in an orderly sequence so that dependent materials or equipment can be assembled and reviewed without causing delay in the work.
- 18.1.1.6 All samples shall be individually and indelibly labeled or tagged indicating thereon all specified physical characteristics and manufacturer's names for identification. Upon receiving approval, one set of samples will be stamped and dated by the Employer and returned to the Contractor for safe keeping in the site office until completion of the work. Unless otherwise specified, all color and textures of specified items shall be selected by the Employer from the manufacturer's standard colors and standard project lines.
- 18.1.1.7 The Contractor shall conduct a Hazard Communication (HAZCOM) exercise prior to the commencement of pre-commissioning activities.

### **18.2 Water Samples**

- 18.2.1 The location of sampling or grab points, shall be identified in the Sampling and Testing Plan, for the Employer's approval prior to undertaking any tests. The Contractor shall install and label the sampling points and provide safe access points/platforms and power points for auto-samplers where appropriate.
- 18.2.2 With the aim of making the samples representative, those samples taken from flow streams shall be taken at mid-channel and mid-depth.
- 18.2.3 Failure to take a sample shall result in the recording of a sample failure at the discretion of the Employer.
- 18.2.4 If the Employer considers there has been a significant error in either the sampling technique or the method of determination for any sample or analytical results, then this shall be excluded from the test results. Failure to correctly calibrate a meter shall result in the recording of a sample failure at the discretion of the Employer.

18.2.5 The Employer shall be entitled to take samples for separate analysis.

### **18.3 Calibration of equipment and instruments**

Instruments used for tests at site shall have been calibrated not more than 3 months. The Contractor shall provide the Engineer with three (3) copies of calibration certificates and, where appropriate, correction graphs etc. at the time of testing.

All metering and measurement instruments and analysers shall be calibrated and certified by independent, approved testing and calibration authority or other approved service providers before Pre-Commissioning. Calibration shall be conducted in accordance with appropriate international standards. The calibration certificate shall have at least one (1) year of validity prior to any tests on Site. Where reason exists, the Engineer has the power to request the test instruments to be re-calibrated. All instruments shall be maintained within calibration in accordance with the manufacturer's recommendations throughout the T&C Period and PPP.

### **18.4 Laboratories and third party services**

18.4.1 The Contractor shall arrange for all sampling and analysis to be carried out using an accredited laboratory that complies with ISO/IEC 17025 for verification of the on-site equipment for the tests. Details of this laboratory shall be submitted to the Employer for approval.

18.4.2 Procedural and Statistical Analytical Quality Control (AQC) must be demonstrated by the Contractor and documentary evidence of the same system shall be required. The Employer may require to inspect the laboratories utilized by the Contractor, and may also wish to inspect the written procedures in use for QC.

18.4.3 Laboratories shall have accreditation from the Department of Health (DOH) to conduct drinking water analysis.

18.4.4 Testing of radiological parameters shall be conducted by the Philippine Nuclear Research Institute or other PNRI-accredited laboratories.

18.4.5 In addition, nominated laboratories shall:

18.4.5.1 Follow the prescribed methods of analysis by the PNSDW;

18.4.5.2 Have established the performance of all relevant analytical methods before they are used to analyze samples;

18.4.5.3 Maintain analytical quality control charts for each method of analysis;

18.4.5.4 Participate in an external quality control scheme; and

18.4.5.5 Send a copy of the results direct to the Employer at the same time as sending the results to the Contractor.

18.4.6 No analytical results will be accepted from the nominated laboratory for the purposes of carrying out the final treated water consent compliance tests if any procedure is shown to be outside the prescribed in-house limits for data validity. It is the Contractor's responsibility to ensure that the nominated laboratory complies with the above requirements.

- 18.4.7 Any areas of non-compliance must be logged and reported to the Employer within 48 hours. In such cases, it is the Contractor’s responsibility to rearrange the taking of the required number of test samples within the specified time period.
- 18.4.8 Should the Contractor wish to engage the services of Employer Laboratory Services he can do so at their own accord and as an independent agreement between him and MWLS, and shall be subjected to the standard fees of the MWLS.
- 18.4.9 In the event of any disputed results the Contractor will arrange for the stored sample to be tested by an accredited third party laboratory.

## **18.5 Minimum documentation levels**

The Contractor shall update the programme of work with actual progress on a monthly basis.

In addition to any specific obligations for sampling and testing, the Contractor shall be responsible for routine inspection, sampling and testing of all materials, workmanship, plant and measuring devices, in order to control the quality of work and to ensure compliance with the specification and with approved samples.

## **18.6 Inspections and off-site verifications**

The Contractor shall prepare and submit the programme for off-site testing and verification at least one (1) week prior to the testing, to the Engineer for review; and obtaining Notice of No Objection.

The off-site testing and laboratories shall be approved by the Engineer.

## **18.7 Factory Acceptance Tests**

- 18.7.1 Due to the travel restrictions brought by the COVID-19 pandemic, all factory acceptance test attended by the Employer shall be suspended.
- 18.7.2 Before dispatch from a manufacturer's plant, each item of equipment shall be tested in accordance with the relevant Standards / Specifications. In the absence of such Standards / Specifications, the tests shall be performed in a manner subject to the acceptance of the Engineer. Refer to Appendix 23 Manila Water Factory Acceptance Test (FAT) / Site Acceptance Test (SAT) Guidelines.
- 18.7.3 FAT shall be performed to ensure an item of equipment or a sub-system is ready for shipment, installation and operation. Should the Employer decide certain FAT shall be witnessed by the Employer’s representatives the Contractor shall facilitate and coordinate such visits. All costs incurred by the Employer’s representatives will be borne by the Employer.
- 18.7.4 If during FAT, any equipment, plant or materials fail to meet the Contract requirements, the defects shall be rectified and the equipment, plant or materials in question shall be offered for re-inspection and witness testing by the Employer. All resulting additional expenses incurred by the Employer’s representatives (minimum 2 officers and maximum 3, for each trip) for such re-inspections shall be borne by the Contractor.

18.7.5 The Contractor shall develop a FAT program for the Engineer's review at least 28 days prior to the FAT. The program shall include these as a minimum:

- 1 Travel plan and itinerary;
- 2 Approved datasheets;
- 3 Values of test parameters, including the boundary of test conditions;
- 4 Citation of reference standards, any other standards;
- 5 Manufacturer's literature including information of all testing facilities and equipment;
- 6 Proposed format of the test sheets which shall have columns for signing off by both the Contractor and the Employer's representative and notes for describing any deficiencies; and
- 7 Certificate of calibration of test instruments.

18.7.6 The complete equipment or package shall be tested in manufacturer's workshop as per the agreed FAT procedure. The FAT can also be conducted at the supplier's workshop provided that it can be proven that the supplier has the capability and experience in carrying out any technical modifications required on that premises within a reasonable period.

18.7.7 Where deemed necessary to fulfil the Contract requirements, coordination with other parties shall be included in the Contractor's scope of works to achieve the intended result of testing.

18.7.8 No inspection or endorsement by the Employer or his representative of the equipment, plant or materials shall absolve the Contractor from any of his obligations under the Contract.

## **18.8 Software Acceptance Tests**

The Contractor shall provide the simulated results of the engineering computations, using the licensed software. The Contractor shall submit the results of the software validation, in case the Contractor proposed to use own software for computation.

## **18.9 Delivery Inspection**

The Contractor shall prepare and submit programme for inspection by the Engineer of the Plant delivered at the Site, for review and obtaining Notice of No Objection.

## **18.10 Storage Maintenance Inspections and Records**

The Contractor shall store and stockpile the materials and components in such a manner as to preserve their quality and condition to the standards required by the Contract.

The quantity of materials stored and stockpiled on the site shall be consistent and sufficient as required for the efficient implementation of work as scheduled.

## **18.11 Pipeline Leak Tests**

### **18.11.1 General**

All pipeline shall undergo specific leak tests to ensure its water-tightness, to prevent infiltration and exfiltration and to ensure the pipes are laid correctly according to the design straightness and grade. All leak testing shall be conducted by the Contractor in the presence of the Engineer and Employer.

- 18.11.1.1 Piping works are defined as any work related to the fabrication, installation and modification of pipes, fittings, valves and its appurtenances. Prior to piping works the Contractor shall submit for approval a method statement detailing such as but not limited to piping installation, bolt tightening sequence (as may apply), leak and other tests, repair works, etc.
- 18.11.1.2 Prior to any leak testing, the Contractor shall submit a test package schedule and conduct all necessary piping works. Works such as but not limited to alignment check, bolt tightening check, external coating check (if applicable), line check, non-destructive examination (NDE), etc.
- 18.11.1.3 The Contractor, upon completion of all welding joints, shall carry out NDE in accordance with ASME B31.3. All welded joints shall undergo Liquid Penetrant Examination and 20% random examination. Random Examination shall be either Ultrasonic Test or Radiographic Test. The Contractor shall prepare all the necessary arrangements, including but not limited to schedules, location, apparatus, equipment and specialists, to carry out the tests. All such tests shall be carried out by the Contractor in the presence of the Engineer. The methodology of testing works shall be submitted subject for review and approval of the Employer and Engineer.
- 18.11.1.4 In the case that a weld joint failed in the NDE, it shall be repaired. Repairs shall only be allowed once at any point in the joints. Repaired weld shall undergo the same NDE where it failed.
- 18.11.1.5 The Contractor shall submit a sketch for each pipeline section to be leak tested. The sketch shall include the section schematically in profile; and show point of air release or water injection and the point of observation.
- 18.11.1.6 The Contractor shall be responsible for providing the facilities for the removal and disposal of water or air used for flushing and leak testing activities. The Contractor shall be responsible for obtaining the relevant consents to discharge, for provision of any discharge/ outfall structures and for complying with the terms of the consents.
- 18.11.1.7 The Contractor shall conduct hydrostatic tests using clean water and clean air for pneumatic tests. Should the Contractor opt to use partially treated water or other gases, the Contractor shall ensure that it will not contaminate the system and that flushing and disinfection shall be conducted at the tested pipeline prior to putting it online.
- 18.11.1.8 The Contractor shall use calibrated instrument and pressure gauges during test. The Contractor shall ensure the availability of a valid calibration sticker and certificate at all times during the testing.

18.11.1.9 There will be 2 leak tests to be conducted for buried pipes. Testing before backfill which will facilitate the replacement of any identified faulty pipes and joint and testing after backfill to reveal leakages cause by the displacement of joints and subsequent damages. Leak test to be conducted after the backfill shall be the same with the leak test done before backfill. Backfilling shall not be allowed unless pipe passes test before backfill.

18.11.1.10 The Contractor shall be allowed to conduct leak test in sections. However, leak testing of the whole pipeline (end-to-end) shall be done for all types of piping system.

18.11.1.11 Should leak tests conducted prove unsatisfactory, the Contractor shall identify the location/s of the leak/s and empty the pipeline for replacement. All replaced elements, if rewelded, shall be tested using NDE to assure quality. Upon completion of replacement works, The Contractor shall invite the Employer and Engineer to rewitness the test.

## 18.11.2 Execution

### 18.11.2.1 Leak Testing for Pressure Pipelines

- 1 All pressurized pipeline shall be leak tested to ensure tightness. Test shall be hydrostatic test. Otherwise, pneumatic test will be implemented if hydrostatic test is deemed impractical as per reasons set forth in ASME B31.3.
- 2 The Contractor shall conduct hydrostatic tests for the WTP pipes to ensure watertightness in accordance with SES 7.
- 3 Minimum testing pressure shall be as per SES 7 or a factor multiplied by the maximum working pressure. Factors shall be 1.5 for hydrostatic test and 1.1 for pneumatic test. Test pressure to be used shall be the pressure with the resulting higher value.
- 4 All leak test of pressurized pipelines shall be conducted for 2 hours.

### 18.11.2.2 Leak Testing of Non-pressure Pipelines

The Contractor shall test the pipelines generally by means of an air or water test or in certain circumstances by a visual or closed-circuit television (CCTV) examination as required by the Employer, in length determined by the course of construction, in accordance with a schedule approved by the Employer.

The Contractor shall carry out final test after the backfilling is complete. The tests that are required to be conducted per specific pipeline system are listed as follows:

- 1 Gravity Fed Pipeline
  - (A) Ball Test (100mmø rubber ball for pipe sizes 150mm and above)
  - (B) Exfiltration / Infiltration and Pressure Test

- (C) All gravity process pipelines shall be leak tested via gravity test. Riser pipe shall be installed in the highest point of the pipe. Riser pipe length shall be 1.50 m higher than the highest point in the system. Riser pipe shall be fully filled with water.
- (D) All plumbing and drainage, except for reinforced concrete sewer or drain pipe material, shall be tested as per provisions in RNPCCP. If no provision on the RNPCCP, UPC provisions shall be followed.
- (E) All punchlist under these pipes shall be category A. All test duration shall be 2 hours.

2 Water Test (Exfiltration)

- (A) The Contractor shall conduct water test of non-pressure pipelines. The test pressure for non-pressure pipelines up to and including 750mmØ shall not be less than 1.2m head of water above the pipe soffit or ground water level, whichever is the higher at the highest point, and not greater than 6m head at the lowest point of the section. Steeply graded pipelines shall be tested in stages in cases where the maximum head, as stated above, would be exceeded if the whole section were tested in one length. Manholes in the tested pipeline shall be included in the test.
- (B) The pipeline shall be filled with water and a minimum period of two hours shall be allowed for absorption, after which water shall be added from a measuring vessel at intervals of 5 minutes and the quantity required to maintain the original water level noted. The length of pipeline shall be accepted if the quantity of water added over a 30-minute period is less than 0.50 liter per linear meter per meter of nominal diameter.
- (C) The test shall be conducted on all non-pressure pipelines with pipe-pipe or pipe-manhole connections other than welded connections.

3 Air Test

- (A) The Contractor shall conduct air test for non-pressure pipelines only in the absence of exfiltration test for pipes. Non-pressure pipelines shall be air tested by suitable means until a pressure of 100mm head of water is indicated in a U-tube connected to the system. The pressure shall be maintained for two minutes to allow the temperature of the air to come to equilibrium with the pipe walls. Manholes in the tested pipeline are excluded to this test and shall be subjected to a separate exfiltration test.
- (B) The pipeline shall be accepted if the air pressure remains above 75mm head of water after a period of 5 minutes without further pumping, following a period for stabilization. Failure to pass the test shall not preclude acceptance of the pipeline if a successful water test can subsequently be carried out in accordance with Clause 14.13.2.3.

4 CCTV Inspection

- (A) Where internal inspection of pipelines by CCTV is required, the Contractor shall provide all necessary equipment, including suitable covered accommodation for viewing the monitor screen, together with personnel experienced in the operation of the equipment and interpretation of the results.



- (B) The intensity of illumination within the pipe and the rate of draw of the camera shall be such as to allow a proper examination of the inside of the pipe. Provision shall be made for the movement of the camera to be stopped and its position recorded and for permanent photographs to be taken at any point requested by the Employer.
- (C) When a CCTV test is to be conducted, the ball test may be excluded as a test requirement, if the equipment is capable of determining the slope of the pipeline.

5 Infiltration

- (A) The Contractor shall conduct testing of non-pressure pipelines (including tunnels) and manholes shall be tested for infiltration after backfilling. All inlets to the system shall be effectively closed, and any residual flow shall be deemed to be infiltration.
- (B) The pipeline, including manholes, shall be accepted as satisfactory if the infiltration, including infiltration to manholes, in 30 minutes does not exceed 0.50 liter per linear meter per meter nominal diameter.
- (C) Notwithstanding the satisfactory completion of the above test, if there is any discernible flow of water entering the pipeline at any point, which can be, located either by visual at CCTV inspection, the Contractor shall take such measure as are necessary to stop such infiltration.
- (D) The test shall be conducted on all non-pressure pipelines subjected to the following conditions:
  - (i) When the pipes are embedded and/or there is a possibility that the pipe will be submerged on any type of liquid.
  - (ii) when connections are present other than welded connections for pipe-pipe or pipe-manhole.

**18.12 Water Retaining Structure Tests**

The water retaining structures shall be tested in conformance with the provisions of ACI Code 350.1R and AWWA 400 for testing reinforced concrete structures for water tightness.

**18.13 Punchlisting**

The Contractor shall prepare a Punchlist and maintain this as a live document at the Site. The Contractor's shall issue the Punchlist to the Engineer on a weekly basis. The Punchlist shall be maintained from the pre-works until completion of the Works.

## **19 Tests on Completion – Pre-commissioning Tests**

### **19.1 General**

#### **19.1.1 Phases of Tests on Completion**

19.1.1.1 The Tests on Completion shall start after completion of construction. The duration of Tests of Completion is defined as testing and commissioning, followed by the 364 days of Process Proving Period (PPP).

19.1.1.2 The intent of WTP Testing and Commissioning (T&C) is to demonstrate that the installed facilities, equipment, processes, and systems perform, in all respects, in accordance with the requirements of the Contract Documents. The Contractor is responsible for operating the WTP throughout the T&C period and thereafter, the Process Proving Period (PPP).

19.1.1.3 WTP T&C shall also demonstrate that each process system, unit, component, and sub-system is capable of performing properly, both individually and as a whole complete WTP system

19.1.1.4 During the WTP T&C period and PPP, O&M training shall be provided to the Employer's personnel to facilitate future taking over of the Works by the Employer upon the successful completion of the PPP.

19.1.1.5 The WTP and every item of equipment and process thereof shall be subjected to series of tests in each of the following four (4) phases:

- 1 Off-site inspection and testing including Factory Acceptance Tests (FATs) during construction.
- 2 On site Pre-commissioning Tests comprising
  - (A) Dry Commissioning
  - (B) Wet Commissioning (Clean Water Test)
- 3 On site Process Commissioning Tests comprising:
  - (A) 28-day process commissioning of the liquid stream; and
  - (B) 28-day process commissioning of the solid stream.
- 4 Process Proving Period (PPP)
  - (A) 364 days of PPP of the liquid stream; and
  - (B) Solids stream PPP that shall end together with the liquid stream PPP but not less than 182 days.

#### **19.1.2 Resources and Materials**

Unless specified otherwise, the Contractor shall supply all necessary resources and materials including labor to operate and attend to all T&C activities including rectifying defects.

During Process Commissioning and PPP, the Contractor shall provide labor on shifts, 24 hours 7 days a week as required to operate the WTP. The Contractor shall also provide maintenance, mechanical, electrical, instrumentation and control system engineers and workmen available 24 hours a day on call to trouble shoot and attend

to defects, repairs or breakdown during such periods. Such staff on call shall respond and be at site within one (1) hour of the telephone call requesting their presence.

The Contractor shall bear all the costs of the utilities used and provide all necessary materials, chemicals, fuels, stores, apparatus, instruments and indicators necessary for the T&C and during the PPP.

#### 19.1.3 Testing and Commissioning Plan

19.1.3.1 The Contractor shall develop a Testing and Commissioning Plan for the Engineer's review at least 28 days prior to the commencement of any Dry Commissioning activities.

19.1.3.2 The Contractor shall form a Testing and Commissioning Team to administer the T&C works. This T&C Team shall identify, plan, coordinate and supervise all T&C activities for the Works. The Team, as a minimum shall include;

- 1 Testing and Commissioning Manager;
- 2 Supporting process, mechanical, electrical and instrumentation engineers as required; and
- 3 Commissioning Specialists (various specialists shall have expert knowledge in their areas of work) for each plant supplied and installed under this Contract.

19.1.3.3 The T&C Plan shall illustrate the scheduling, timelines, and interdependencies of inspection, testing and commissioning activities. As a minimum, the Plan shall include the following information:

- 1 T&C Team organization chart and contact information;
- 2 The roles and experience of each member of the T&C Team for each phase of the works;
- 3 Method statements for each item of equipment;
- 4 Schedules sequentially displaying for each item of equipment, the beginning and completion dates of installation and for each stage of inspection, testing and commissioning;
- 5 Test plans and methods outlining step-by-step procedures for conducting the test and to create the operating conditions, and methods to measure the operational results. Test conditions shall reflect requirements in the Specifications for each item of the plant. The test plans shall also outline the rationale of each of the test procedures and how they will demonstrate achievement or failure of the performance requirements.
- 6 Sampling plan and a listing of parameters to be measured and monitored;
- 7 Quantities of influent, chemicals and power required, including flow rates and duration of flows;
- 8 Quantities of testing water required, wastes produced and methods of their disposal;
- 9 Log sheets for recording of plant information, operating parameters, qualify parameters for presentation and interpretation of test data;

- 10 Shutdown procedures when the equipment required to be shut down; and
- 11 A safety response plan including listing of contacts to be notified in case of emergency.

#### 19.1.4 Calibration of Instruments

Instruments used for tests at site shall have been calibrated not more than 3 months before the start of testing. The Contractor shall provide the Engineer with three (3) copies of calibration certificates and, where appropriate, correction graphs etc. at the time of testing.

All metering and measurement instruments and analyzers shall be calibrated and certified by independent, approved testing and calibration authority or other approved service providers before Dry Commissioning. Calibration shall be conducted in accordance with appropriate international standards. Where reason exists, the Engineer has the power to request the test instruments to be re-calibrated. All instruments shall be maintained within calibration in accordance with the manufacturer's recommendations throughout the T&C Period and PPP.

#### 19.1.5 Laboratory and Sampling

19.1.5.1 The Contractor shall provide a sampling and testing plan as part of the Contract detailing a list of the samples and testing to be undertaken and locations and frequency for sampling.

19.1.5.2 The methods to be used to analyze the listed parameters shall be as given in latest edition of the Standard Methods for the Examination of Water and Wastewater; published by APHA, AWWA and WEF.

19.1.5.3 The Contractor shall engage third party laboratories with DENR accreditation that complies with ISO/IEC 17025. The Contractor shall submit full details of the proposed accredited laboratory, the methods of sampling and collection, storage, preservation and transfer, and the method of analysis for each and all of the tests to the Engineer for review prior to commencement of T&C of WTP.

19.1.5.4 The Contractor shall instruct the laboratories to send a copy of the test results direct to the Engineer at the same time as sending the results to the Contractor. Any areas of non-compliance shall be logged and reported.

19.1.5.5 Method of sample collection shall be by grab sampling for the entire duration of Tests on Completion.

19.1.5.6 Each grab sample collected shall be divided in three parts:

- 1 One part of the sample shall be analyzed by the Contractor's third-party laboratory;
- 2 One part shall be sent to the Employer's (Manila Water's) Central Laboratory for analysis; and

- 3 One part shall be kept refrigerated and shall be stored for a period of 15 days according to handling and preservation methods prescribed by USEPA Standards, for verification in case of conflict between the Contractor's and the Employer's laboratory results. The verification test shall be conducted, upon the notice from the Engineer, at a different third-party laboratory to the Contractor's expense, and the results of which shall prevail. For parameters with less than 48 hours holding time, the Contractor shall arrange for a second (2<sup>nd</sup>) third-party laboratory to conduct parallel analysis on duplicate samples of Item (1) above, within the allowable holding period.

19.1.5.7 In the event that the Contractor's result failed, process adjustment should be done, and shall proceed in accordance with the provisions in Sections 19 and 20 of this Employer's Requirements. The Employer shall be entitled to conduct separate analysis for verification. In the event of conflict between the result of the Contractor's and Employer's sample analysis, the third part of the sample will be sent for analysis, at the expense of the Contractor, to an accredited third party laboratory different from the laboratory previously engaged by the Contractor. The result of this third party analysis will prevail.

19.1.5.8 The taking of the grab sample shall be offset by one hour each day. All samples shall be taken with an auto-sampler set to extract samples at 2-hour intervals for deposition into a single sample bottle. The sample bottle shall have a minimum volume of 3 liters.

## **19.2 Pre-Commissioning Testing**

### **19.2.1 Individual Tests of WTP Equipment**

19.2.1.1 All individual tests of WTP equipment making up a complete system shall be completed before starting the preliminary tests on that system. These tests shall as a minimum include:

- 1 Setting and fine tuning of the Programmable Logic Controller (PLC) and control loops;
- 2 Setting of protection relays and timers;
- 3 Checking of instrument readings, both local and on the control system;
- 4 Testing of pressure and flow switches and level sensors;
- 5 Checking of drive status conditions;
- 6 Checking of control logic and functionality;
- 7 Checking of equipment start-up and shutdowns (including emergency);
- 8 Checking of equipment safety devices and interlocks;
- 9 Checking of automatic sequencing (e.g. start-up and shut down);
- 10 Operation of equipment, including pumps and valves;
- 11 Measurement of noise levels to verify suitability for unrestricted operation and compliance with noise requirements;
- 12 Recording of all settings, timers, etc., both fixed and operator adjustable; and

- 13 Conducting signal strength propagation survey for Wireless 2.4G and 3G and ensure reliable wireless signal transmissions.

#### 19.2.2 Before Commencement of Dry Commissioning

19.2.2.1 The proposed inspection procedure together with the following information as a minimum shall be submitted for the Engineer's review at least 28 days prior to Dry Commissioning:

- 1 Approved T&C Plan;
- 2 Equipment manufacturer's certification of proper installation to proceed with testing;
- 3 List of necessary spares parts, tools and special tools, and proof that these have been delivered to site;
- 4 Three (3) copies of the approved final draft O&M Manual;
- 5 As-built Drawings;
- 6 O&M Training Plan for the Employer's (Manila Water's) personnel, including classroom lectures and on-the-job training during T&C;
- 7 Information on manufacturer's representatives qualified to assist in commissioning;
- 8 Licenses and certifications obtained from local authorities; including any statutory approvals required to carry out the test procedures;
- 9 Proof that pressure testing of pipe, valves, ducts, dampers and any other appurtenances has been successfully conducted;
- 10 Calibration certificates of instruments;
- 11 Hydraulic monitoring program;
- 12 Electrical earthing tests results;
- 13 Electrical termination checks of inputs/outputs (I/Os);
- 14 Testing of local and remote monitoring and control functions;
- 15 Safety plan and proposal for installing any safety equipment as required may it be temporary or permanent;
- 16 Any other checks as necessary and specified in the manufacturer's instructions; and
- 17 Any other issues such as safety aspect, precautionary measures.

19.2.2.2 The Contractor shall inform the Engineer 14 days prior to commencing any testing associated with Dry Commissioning. As soon as the Engineer is satisfied that the erection of the WTP has been completed as specified, the equipment and material are found to be in good working order, and that the associated civil works have been completed to an extent permitting the proper operation of the plant, Dry Commissioning may commence at Site.

#### 19.2.3 Dry Commissioning

The following are examples of individual tests to be carried out during Dry Commissioning:

- 19.2.3.1 Tests on all items of equipment in accordance with the Employer's Requirements and the Reference Standard applicable to the item being tested.
- 19.2.3.2 Electrical tests to demonstrate compliance of the electrical installation with specified and statutory requirements. These include checking wiring connection and signal status of the associated feedback and control system.
- 19.2.3.3 Operational tests for all valves which shall include torque switch setting and functional test of each electric valve actuator.
- 19.2.3.4 Local operation of equipment. For example, running the pumps for a short duration; such duration is to allow the stabilization of heat, noise and vibration reading for rotating equipment. The duration of operating the pump in dry condition shall be recommended by the manufacturer.
- 19.2.3.5 Noise and vibration levels measurement for all rotating equipment.
- 19.2.3.6 Functional test of all protective devices and setting of protection relays and timers, including testing of pressure and flow switches.
- 19.2.3.7 Checking of equipment safety devices and interlocks, including necessary safety training or briefing prior to commencement of testing to allow testing to progress safely and effectively.
- 19.2.3.8 During the Dry Commissioning stage, the system that does not require water shall be fully commissioned. They shall include, but not be limited to, the following:
  - 1 ACMV system;
  - 2 Potable water system;
  - 3 Safety system;
  - 4 Electrical system such as lighting, stand-by generator set, etc.; and
  - 5 Control system.
- 19.2.3.9 The Contractor shall rectify any deficiencies in the equipment design, installation, performance, and including operational safety identified. Any modification or adjustments shall be reported to the Engineer before fully re-tested. Deficiencies and their rectification shall be recorded in the Dry Commissioning Report.
- 19.2.3.10 The Contractor shall inform the Engineer 14 days prior to commencing any testing associated with Wet Commissioning. As soon as the Engineer is satisfied that all the above checks and tests are completed, Wet Commissioning may commence at Site.
- 19.2.3.11 O&M Manual, As-built Drawings and O&M Training Plan shall be revised and updated as necessary with information obtained during Dry Commissioning.
- 19.2.3.12 The Contractor shall obtain no-objection certificate from the Engineer to commence Wet Commissioning. The Contractor shall produce, as a minimum, the evidence of the successful completion of Dry Commissioning.

#### 19.2.4 Wet Commissioning (Clean Water Test)

19.2.4.1 Clean water is required during Wet Commissioning. Clean water shall be potable water, or other "clean liquid" as deemed appropriate.

19.2.4.2 Wet Commissioning involves the operation of all equipment, subsystems, control systems and ancillary systems making up the complete system, in conditions that are representative of the anticipated operating hydraulic conditions. During this time, each train needs to operate and actual input/outputs will be measured to verify that the equipment meets its specified level of performance. Performance of the equipment, ancillary systems, monitoring and control, SCADA and other systems, shall be fully documented during this phase e.g. noise, vibration, motor/pump speed, all protection and safety features, alarms and shutdowns, water quality analyzers/controllers/monitors, automatic and manual operation.

19.2.4.3 The Contractor shall carry out such tests and re-tests on completed systems as specified and are required to demonstrate to the satisfaction of the Engineer that the Works or part thereof are ready to undergo the next stage of T&C. The operating data obtained during Wet Commissioning shall demonstrate, measure and record the following as a minimum:

- 1 Operation of all the items of WTP under normal operation including their response to simulated abnormal and emergency conditions;
- 2 Each process train/system is primarily set to work under manual control and equipment and subsystem commissioning are carried out for such time appropriate to the process or system being tested. Subsequently the automatic control equipment is set to work and further equipment and subsystem commissioning tests are carried out;
- 3 Simulation of the full range of alarm conditions over possible modes of operation which also include tests of emergency shutdown procedures and electricity power failure;
- 4 Automatic operation of the system and subsystems (including changeover between duty and standby unit);
- 5 Operator-adjustable set points;
- 6 Alarm initiation and priority/action;
- 7 Recording and trending of data;
- 8 Demonstration of equipment operation at full design capacity;
- 9 Demonstration of system or equipment fail scenarios; and
- 10 Automatic operation of all control systems.

19.2.4.4 Each component of the entire WTP shall be subjected to hydraulic checks under simulated maximum flow conditions, that is operations under ultimate flow and 10% hydraulic allowance. The Contractor shall demonstrate that the plant is performing at all possible hydraulic conditions with overflowing from any section or process unit, maintaining adequate hydraulic free board. Adjustment of water flow rate shall be made to demonstrate performance of the Plant over its design range of throughput. Should there be overflow observed during this stage, the Contractor shall rectify this immediately.



- 19.2.4.5 The Contractor shall inform the Engineer 14 days prior to commencing any testing associated with Process Commissioning. As soon as the Engineer is satisfied that all the above checks and tests are completed and that Manila Water's personnel have received substantial training in plant O&M, Process Commissioning may commence.
- 19.2.4.6 O&M Manual, As-built Drawings and O&M Training Plan shall be revised and updated as necessary with information obtained during Wet Commissioning.
- 19.2.4.7 The Contractor shall obtain No Objection Certificate from the Engineer to commence Process Commissioning. The Contractor shall produce, as a minimum, the evidence of the successful completion of Wet Commissioning.

## **20 Tests on Completion – Liquid and Solids Process Commissioning**

### **20.1 Process Commissioning**

20.1.1 The Process Commissioning stage comprises two (2) phases of works:

20.1.1.1 Process stabilization;

20.1.1.2 28-day Process Commissioning Test.

20.1.2 Prior to the start of the Process Commissioning, the Contractor shall acquire the necessary certification, registration, and permits to operate the WTP. Refer to Section 10.8 for the documentation of permits.

20.1.3 Process Commissioning shall include significant sampling, analyzing, testing, monitoring, and recording of data by the Contractor.

20.1.4 Process Commissioning of the WTP equipment shall be performed using raw water.

In case there is no raw water flow at the time of commissioning, tests shall not be conducted until such time that flow is available. In case that flow is available, but is less than the average flow indicated, the Contractor, with the agreement of the Employer shall determine the number of units of equipment, or stream of process to commission. At least one process train should be used for commissioning the works.

While the treated water is not suited and cleared for distribution, the Contractor shall be responsible for providing the facilities for the removal and disposal of water used for the commissioning activities. The Contractor shall be responsible for obtaining the relevant consents to discharge, for provision of any discharge/ outfall structures and for complying with the terms of the consents.

Prior to the start of the Trial Operation, the Contractor shall conduct all necessary jar tests to identify the optimum chemical dosages prior Trial Operations, soon as raw water is available.

20.1.5 The following sub-sections provide the requirement for Liquid Process Commissioning and Solids Process Commissioning separately. The Contractor shall ensure that raw water and sludge is made available for the process tests.

### **20.2 Liquid Process Commissioning**

20.2.1 Liquid Process Stabilization

20.2.1.1 A consistent treated water quality will indicate the stabilization of Liquid Process Commissioning.

20.2.1.2 During the final phase of stabilization prior to the 28-day Process Commissioning Test, daily meetings shall be conducted by the Contractor to review the performance of the WTP and to update the Engineer on the stabilization progress. The Contractor shall provide a 7-day notice to the Engineer of their intention to begin the Process Commissioning Tests.

20.2.2 Liquid Process Commissioning Test

20.2.2.1 The purpose of Liquid Process Commissioning Test is to test the WTP’s performance, reliability, and ability to operate continuously using available raw water for a continuous period of twenty-eight (28) days under the annual average flow condition.

Within the 28-day period, each train of the WTP shall also be tested to operate under the simulated maximum flow conditions. This shall be done for at least 7 days for each train.

20.2.2.2 During the Liquid Process Commissioning Test, the WTP shall operate normally in an automatic mode, without interruption, with guaranteed output of all process systems and equipment. At all times, the plant shall meet the specified performance requirements. These requirements shall include but not be limited to the treated water quality and equipment runtime/downtime.

20.2.2.3 The minimum testing and sampling criteria during 28-day Liquid Process Commissioning Test are shown below:

| Sampling Location   | Item/ Stream | Parameter      | Type of Sample | Frequency                       | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|---------------------|--------------|----------------|----------------|---------------------------------|-------------------------------------------------------------|--------------------------------------|
| Raw Water Reception | Inlet        | Flow           | Monitoring     | Instantaneous and Daily Average | 28                                                          | 300 MLD                              |
|                     | Inlet        | TSS            | Grab           | Daily                           | 28                                                          | N/A                                  |
|                     | Inlet        | Temperature    | Grab           | Daily                           | 28                                                          | N/A                                  |
|                     | Inlet        | Ammonia        | Grab           | Daily                           | 28                                                          | N/A                                  |
|                     | Inlet        | Alkalinity     | Grab           | Daily                           | 28                                                          | N/A                                  |
|                     | Inlet        | Total Coliform | Grab           | Daily                           | 28                                                          | N/A                                  |
|                     | Inlet        | Fecal Coliform | Grab           | Daily                           | 28                                                          | N/A                                  |
|                     | Inlet        | HPC            | Grab           | Daily                           | 28                                                          | N/A                                  |
|                     | Inlet        | Antimony       | Grab           | Daily                           | 28                                                          | N/A                                  |

| Sampling Location | Item/ Stream | Parameter        | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|-------------------|--------------|------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                   | Inlet        | Arsenic          | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Barium           | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Boron            | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Cadmium          | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Chromium (Total) | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Cyanide (Total)  | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Fluoride         | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Lead             | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Manganese        | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Mercury (Total)  | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Nickel           | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Nitrate          | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Nitrite          | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Selenium         | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Benzene          | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Benzo(a)pyrene   | Grab           | Daily     | 28                                                          | N/A                                  |

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| Sampling Location | Item/ Stream | Parameter                 | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|-------------------|--------------|---------------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                   | Inlet        | Carbon Tetrachloride      | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | 1,2-Dichlorobenzene       | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | 1,4-Dichlorobenzene       | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | 1,2-Dichloroethane        | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | 1,2-Dichloroethene        | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Dichloromethane           | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Di(2-ethylhexyl)phthalate | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Ethylbenzene              | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Styrene                   | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Tetrachloroethene         | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Toluene                   | Grab           | Daily     | 28                                                          | N/A                                  |

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Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

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| Sampling Location | Item/ Stream | Parameter                                      | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|-------------------|--------------|------------------------------------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                   | Inlet        | Vinyl chloride                                 | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Xylenes (total)                                | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Aldrin and Dieldrin (combined)                 | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Atrazine and its chloro-s-triazine metabolites | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Carbofuran                                     | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Chlordane                                      | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | DDT                                            | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | 1,2-Dibromo-3-chloropropane (DBCP)             | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | 2,4-dichlorophenoxyacetic acid (2,4-D)         | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Endrin                                         | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | 1,2-dibromoethane                              | Grab           | Daily     | 28                                                          | N/A                                  |

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Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

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| Sampling Location | Item/ Stream | Parameter                 | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|-------------------|--------------|---------------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                   |              | hane (Ethylenedi bromide) |                |           |                                                             |                                      |
|                   | Inlet        | Glyphosate                | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Lindane                   | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Pendimeth alin            | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Taste                     | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Odor                      | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Color (Apparent)          | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Turbidity                 | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Aluminum                  | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Chloride                  | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Copper                    | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Hardness, total           | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Hydrogen Sulfide          | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | Iron                      | Grab           | Daily     | 28                                                          | N/A                                  |
|                   | Inlet        | pH                        | Grab           | Daily     | 28                                                          | N/A                                  |

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| Sampling Location        | Item/ Stream     | Parameter                              | Type of Sample | Frequency                       | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|--------------------------|------------------|----------------------------------------|----------------|---------------------------------|-------------------------------------------------------------|--------------------------------------|
|                          | Inlet            | Sodium                                 | Grab           | Daily                           | 28                                                          | N/A                                  |
|                          | Inlet            | Sulfate                                | Grab           | Daily                           | 28                                                          | N/A                                  |
|                          | Inlet            | Total Dissolved Solids, TDS            | Grab           | Daily                           | 28                                                          | N/A                                  |
|                          | Inlet            | Zinc                                   | Grab           | Daily                           | 28                                                          | N/A                                  |
|                          | Inlet            | Gross alpha activity (excluding radon) | Grab           | Daily                           | 28                                                          | N/A                                  |
|                          | Inlet            | Gross beta                             | Grab           | Daily                           | 28                                                          | N/A                                  |
|                          | Inlet            | Radon                                  | Grab           | Daily                           | 28                                                          | N/A                                  |
| Coagulation              | Outlet           | Mixing                                 | Grab           | Daily                           | One sample from each flocculator unit per day               | 0.05 COV                             |
| Sedimentation            | Inlet and Outlet | Turbidity                              | Grab           | Daily                           | 28                                                          | Outlet NTU less than 7.0 NTU         |
| Filter                   | Outlet           | Turbidity                              | Grab           | Daily                           | 28                                                          | Outlet NTU less than 2.50 NTU        |
| Filtered Water Discharge | Outlet           | Flow                                   | Monitoring     | Instantaneous and Daily Average | 28                                                          | Refer to Performance guarantee       |



## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream | Parameter        | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|-------------------|--------------|------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                   | Outlet       | TSS              | Grab           | Daily     | 28                                                          | For information                      |
|                   | Outlet       | Temperature      | Grab           | Daily     | 28                                                          | For information                      |
|                   | Outlet       | Ammonia          | Grab           | Daily     | 28                                                          | <0.20 mg/L                           |
|                   | Outlet       | Total Coliform   | Grab           | Daily     | 28                                                          | Absent or <1.00 MFN/100ml            |
|                   | Outlet       | Fecal Coliform   | Grab           | Daily     | 28                                                          | Absent or <1.00 MFN/100ml            |
|                   | Outlet       | HPC              | Grab           | Daily     | 28                                                          | ≤10.00 CFU/mL                        |
|                   | Outlet       | Antimony         | Grab           | Daily     | 28                                                          | 0.02 mg/L                            |
|                   | Outlet       | Arsenic          | Grab           | Daily     | 28                                                          | 0.01 mg/L                            |
|                   | Outlet       | Barium           | Grab           | Daily     | 28                                                          | 0.70 mg/L                            |
|                   | Outlet       | Boron            | Grab           | Daily     | 28                                                          | 2.00 mg/L                            |
|                   | Outlet       | Cadmium          | Grab           | Daily     | 28                                                          | 0.003 mg/L                           |
|                   | Outlet       | Chromium (Total) | Grab           | Daily     | 28                                                          | 0.05 mg/L                            |
|                   | Outlet       | Cyanide (Total)  | Grab           | Daily     | 28                                                          | 0.50 mg/L                            |
|                   | Outlet       | Fluoride         | Grab           | Daily     | 28                                                          | 1.50 mg/L                            |

| Sampling Location | Item/ Stream | Parameter            | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|-------------------|--------------|----------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                   | Outlet       | Lead                 | Grab           | Daily     | 28                                                          | 0.01 mg/L                            |
|                   | Outlet       | Manganese            | Grab           | Daily     | 28                                                          | 0.021 mg/L                           |
|                   | Outlet       | Mercury (Total)      | Grab           | Daily     | 28                                                          | 0.001 mg/L                           |
|                   | Outlet       | Nickel               | Grab           | Daily     | 28                                                          | 0.07 mg/L                            |
|                   | Outlet       | Nitrate              | Grab           | Daily     | 28                                                          | 50.00 mg/L                           |
|                   | Outlet       | Nitrite              | Grab           | Daily     | 28                                                          | 3.00 mg/L                            |
|                   | Outlet       | Selenium             | Grab           | Daily     | 28                                                          | 0.04 mg/L                            |
|                   | Outlet       | Benzene              | Grab           | Daily     | 28                                                          | 0.01 mg/L                            |
|                   | Outlet       | Benzo(a)pyrene       | Grab           | Daily     | 28                                                          | 0.0007 mg/L                          |
|                   | Outlet       | Carbon Tetrachloride | Grab           | Daily     | 28                                                          | 0.004 mg/L                           |
|                   | Outlet       | 1,2-Dichlorobenzene  | Grab           | Daily     | 28                                                          | 1.00 mg/L                            |
|                   | Outlet       | 1,4-Dichlorobenzene  | Grab           | Daily     | 28                                                          | 0.30 mg/L                            |
|                   | Outlet       | 1,2-Dichloroethane   | Grab           | Daily     | 28                                                          | 0.03 mg/L                            |

| Sampling Location | Item/ Stream | Parameter                                      | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|-------------------|--------------|------------------------------------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                   | Outlet       | 1,2-Dichloroethene                             | Grab           | Daily     | 28                                                          | 0.05 mg/L                            |
|                   | Outlet       | Dichloromethane                                | Grab           | Daily     | 28                                                          | 0.02 mg/L                            |
|                   | Outlet       | Di(2-ethylhexyl)phthalate                      | Grab           | Daily     | 28                                                          | 0.008 mg/L                           |
|                   | Outlet       | Ethylbenzene                                   | Grab           | Daily     | 28                                                          | 0.30 mg/L                            |
|                   | Outlet       | Styrene                                        | Grab           | Daily     | 28                                                          | 0.02 mg/L                            |
|                   | Outlet       | Tetrachloroethene                              | Grab           | Daily     | 28                                                          | 0.04 mg/L                            |
|                   | Outlet       | Toluene                                        | Grab           | Daily     | 28                                                          | 0.70 mg/L                            |
|                   | Outlet       | Vinyl chloride                                 | Grab           | Daily     | 28                                                          | 0.0003 mg/L                          |
|                   | Outlet       | Xylenes (total)                                | Grab           | Daily     | 28                                                          | 0.50 mg/L                            |
|                   | Outlet       | Aldrin and Dieldrin (combined)                 | Grab           | Daily     | 28                                                          | 0.00003 mg/L                         |
|                   | Outlet       | Atrazine and its chloro-s-triazine metabolites | Grab           | Daily     | 28                                                          | 0.10 mg/L                            |

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| Sampling Location | Item/ Stream | Parameter                              | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|-------------------|--------------|----------------------------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                   | Outlet       | Carbofuran                             | Grab           | Daily     | 28                                                          | 0.007 mg/L                           |
|                   | Outlet       | Chlordane                              | Grab           | Daily     | 28                                                          | 0.0002 mg/L                          |
|                   | Outlet       | DDT                                    | Grab           | Daily     | 28                                                          | 0.001 mg/L                           |
|                   | Outlet       | 1,2-Dibromo-3-chloropropane (DBCP)     | Grab           | Daily     | 28                                                          | 0.001 mg/L                           |
|                   | Outlet       | 2,4-dichlorophenoxyacetic acid (2,4-D) | Grab           | Daily     | 28                                                          | 30.00 mg/L                           |
|                   | Outlet       | Endrin                                 | Grab           | Daily     | 28                                                          | 0.0006 mg/L                          |
|                   | Outlet       | 1,2-dibromethane (Ethylene dibromide)  | Grab           | Daily     | 28                                                          | 0.0004 mg/L                          |
|                   | Outlet       | Glyphosate                             | Grab           | Daily     | 28                                                          | 1.00 mg/L                            |
|                   | Outlet       | Lindane                                | Grab           | Daily     | 28                                                          | 0.002 mg/L                           |
|                   | Outlet       | Pendimethalin                          | Grab           | Daily     | 28                                                          | 0.02 mg/L                            |
|                   | Outlet       | Taste                                  | Grab           | Daily     | 28                                                          | No objectionable Taste               |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream | Parameter                   | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|-------------------|--------------|-----------------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                   | Outlet       | Odor                        | Grab           | Daily     | 28                                                          | No objectionable Odor                |
|                   | Outlet       | Color                       | Grab           | Daily     | 28                                                          | <5.00 CU                             |
|                   | Outlet       | Turbidity                   | Grab           | Daily     | 28                                                          | <2.50 NTU                            |
|                   | Outlet       | Aluminum                    | Grab           | Daily     | 28                                                          | <0.12 mg/L                           |
|                   | Outlet       | Chloride                    | Grab           | Daily     | 28                                                          | <200.00 mg/L                         |
|                   | Outlet       | Copper                      | Grab           | Daily     | 28                                                          | 1.00 mg/L                            |
|                   | Outlet       | Hardness, total             | Grab           | Daily     | 28                                                          | <250.00 mg/L                         |
|                   | Outlet       | Hydrogen Sulfide            | Grab           | Daily     | 28                                                          | 0.05 mg/L                            |
|                   | Outlet       | Iron                        | Grab           | Daily     | 28                                                          | <0.40 mg/L                           |
|                   | Outlet       | pH                          | Grab           | Daily     | 28                                                          | 6.5 - 8.0                            |
|                   | Outlet       | Sodium                      | Grab           | Daily     | 28                                                          | 200.00 mg/L                          |
|                   | Outlet       | Sulfate                     | Grab           | Daily     | 28                                                          | 200.00 mg/L                          |
|                   | Outlet       | Total Dissolved Solids, TDS | Grab           | Daily     | 28                                                          | 400.00 mg/L                          |
|                   | Outlet       | Zinc                        | Grab           | Daily     | 28                                                          | 5.00 mg/L                            |
|                   | Outlet       | Acrylamide                  | Grab           | Daily     | 28                                                          | 0.0005 mg/L                          |

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| Sampling Location | Item/ Stream | Parameter                   | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|-------------------|--------------|-----------------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                   | Outlet       | Epichlorohydrin             | Grab           | Daily     | 28                                                          | 0.0004 mg/L                          |
|                   | Outlet       | Chlorine Residual           | Grab           | Daily     | 28                                                          | 0.90 – 1.50 mg/L                     |
|                   | Outlet       | Bromate                     | Grab           | Daily     | 28                                                          | 0.01 mg/L                            |
|                   | Outlet       | Chlorite                    | Grab           | Daily     | 28                                                          | 0.70 mg/L                            |
|                   | Outlet       | Chlorate                    | Grab           | Daily     | 28                                                          | 0.70 mg/L                            |
|                   | Outlet       | Dibromoacetonitrile         | Grab           | Daily     | 28                                                          | 0.07 mg/L                            |
|                   | Outlet       | Dichloroacetate             | Grab           | Daily     | 28                                                          | 0.05 mg/L                            |
|                   | Outlet       | Dichloroacetonitrile        | Grab           | Daily     | 28                                                          | 0.02 mg/L                            |
|                   | Outlet       | Monochloroacetate           | Grab           | Daily     | 28                                                          | 0.02 mg/L                            |
|                   | Outlet       | Trichloroacetate            | Grab           | Daily     | 28                                                          | 0.20 mg/L                            |
|                   | Outlet       | 2,4,6-trichlorophenol       | Grab           | Daily     | 28                                                          | 0.20 mg/L                            |
|                   | Outlet       | Bromoform                   | Grab           | Daily     | 28                                                          | 0.10 mg/L                            |
|                   | Outlet       | Bromodichloromethane (BDCM) | Grab           | Daily     | 28                                                          | 0.06 mg/L                            |

| Sampling Location      | Item/ Stream          | Parameter                              | Type of Sample | Frequency | No. of Samples or Calculations Taken (Liquid Process Tests) | Required Values/ Acceptance Criteria |
|------------------------|-----------------------|----------------------------------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
|                        | Outlet                | Chloroform                             | Grab           | Daily     | 28                                                          | 0.30 mg/L                            |
|                        | Outlet                | Dibromochloromethane (DBCM)            | Grab           | Daily     | 28                                                          | 0.10 mg/L                            |
|                        | Outlet                | Total trihalomethanes                  | Grab           | Daily     | 28                                                          | 1.00 mg/L                            |
|                        | Outlet                | Gross alpha activity (excluding radon) | Grab           | Daily     | 28                                                          | 0.50 Bq/L                            |
|                        | Outlet                | Gross beta                             | Grab           | Daily     | 28                                                          | 1.00 Bq/L                            |
|                        | Outlet                | Radon                                  | Grab           | Daily     | 28                                                          | 11.00 Bq/L                           |
| Liquid Treatment Plant | Process Reliability   | Plant down time                        | Monitoring     | Daily     | 28                                                          | 99.9%                                |
| Liquid Treatment Plant | Electrical Controls   | Plant down time                        | Monitoring     | Daily     | 28                                                          | 99.9%                                |
| Liquid Treatment Plant | Equipment Reliability | Plant down time                        | Monitoring     | Daily     | 28                                                          | 99.9%                                |
| Reliability            | PLC                   | Plant down time                        | Monitoring     | Daily     | 28                                                          | 99.9%                                |

20.2.2.4 During the Liquid Process Test, a “failed” day is defined as any of the following:

- 1 Inability to meet any of the target treated water quality;
- 2 Two failures of same instrument or equipment during the 28-day test period;
- 3 Three failures combined for any instrument or equipment during the 28-day test period.

20.2.2.5 The Liquid Process Test shall be extended under the following “failed” scenarios:

- 1 Whenever there is one (1) “failed” day due to inability to meet target treated water quality, the Liquid Process Commissioning will restart to Day 1.
- 2 Whenever there is one (1) “failed” day due to instrument or equipment failure, one (1) more test day will be added to the Liquid Process Commissioning test period.
- 3 The Liquid Process Commissioning will be restarted to Day 1 if there is any occurrence of “failed” day during the final five (5) days.
- 4 Whenever there is more than three (3) “failed” days due to instrument or equipment failure, the Liquid Process Commissioning will be restarted to Day 1.

20.2.2.6 In the event that influent quality is unfavorable as compared with the value as defined in the Employer’s Requirements, measure of success shall generally be the percent removal rate from the approved mass balance and process design calculations.

20.2.2.7 The Contractor shall daily provide the results of the previous day’s operation and testing; and shall report details of any failure to the Engineer. The report shall contain sufficient details to provide a comprehensive assessment of cause and recommendation to rectify. The Engineer may accept or reject the reported results and thereby assess and determine if the previous day is a “failed” day or “passed” day.

20.2.2.8 It shall be the Contractor’s responsibility to obtain and report the results from the third-party laboratory within 7 days upon sampling. For online analysers, results shall be reported within 24 hours.

20.2.2.9 Any deficiencies or deviations from the acceptance criteria of plant component or parameter presented by the tests shall be corrected by the Contractor and tests shall be repeated as necessary until acceptable results are achieved.

20.2.2.10 The Contractor shall be responsible for collecting, recording and collating all data and test results and shall carry out all necessary calculations to confirm compliance with the Specification and Performance Guarantees. A report comprising test data, results, calculations and conclusions shall be submitted within one week of the date of completion of the tests, or set of tests.



- 20.2.2.11 Within seven (7) days from when the Engineer endorsed successful completion of the Liquid Process Commissioning Test, the Contractor shall submit to the Engineer the Liquid Process Test Report documenting all the activities and tests carried out, plant and equipment operation data including its performance. Any interruptions and corrective actions taken shall also be documented.
- 20.2.2.12 Prior to storing final treated (chlorinated) water into the reservoir, the Liquid Process Commissioning Test shall be completed by the Contractor.
- 20.2.2.13 The Contractor shall provide all required bypass lines to successfully divert the treated water from a suitable discharge location before allowing to be sent to the reservoir. All required bypass lines shall be considered in the plant's design.
- 20.2.2.14 Prior to supplying treated water for distribution, the Contractor shall prove the potability of the water produced from the WTP and its safety for public consumption by securing a Certificate of Potability from DOH.
- 20.2.2.15 O&M Manual, As-built Drawings and O&M Training Plan shall be revised and updated as necessary with information obtained during Liquid Process Commissioning
- 20.2.2.16 The WTP shall be deemed to have passed the Liquid Process Test if:
- 1 All pre-commissioning, commissioning and Liquid Process Commissioning tests have been successfully completed and records and report issued
  - 2 The Contractor has obtained final "No Objection" from the Engineer and the Operation and Maintenance Manuals has been issued.
  - 3 All As-Built Drawings have been issued.
  - 4 All spare parts have been delivered.
  - 5 The Training Plan and the Training Manual has been approved by the Engineer.

### **20.3 Solids Process Commissioning**

#### **20.3.1 Solids Process Commissioning Test**

- 20.3.1.1 The Contractor shall provide the detailed programme of Solids Process Commissioning Tests. It is expected that Solids Process Tests will start in parallel with the Liquid Process Tests. It is understood that sufficient amount of sludge is needed to be available for the Solids Process Tests to begin.
- 20.3.1.2 The purpose of Solids Process Commissioning Test is to test the solids treatment system's performance, reliability, and its ability to operate continuously for a period of twenty eight (28) days under the average flow condition.

20.3.1.3 During the Solids Process Commissioning Test, the plant shall operate normally in an automatic mode, without interruption, with guaranteed output of all process systems and equipment. At all times, the plant shall meet the specified performance requirements. These requirements shall include but are not be limited to sludge cake dryness and equipment runtime / downtime.

20.3.1.4 As a minimum, at least one grab sample biosolids samples taken at interval of three (3) hours over a continuous twenty eight (28) days testing period.

20.3.1.5 The minimum testing and sampling criteria during 28-day Solid Process Commissioning Test are shown below:

| Sampling Location      | Item/ Stream          | Parameter       | Type of Sample | Frequency | No. of Samples or Calculations Taken (Solids Process Tests) | Required Values/ Acceptance Criteria |
|------------------------|-----------------------|-----------------|----------------|-----------|-------------------------------------------------------------|--------------------------------------|
| Sludge Dewatering      | Dewatered sludge      | % DS            | Grab           | Daily     | 28                                                          | 18% minimum                          |
| Sludge Dewatering      | Dewatered sludge      | Volume          | Grab           | Daily     | 28                                                          | Refer to Performance guarantee       |
| Solids Treatment Plant | Process Reliability   | Plant down time | Monitoring     | Daily     | 28                                                          | 99.9%                                |
| Solids Treatment Plant | Electrical Controls   | Plant down time | Monitoring     | Daily     | 28                                                          | 99.9%                                |
| Solids Treatment Plant | Equipment Reliability | Plant down time | Monitoring     | Daily     | 28                                                          | 99.9%                                |
| Reliability            | PLC                   | Plant down time | Monitoring     | Daily     | 28                                                          | 99.9%                                |

#### **20.4 Punchlisting**

The Contractor shall maintain a punchlist throughout the process of the Tests on Completion; and submit on a daily basis to the Engineer for review. The Contractor shall update the status of all items on the punchlist on a daily basis.

## **21 Tests on Completion – Process Proving Period**

### **21.1 Process Proving Period**

21.1.1 The Process Proving Period (PPP) is to demonstrate the WTP can meet the intended design performance for a continuous period of 1 year under the actual incoming flow condition. PPP shall only commence after the WTP passes the Liquid Process Commissioning Test and the Works is certified complete. The WTP, other than the solids treatment system, shall be operated for a continuous period of 1 year to achieve successful completion of PPP. The Process Proving Period shall include 28 days of Guarantee Run period. The requirements of the Guarantee Run have been stated in the Employer's Requirements.

21.1.2 It is expected that the PPP for solids treatment system will start later than the liquid treatment system but shall be no less than a continuous period of 182 days. Unless otherwise agreed, the PPP of the whole WTP shall end when both the liquid and solids treatment systems achieve their respective successful passing of PPP.

21.1.3 The WTP shall operate normally in an automatic mode, without severe interruption, with guaranteed output of all process systems and equipment. The Contractor shall timely attend to any failure to minimize operation interruption.

21.1.4 The monitoring and tests during Process Proving Period shall include:

- 1 Instantaneous and daily average plant raw water and treated water flow;
- 2 Measurement of each of the parameters within the Schedule of Guarantees;
- 3 Water quality parameters, raw water and final treated water;
- 4 Individual unit process and overall plant power consumption;
- 5 Liquid, solids and chemical consumption;
- 6 Plant manning levels; and
- 7 Plant availability – equipment reliability

21.1.5 The minimum testing and sampling criteria during PPP are shown below. Parameters of concern shall be tested daily in the plant's in-house laboratory, while all other PNSDW-mandated parameters shall be tested monthly through an accredited third-party laboratory. Note that upon conducting the raw water verification study and process commissioning tests, it shall be the Contractor's responsibility to add parameters of concern/frequency to the list for monitoring.

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| Sampling Location | Item/ Stream | Parameter        | Type of Sample    | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|--------------|------------------|-------------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |              |                  |                   | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
| Inlet             | Raw Water    | Flow             | Monitoring        | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Turbidity        | Monitoring + Grab | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Taste            | Grab              | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Odor             | Grab              | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Color (apparent) | Monitoring + Grab | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | pH               | Monitoring        | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Iron             | Monitoring + Grab | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Aluminum         | Monitoring + Grab | Daily                                                  | 365                                  | N/A                                         | N/A                                  |

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| Sampling Location | Item/ Stream | Parameter                 | Type of Sample    | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|--------------|---------------------------|-------------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |              |                           |                   | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water    | Manganese                 | Monitoring + Grab | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Total Coliform            | Grab              | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Fecal Coliform            | Grab              | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Heterotrophic Plate Count | Grab              | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Ammonia                   | Monitoring        | Daily                                                  | 365                                  | N/A                                         | N/A                                  |
|                   | Raw Water    | Antimony                  | Grab              | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Arsenic                   | Grab              | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Barium                    | Grab              | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Boron                     | Grab              | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Cadmium                   | Grab              | Monthly                                                | 12                                   | N/A                                         | N/A                                  |

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| Sampling Location | Item/ Stream | Parameter        | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|--------------|------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |              |                  |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water    | Chromium (Total) | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Cyanide (Total)  | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Fluoride         | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Lead             | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Mercury (Total)  | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Nickel           | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Nitrate          | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Nitrite          | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Selenium         | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Benzene          | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Benzo(a)pyrene   | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream | Parameter                   | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|--------------|-----------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |              |                             |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water    | Carbon Tetrachloride        | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | 1,2-Dichlorobenzene         | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | 1,4-Dichlorobenzene         | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | 1,2-Dichloroethane          | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | 1,2-Dichloroethene          | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Dichloromethane             | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Di(2-ethylhexylyl)phthalate | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Ethylbenzene                | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Styrene                     | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Tetrachloroethene           | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |



## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream | Parameter                                      | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|--------------|------------------------------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |              |                                                |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water    | Toluene                                        | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Vinyl chloride                                 | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Xylenes (total)                                | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Aldrin and Dieldrin (combined)                 | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Atrazine and its chloro-s-triazine metabolites | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Carbofuran                                     | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Chlordane                                      | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | DDT                                            | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | 1,2-Dibromo-3-chloropropane (DBCP)             | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream | Parameter                              | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|--------------|----------------------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |              |                                        |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water    | 2,4-dichlorophenoxyacetic acid (2,4-D) | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Endrin                                 | Grab           | Monthly                                                | 12                                   | 0                                           | N/A                                  |
|                   | Raw Water    | 1,2-dibromoethane (Ethylenedibromide)  | Grab           | Monthly                                                | 12                                   | 0                                           | N/A                                  |
|                   | Raw Water    | Glyphosate                             | Grab           | Monthly                                                | 12                                   | 0                                           | N/A                                  |
|                   | Raw Water    | Lindane                                | Grab           | Monthly                                                | 12                                   | 0                                           | N/A                                  |
|                   | Raw Water    | Pendimethalin                          | Grab           | Monthly                                                | 12                                   | 0                                           | N/A                                  |
|                   | Raw Water    | Chloride                               | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Copper                                 | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                   | Raw Water    | Hardness, total                        | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location        | Item/ Stream  | Parameter                              | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|--------------------------|---------------|----------------------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                          |               |                                        |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                          | Raw Water     | Hydrogen Sulfide                       | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                          | Raw Water     | Sodium                                 | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                          | Raw Water     | Sulfate                                | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                          | Raw Water     | Total Dissolved Solids, TDS            | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                          | Raw Water     | Zinc                                   | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                          | Raw Water     | Gross alpha activity (excluding radon) | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                          | Raw Water     | Gross beta                             | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
|                          | Raw Water     | Radon                                  | Grab           | Monthly                                                | 12                                   | N/A                                         | N/A                                  |
| Filtered Water Discharge | Treated Water | Flow                                   | Monitoring     | Daily                                                  | 365                                  | 0                                           | 100MLD minimum                       |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter        | Type of Sample    | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|------------------|-------------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                  |                   | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Arsenic          | Grab              | Daily                                                  | 365                                  | 0                                           | 0.01 mg/L                            |
|                   | Treated Water | Cadmium          | Grab              | Daily                                                  | 365                                  | 0                                           | 0.003 mg/L                           |
|                   | Treated Water | Lead             | Grab              | Daily                                                  | 365                                  | 0                                           | 0.01 mg/L                            |
|                   | Treated Water | Nitrate          | Grab              | Daily                                                  | 365                                  | 0                                           | 50.00 mg/L                           |
|                   | Treated Water | Turbidity        | Monitoring + Grab | Daily                                                  | 365                                  | 0                                           | <2.50 NTU                            |
|                   | Treated Water | Color (apparent) | Grab              | Daily                                                  | 365                                  | 0                                           | <5.00 CU                             |
|                   | Treated Water | pH               | Monitoring + Grab | Daily                                                  | 365                                  | 0                                           | 6.80 - 8.00                          |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter              | Type of Sample    | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|------------------------|-------------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                        |                   | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Odor                   | Grab              | Daily                                                  | 365                                  | 0                                           | No objectionable odor                |
|                   | Treated Water | Taste                  | Grab              | Daily                                                  | 365                                  | 0                                           | No objectionable taste               |
|                   | Treated Water | Iron                   | Monitoring + Grab | Daily                                                  | 365                                  | 0                                           | <0.40 mg/L                           |
|                   | Treated Water | Aluminum               | Monitoring + Grab | Daily                                                  | 365                                  | 0                                           | <0.12 mg/L                           |
|                   | Treated Water | Total Dissolved Solids | Grab              | Daily                                                  | 365                                  | 0                                           | <400.00 mg/L                         |
|                   | Treated Water | Manganese              | Monitoring + Grab | Daily                                                  | 365                                  | 0                                           | <0.021 mg/L                          |
|                   | Treated Water | Total Coliform         | Grab              | Daily                                                  | 365                                  | 0                                           | Absent or <1.00 MPN/100ml            |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter                 | Type of Sample    | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|---------------------------|-------------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                           |                   | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Fecal Coliform            | Grab              | Daily                                                  | 365                                  | 0                                           | Absent or <1.00 MPN/100ml            |
|                   | Treated Water | Heterotrophic Plate Count | Grab              | Daily                                                  | 365                                  | 0                                           | ≤10.00 CFU/mL                        |
|                   | Treated Water | Ammonia                   | Grab              | Daily                                                  | 365                                  | 0                                           | <0.20 mg/L                           |
|                   | Treated Water | Residual Chlorine         | Monitoring + Grab | Daily                                                  | 365                                  | 0                                           | 0.90 - 1.5 mg/L                      |
|                   | Treated Water | Antimony                  | Grab              | Monthly                                                | 12                                   | 0                                           | 0.02 mg/L                            |
|                   | Treated Water | Barium                    | Grab              | Monthly                                                | 12                                   | 0                                           | 0.70 mg/L                            |
|                   | Treated Water | Boron                     | Grab              | Monthly                                                | 12                                   | 0                                           | 2.00 mg/L                            |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter        | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                  |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Chromium (Total) | Grab           | Monthly                                                | 12                                   | 0                                           | 0.05 mg/L                            |
|                   | Treated Water | Cyanide (Total)  | Grab           | Monthly                                                | 12                                   | 0                                           | 0.50 mg/L                            |
|                   | Treated Water | Fluoride         | Grab           | Monthly                                                | 12                                   | 0                                           | 1.50 mg/L                            |
|                   | Treated Water | Mercury (Total)  | Grab           | Monthly                                                | 12                                   | 0                                           | 0.001 mg/L                           |
|                   | Treated Water | Nickel           | Grab           | Monthly                                                | 12                                   | 0                                           | 0.07 mg/L                            |
|                   | Treated Water | Nitrite          | Grab           | Monthly                                                | 12                                   | 0                                           | 3.00 mg/L                            |
|                   | Treated Water | Selenium         | Grab           | Monthly                                                | 12                                   | 0                                           | 0.04 mg/L                            |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter            | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|----------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                      |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Benzene              | Grab           | Monthly                                                | 12                                   | 0                                           | 0.01 mg/L                            |
|                   | Treated Water | Benzo(a)pyrene       | Grab           | Monthly                                                | 12                                   | 0                                           | 0.0007 mg/L                          |
|                   | Treated Water | Carbon Tetrachloride | Grab           | Monthly                                                | 12                                   | 0                                           | 0.004 mg/L                           |
|                   | Treated Water | 1,2-Dichlorobenzene  | Grab           | Monthly                                                | 12                                   | 0                                           | 1.00 mg/L                            |
|                   | Treated Water | 1,4-Dichlorobenzene  | Grab           | Monthly                                                | 12                                   | 0                                           | 0.30 mg/L                            |
|                   | Treated Water | 1,2-Dichloroethane   | Grab           | Monthly                                                | 12                                   | 0                                           | 0.03 mg/L                            |
|                   | Treated Water | 1,2-Dichloroethene   | Grab           | Monthly                                                | 12                                   | 0                                           | 0.05 mg/L                            |



## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter                   | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|-----------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                             |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Dichloromethane             | Grab           | Monthly                                                | 12                                   | 0                                           | 0.02 mg/L                            |
|                   | Treated Water | Di(2-ethylhexylyl)phthalate | Grab           | Monthly                                                | 12                                   | 0                                           | 0.008 mg/L                           |
|                   | Treated Water | Ethylbenzene                | Grab           | Monthly                                                | 12                                   | 0                                           | 0.30 mg/L                            |
|                   | Treated Water | Styrene                     | Grab           | Monthly                                                | 12                                   | 0                                           | 0.02 mg/L                            |
|                   | Treated Water | Tetrachloroethene           | Grab           | Monthly                                                | 12                                   | 0                                           | 0.04 mg/L                            |
|                   | Treated Water | Toluene                     | Grab           | Monthly                                                | 12                                   | 0                                           | 0.70 mg/L                            |
|                   | Treated Water | Vinyl chloride              | Grab           | Monthly                                                | 12                                   | 0                                           | 0.0003 mg/L                          |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter                                      | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|------------------------------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                                                |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Xylenes (total)                                | Grab           | Monthly                                                | 12                                   | 0                                           | 0.50 mg/L                            |
|                   | Treated Water | Aldrin and Dieldrin (combined)                 | Grab           | Monthly                                                | 12                                   | 0                                           | 0.00003 mg/L                         |
|                   | Treated Water | Atrazine and its chloro-s-triazine metabolites | Grab           | Monthly                                                | 12                                   | 0                                           | 0.10 mg/L                            |
|                   | Treated Water | Carbofuran                                     | Grab           | Monthly                                                | 12                                   | 0                                           | 0.007 mg/L                           |
|                   | Treated Water | Chlordane                                      | Grab           | Monthly                                                | 12                                   | 0                                           | 0.0002 mg/L                          |
|                   | Treated Water | DDT                                            | Grab           | Monthly                                                | 12                                   | 0                                           | 0.001 mg/L                           |
|                   | Treated Water | 1,2-Dibromo-3-chloropropane (DBCP)             | Grab           | Monthly                                                | 12                                   | 0                                           | 0.001 mg/L                           |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter                              | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|----------------------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                                        |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | 2,4-dichlorophenoxyacetic acid (2,4-D) | Grab           | Monthly                                                | 12                                   | 0                                           | 30.00 mg/L                           |
|                   | Treated Water | Endrin                                 | Grab           | Monthly                                                | 12                                   | 0                                           | 0.0006 mg/L                          |
|                   | Treated Water | 1,2-dibromoethane (Ethylenedibromide)  | Grab           | Monthly                                                | 12                                   | 0                                           | 0.0004 mg/L                          |
|                   | Treated Water | Glyphosate                             | Grab           | Monthly                                                | 12                                   | 0                                           | 1.00 mg/L                            |
|                   | Treated Water | Lindane                                | Grab           | Monthly                                                | 12                                   | 0                                           | 0.002 mg/L                           |
|                   | Treated Water | Pendimethalin                          | Grab           | Monthly                                                | 12                                   | 0                                           | 0.02 mg/L                            |
|                   | Treated Water | Chloride                               | Grab           | Monthly                                                | 12                                   | 0                                           | <200.00 mg/L                         |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter        | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                  |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Copper           | Grab           | Monthly                                                | 12                                   | 0                                           | 1.00 mg/L                            |
|                   | Treated Water | Hardness, total  | Grab           | Monthly                                                | 12                                   | 0                                           | <250.00 mg/L                         |
|                   | Treated Water | Hydrogen Sulfide | Grab           | Monthly                                                | 12                                   | 0                                           | 0.05 mg/L                            |
|                   | Treated Water | Sodium           | Grab           | Monthly                                                | 12                                   | 0                                           | 200.00 mg/L                          |
|                   | Treated Water | Sulfate          | Grab           | Monthly                                                | 12                                   | 0                                           | 200.00 mg/L                          |
|                   | Treated Water | Zinc             | Grab           | Monthly                                                | 12                                   | 0                                           | 5.00 mg/L                            |
|                   | Treated Water | Acrylamide       | Grab           | Monthly                                                | 12                                   | 0                                           | 0.0005 mg/L                          |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter            | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|----------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                      |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Epichlorohydrin      | Grab           | Monthly                                                | 12                                   | 0                                           | 0.0004 mg/L                          |
|                   | Treated Water | Bromate              | Grab           | Monthly                                                | 12                                   | 0                                           | 0.01 mg/L                            |
|                   | Treated Water | Chlorite             | Grab           | Monthly                                                | 12                                   | 0                                           | 0.70 mg/L                            |
|                   | Treated Water | Chlorate             | Grab           | Monthly                                                | 12                                   | 0                                           | 0.70 mg/L                            |
|                   | Treated Water | Dibromoacetonitrile  | Grab           | Monthly                                                | 12                                   | 0                                           | 0.07 mg/L                            |
|                   | Treated Water | Dichloroacetate      | Grab           | Monthly                                                | 12                                   | 0                                           | 0.05 mg/L                            |
|                   | Treated Water | Dichloroacetonitrile | Grab           | Monthly                                                | 12                                   | 0                                           | 0.02 mg/L                            |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream  | Parameter                   | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------|-----------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                             |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Monochloroacetate           | Grab           | Monthly                                                | 12                                   | 0                                           | 0.02 mg/L                            |
|                   | Treated Water | Trichloroacetate            | Grab           | Monthly                                                | 12                                   | 0                                           | 0.20 mg/L                            |
|                   | Treated Water | 2,4,6-trichlorophenol       | Grab           | Monthly                                                | 12                                   | 0                                           | 0.20 mg/L                            |
|                   | Treated Water | Bromoform                   | Grab           | Monthly                                                | 12                                   | 0                                           | 0.10 mg/L                            |
|                   | Treated Water | Bromodichloromethane (BDCM) | Grab           | Monthly                                                | 12                                   | 0                                           | 0.06 mg/L                            |
|                   | Treated Water | Chloroform                  | Grab           | Monthly                                                | 12                                   | 0                                           | 0.30 mg/L                            |
|                   | Treated Water | Dibromochloromethane (DBCM) | Grab           | Monthly                                                | 12                                   | 0                                           | 0.10 mg/L                            |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream     | Parameter                              | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|------------------|----------------------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |                  |                                        |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water    | Total trihalomethanes                  | Grab           | Monthly                                                | 12                                   | 0                                           | 1.00 mg/L                            |
|                   | Treated Water    | Gross alpha activity (excluding radon) | Grab           | Monthly                                                | 12                                   | 0                                           | 0.50 Bq/L                            |
|                   | Treated Water    | Gross beta                             | Grab           | Monthly                                                | 12                                   | 0                                           | 1.00 Bq/L                            |
|                   | Treated Water    | Radon                                  | Grab           | Monthly                                                | 12                                   | 0                                           | 11.00 Bq/L                           |
| Solids Treatment  | Dewatered Sludge | % DS                                   | Grab           | Daily                                                  | 365                                  | 0                                           | Minimum 18%                          |
| Solids Treatment  | Dewatered Sludge | Volume                                 | Grab           | Daily                                                  | 365                                  | 0                                           | Refer to Performance guarantee       |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location      | Item/ Stream | Parameter                    | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|------------------------|--------------|------------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                        |              |                              |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
| Liquid Treatment Line  | Power        | Power/Electrical Consumption | Reading        | Daily                                                  | 365                                  | 0                                           | Refer to Performance Guarantee       |
| Solids Treatment Plant | Power        | Power/Electrical Consumption | Reading        | Daily                                                  | 365                                  | 0                                           | Refer to Performance Guarantee       |
| Liquid Treatment Line  | Chemical     | Chemical Consumption         | Reading        | Daily                                                  | 365                                  | 0                                           | Refer to Performance Guarantee       |
| Solids Treatment Plant | Chemical     | Chemical Consumption         | Reading        | Daily                                                  | 365                                  | 0                                           | Refer to Performance Guarantee       |
| Whole Plant            | Manning      | Man Hours                    | Monitoring     | Daily                                                  | 365                                  | 0                                           | Refer to Performance Guarantee       |



## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/ Stream        | Parameter                                 | Type of Sample | Sampling and Testing during the Process Proving Period |                                      |                                             |                                      |
|-------------------|---------------------|-------------------------------------------|----------------|--------------------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |                     |                                           |                | Frequency                                              | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
| Whole Plant       | Power               | Base Power (not influenced by flow)       | Reading        | Daily                                                  | 365                                  | 0                                           | Refer to Performance Guarantee       |
| Environmental     | Operation           | Occupational Noise Levels                 | Site Survey    | Weekly                                                 | 52                                   | 0                                           | Refer to Performance Guarantee       |
| Environmental     | Wastewater          | Refer to DAO 2021-19 parameter and limits | Grab           | Weekly                                                 | 52                                   | 0                                           | Subclause 11.5                       |
| Treatment Plant   | Process Reliability | Plant down time                           | Monitoring     | 24-hour duration                                       | Running hours/day                    | -                                           | 99.9%                                |
| Treatment Plant   | Electrical Controls | Plant down time                           | Monitoring     | 24-hour duration                                       | Running hours/day                    | -                                           | 99.9%                                |
| Treatment Plant   | PLC Reliability     | Plant down time                           | Monitoring     | 24-hour duration                                       | Running hours/day                    | -                                           | 99.9%                                |

21.1.6 The Contractor shall record all the online measurement and collect necessary samples, to document the operating conditions and to demonstrate compliance with all treated water quality and sludge requirements. All readings or monitoring results of consumptions (e.g. power, air flow, chemicals, etc.) shall be dutifully recorded in an agreed format available for inspection at all times. All these records shall be handed over to the Employer at the end of the PPP.

21.1.7 During PPP, the final treated water is intended to be supplied for distribution. During this period, the Contractor will have the obligation to maintain the availability and quality of water. The Contractor shall guarantee a minimum treated water output of 100MLD. Further, in the event of failed treated water quality during PPP, the Contractor shall pay any penalties imposed by MWSS for non-compliance to PNSDW. The calculation for the penalty is provided below:

- 1 Water availability – average water tariff x two cubic meters (2m<sup>3</sup>)/day for each affected connection x number of days; and
- 2 Water quality – fifty percent (50%) of average water tariff x volume of discharged by the affected water distribution center.

21.1.8 During the PPP, interruptions and its follow-up actions are defined as follows:

21.1.8.1 SEVERE: Interruptions that require shutdown of the process or subsystem or placement of any process or subsystem under continual monitoring and/or unintended manual control.

- 1 Process proving shall be discontinued immediately, urgent corrective action shall be carried out immediately.
- 2 Counting of “passed” days shall stop.
- 3 Counting of days shall only resume after rectification.

21.1.8.2 MODERATE: Interruptions that potentially could affect operation of the WTP but can be compensated by operational changes.

- 1 Process proving may continue.
- 2 Immediate corrective action shall be carried out.
- 3 If rectification cannot be completed within 7 days, the interruption shall be reclassified as SEVERE from the date of interruption occurrence.

21.1.8.3 MINOR: Defects that do not affect operation.

- 1 Process proving continues.
- 2 Immediate corrective action shall be carried out.
- 3 If rectification is not completed within 7 days, the interruption shall be reclassified as MODERATE from the date of interruption occurrence.

21.1.9 The Contractor shall daily provide the results of the previous day’s operation and testing; and shall report details of any failure to the Engineer. The report shall contain sufficient details to provide a comprehensive assessment of cause and recommendation to rectify. The Engineer may accept or reject the reported results and thereby assess and determine if the previous day is a “failed” day or “passed” day.

21.1.10 It shall be the Contractor's responsibility to obtain and report the results from internal and third-party laboratories within 7 days upon sampling. For online analysers, results shall be reported within 24 hours.

21.1.11 Any deficiencies or deviations from PNSDW as presented by the tests shall be corrected by the Contractor and tests shall be repeated as necessary until acceptable results are achieved.

21.1.12 Filter Media Loss

21.1.12.1 Once the filters have been in operation for a period of approximately one month, the top level of media in each filter shall be measured over the surface of the filter on a 1 meter grid and recorded by the Contractor. These measurements shall be made just after backwash in each filter.

21.1.12.2 The same measurement shall be made after 6 months and again after a full year of filter operation. Media loss from each filter shall be obtained as the product of any change in media level and the surface area of the media in each filter.

21.1.12.3 Unless the Contractor can demonstrate otherwise, the above figure which measures the loss shall be taken for the purposes of the Contract.

21.1.12.4 Media loss calculated in this way shall comply with the Contractor's guarantee for media loss and shall in any event be less than 0.25% by volume of the total media per quarter (excluding supporting gravel layers).

21.1.13 Safety During PPP

21.1.13.1 The Contractor shall provide full-time key personnels per shift as per Section 2.2, with adequate experience and qualifications to support the process proving of the WTP.

21.1.13.2 The Contractor's safety officer shall be present on site at all times and shall be responsible in ensuring observance of safety while working during the entire duration fo the PPP. This shall include weekly monitoring and reporting of hazards during operations.

21.1.13.3 In addition, pending action items identified during HAZOP and HAZCOM workshops shall be monitored quarterly and reported to the Engineer for close-out.

## **21.2 Guarantee Run**

- 21.2.1 In the 9th month of the PPP the Contractor may give 14-day notice to the Engineer of their intention to conduct the 28-day Guarantee Run. The Guarantee Run shall be conducted within the last 3 months (10th to 12th month) of the PPP.
- 21.2.2 The 28-day Guarantee Run is a contractual requirement to monitor the performance of the WTP against both the quality and functional guarantees as listed in the Schedule of Guarantees. The tests during the Guarantee Run shall apply to the WTP as a whole and shall demonstrate the reliability of operation, correct functionality, process and hydraulic performance of the WTP as designed and in accordance with the Contract. Compliance with the variable components of the operation and maintenance including specific chemicals and power consumption criteria shall also be assessed.
- 21.2.3 The parameters outlined in these Employer's Requirements and the Schedule of Guarantees shall be monitored and evaluated against the required values to ensure that it does not exceed the values given in the schedule of guarantees
- 21.2.4 If the daily average raw water values exceed the values in Section 11 of these Employer's Requirements, the power and chemical consumption shall be continued to be monitored, but the consumption levels for that particular day shall not be used when calculating the average consumption value for the remaining period of the 28-day tests and the tests shall be continued until it satisfies 28 days of proven performance.
- 21.2.5 If the Engineer considers that there has been a significant error in either the sampling technique or the method of determination for any sample or analytical result, then it shall be excluded from the results. In the event that sample failure arises from mal-operation or maintenance of the Plant in breach of the requirements of the operation and maintenance manuals, these failures will not be recorded
- 21.2.6 If the Plant fails to meet any of the performance requirements as indicated in the Performance Guarantees for plant reliability, functionality and hydraulic performance, final treated water quality or sludge solids concentration criteria, the Contractor shall undertake necessary remedial or improvements in the Plant. The Contractor shall be responsible for the payment of the penalties.
- 21.2.7 The 28-day period shall be repeated as soon as the Employer's Representative is satisfied that the defect has been rectified. Compliance with specific chemical and power consumption criteria shall be assessed following completion of 28-day guarantee run which successfully pass tests for plant reliability, functionality and hydraulic performance, final treated water quality and sludge solids concentration criteria.
- 21.2.8 If the Plant fails to meet the necessary specific chemical and power consumption criteria and the Contractor undertakes necessary remedial or improvements to rectify the problem, failed tests and tests on any related work shall be repeated after the Engineer is satisfied that the problem has been rectified. Unless otherwise agreed with the Engineer, the failed tests and tests on any related work will be repeated for a full 28 day period.

21.2.9 If, in the opinion of the Engineer, the requirement to repeat one or more 28-day test periods is due to failure of the Plant to meet plant reliability; functionality and hydraulic performance; final treated water quality or sludge solids concentration criteria, this would invalidate the assumption that the 2 number 28 day periods are representative of the operating conditions typically experienced in any 12 months period. The Engineer shall require the Contractor to repeat part or all of the tests.

21.2.10 The minimum testing and sampling criteria during the Guarantee Run are shown below:

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| Sampling Location | Item/Stream | Parameter        | Type of Sample    | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|-------------|------------------|-------------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |             |                  |                   | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
| Inlet             | Raw Water   | Flow             | Monitoring        | Instantaneous and Daily Average               | -                                    | N/A                                         | N/A                                  |
|                   | Raw Water   | Turbidity        | Monitoring + Grab | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Taste            | Grab              | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Odor             | Grab              | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Color (apparent) | Monitoring + Grab | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | pH               | Monitoring        | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Iron             | Monitoring + Grab | Daily                                         | 28                                   | N/A                                         | N/A                                  |

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| Sampling Location | Item/Stream | Parameter                 | Type of Sample    | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|-------------|---------------------------|-------------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |             |                           |                   | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water   | Aluminum                  | Monitoring + Grab | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Manganese                 | Monitoring + Grab | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Total Coliform            | Grab              | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Fecal Coliform            | Grab              | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Heterotrophic Plate Count | Grab              | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Ammonia                   | Monitoring        | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Antimony                  | Grab              | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Arsenic                   | Grab              | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Barium                    | Grab              | Daily                                         | 28                                   | N/A                                         | N/A                                  |

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| Sampling Location | Item/Stream | Parameter        | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|-------------|------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |             |                  |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water   | Boron            | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Cadmium          | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Chromium (Total) | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Cyanide (Total)  | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Fluoride         | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Lead             | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Mercury (Total)  | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Nickel           | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Nitrate          | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Nitrite          | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Selenium         | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |



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| Sampling Location | Item/Stream | Parameter                 | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|-------------|---------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |             |                           |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water   | Benzene                   | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Benzo(a)pyrene            | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Carbon Tetrachloride      | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | 1,2-Dichlorobenzene       | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | 1,4-Dichlorobenzene       | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | 1,2-Dichloroethane        | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | 1,2-Dichloroethene        | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Dichloromethane           | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Di(2-ethylhexyl)phthalate | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Ethylbenzene              | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |

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| Sampling Location | Item/Stream | Parameter                                      | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|-------------|------------------------------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |             |                                                |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water   | Styrene                                        | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Tetrachloroethene                              | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Toluene                                        | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Vinyl chloride                                 | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Xylenes (total)                                | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Aldrin and Dieldrin (combined)                 | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Atrazine and its chloro-s-triazine metabolites | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Carbofuran                                     | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Chlordane                                      | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | DDT                                            | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |

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| Sampling Location | Item/Stream | Parameter                              | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|-------------|----------------------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |             |                                        |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water   | 1,2-Dibromo-3-chloropropane (DBCP)     | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | 2,4-dichlorophenoxyacetic acid (2,4-D) | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Endrin                                 | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | 1,2-dibromoethane (Ethylenedibromide)  | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Glyphosate                             | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Lindane                                | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Pendimethalin                          | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Chloride                               | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Copper                                 | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |

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| Sampling Location | Item/Stream | Parameter                              | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|-------------|----------------------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |             |                                        |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Raw Water   | Hardness, total                        | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Hydrogen Sulfide                       | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Sodium                                 | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Sulfate                                | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Total Dissolved Solids, TDS            | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Zinc                                   | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Gross alpha activity (excluding radon) | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Gross beta                             | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |
|                   | Raw Water   | Radon                                  | Grab           | Daily                                         | 28                                   | N/A                                         | N/A                                  |

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| Sampling Location        | Item/Stream   | Parameter        | Type of Sample    | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|--------------------------|---------------|------------------|-------------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                          |               |                  |                   | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
| Filtered Water Discharge | Treated Water | Flow             | Monitoring        | Daily                                         | 28                                   | 0                                           | Refer to Performance guarantee       |
|                          | Treated Water | Arsenic          | Grab              | Daily                                         | 28                                   | 0                                           | 0.01 mg/L                            |
|                          | Treated Water | Cadmium          | Grab              | Daily                                         | 28                                   | 0                                           | 0.003 mg/L                           |
|                          | Treated Water | Lead             | Grab              | Daily                                         | 28                                   | 0                                           | 0.01 mg/L                            |
|                          | Treated Water | Nitrate          | Grab              | Daily                                         | 28                                   | 0                                           | 50.00 mg/L                           |
|                          | Treated Water | Turbidity        | Monitoring + Grab | Daily                                         | 28                                   | 0                                           | <2.50 NTU                            |
|                          | Treated Water | Color (apparent) | Grab              | Daily                                         | 28                                   | 0                                           | <5.00 CU                             |

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| Sampling Location | Item/Stream   | Parameter              | Type of Sample    | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------|------------------------|-------------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                        |                   | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | pH                     | Monitoring + Grab | Daily                                         | 28                                   | 0                                           | 6.80 - 8.00                          |
|                   | Treated Water | Odor                   | Grab              | Daily                                         | 28                                   | 0                                           | No objectionable odor                |
|                   | Treated Water | Taste                  | Grab              | Daily                                         | 28                                   | 0                                           | No objectionable taste               |
|                   | Treated Water | Iron                   | Monitoring + Grab | Daily                                         | 28                                   | 0                                           | <0.40 mg/L                           |
|                   | Treated Water | Aluminum               | Monitoring + Grab | Daily                                         | 28                                   | 0                                           | <0.12 mg/L                           |
|                   | Treated Water | Total Dissolved Solids | Grab              | Daily                                         | 28                                   | 0                                           | <400.00 mg/L                         |
|                   | Treated Water | Manganese              | Monitoring + Grab | Daily                                         | 28                                   | 0                                           | <0.021 mg/L                          |

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| Sampling Location | Item/Stream   | Parameter                 | Type of Sample    | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------|---------------------------|-------------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                           |                   | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Total Coliform            | Grab              | Daily                                         | 28                                   | 0                                           | Absent or <1.00 MPN/100ml            |
|                   | Treated Water | Fecal Coliform            | Grab              | Daily                                         | 28                                   | 0                                           | Absent or <1.00 MPN/100ml            |
|                   | Treated Water | Heterotrophic Plate Count | Grab              | Daily                                         | 28                                   | 0                                           | ≤10.00 CFU/mL                        |
|                   | Treated Water | Ammonia                   | Grab              | Daily                                         | 28                                   | 0                                           | <0.20 mg/L                           |
|                   | Treated Water | Residual Chlorine         | Monitoring + Grab | Daily                                         | 28                                   | 0                                           | 0.90 - 1.5 mg/L                      |
|                   | Treated Water | Antimony                  | Grab              | Daily                                         | 28                                   | 0                                           | 0.02 mg/L                            |
|                   | Treated Water | Barium                    | Grab              | Daily                                         | 28                                   | 0                                           | 0.70 mg/L                            |

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| Sampling Location | Item/Stream   | Parameter        | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------|------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                  |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Boron            | Grab           | Daily                                         | 28                                   | 0                                           | 2.00 mg/L                            |
|                   | Treated Water | Chromium (Total) | Grab           | Daily                                         | 28                                   | 0                                           | 0.05 mg/L                            |
|                   | Treated Water | Cyanide (Total)  | Grab           | Daily                                         | 28                                   | 0                                           | 0.50 mg/L                            |
|                   | Treated Water | Fluoride         | Grab           | Daily                                         | 28                                   | 0                                           | 1.50 mg/L                            |
|                   | Treated Water | Mercury (Total)  | Grab           | Daily                                         | 28                                   | 0                                           | 0.001 mg/L                           |
|                   | Treated Water | Nickel           | Grab           | Daily                                         | 28                                   | 0                                           | 0.07 mg/L                            |
|                   | Treated Water | Nitrite          | Grab           | Daily                                         | 28                                   | 0                                           | 3.00 mg/L                            |



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| Sampling Location | Item/Stream   | Parameter            | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------|----------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                      |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Selenium             | Grab           | Daily                                         | 28                                   | 0                                           | 0.04 mg/L                            |
|                   | Treated Water | Benzene              | Grab           | Daily                                         | 28                                   | 0                                           | 0.01 mg/L                            |
|                   | Treated Water | Benzo(a)pyrene       | Grab           | Daily                                         | 28                                   | 0                                           | 0.0007 mg/L                          |
|                   | Treated Water | Carbon Tetrachloride | Grab           | Daily                                         | 28                                   | 0                                           | 0.004 mg/L                           |
|                   | Treated Water | 1,2-Dichlorobenzene  | Grab           | Daily                                         | 28                                   | 0                                           | 1.00 mg/L                            |
|                   | Treated Water | 1,4-Dichlorobenzene  | Grab           | Daily                                         | 28                                   | 0                                           | 0.30 mg/L                            |
|                   | Treated Water | 1,2-Dichloroethane   | Grab           | Daily                                         | 28                                   | 0                                           | 0.03 mg/L                            |

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| Sampling Location | Item/Stream   | Parameter                   | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------|-----------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                             |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | 1,2-Dichloroethene          | Grab           | Daily                                         | 28                                   | 0                                           | 0.05 mg/L                            |
|                   | Treated Water | Dichloromethane             | Grab           | Daily                                         | 28                                   | 0                                           | 0.02 mg/L                            |
|                   | Treated Water | Di(2-ethylhexylyl)phthalate | Grab           | Daily                                         | 28                                   | 0                                           | 0.008 mg/L                           |
|                   | Treated Water | Ethylbenzene                | Grab           | Daily                                         | 28                                   | 0                                           | 0.30 mg/L                            |
|                   | Treated Water | Styrene                     | Grab           | Daily                                         | 28                                   | 0                                           | 0.02 mg/L                            |
|                   | Treated Water | Tetrachloroethene           | Grab           | Daily                                         | 28                                   | 0                                           | 0.04 mg/L                            |
|                   | Treated Water | Toluene                     | Grab           | Daily                                         | 28                                   | 0                                           | 0.70 mg/L                            |

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| Sampling Location | Item/Stream   | Parameter                                      | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------|------------------------------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                                                |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Vinyl chloride                                 | Grab           | Daily                                         | 28                                   | 0                                           | 0.0003 mg/L                          |
|                   | Treated Water | Xylenes (total)                                | Grab           | Daily                                         | 28                                   | 0                                           | 0.50 mg/L                            |
|                   | Treated Water | Aldrin and Dieldrin (combined)                 | Grab           | Daily                                         | 28                                   | 0                                           | 0.00003 mg/L                         |
|                   | Treated Water | Atrazine and its chloro-s-triazine metabolites | Grab           | Daily                                         | 28                                   | 0                                           | 0.10 mg/L                            |
|                   | Treated Water | Carbofuran                                     | Grab           | Daily                                         | 28                                   | 0                                           | 0.007 mg/L                           |
|                   | Treated Water | Chlordane                                      | Grab           | Daily                                         | 28                                   | 0                                           | 0.0002 mg/L                          |
|                   | Treated Water | DDT                                            | Grab           | Daily                                         | 28                                   | 0                                           | 0.001 mg/L                           |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/Stream   | Parameter                              | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------|----------------------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                                        |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | 1,2-Dibromo-3-chloropropane (DBCP)     | Grab           | Daily                                         | 28                                   | 0                                           | 0.001 mg/L                           |
|                   | Treated Water | 2,4-dichlorophenoxyacetic acid (2,4-D) | Grab           | Daily                                         | 28                                   | 0                                           | 30.00 mg/L                           |
|                   | Treated Water | Endrin                                 | Grab           | Daily                                         | 28                                   | 0                                           | 0.0006 mg/L                          |
|                   | Treated Water | 1,2-dibromoethane (Ethylenedibromide)  | Grab           | Daily                                         | 28                                   | 0                                           | 0.0004 mg/L                          |
|                   | Treated Water | Glyphosate                             | Grab           | Daily                                         | 28                                   | 0                                           | 1.00 mg/L                            |
|                   | Treated Water | Lindane                                | Grab           | Daily                                         | 28                                   | 0                                           | 0.002 mg/L                           |
|                   | Treated Water | Pendimethalin                          | Grab           | Daily                                         | 28                                   | 0                                           | 0.02 mg/L                            |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/Stream   | Parameter        | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------|------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                  |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Chloride         | Grab           | Daily                                         | 28                                   | 0                                           | <200.00 mg/L                         |
|                   | Treated Water | Copper           | Grab           | Daily                                         | 28                                   | 0                                           | 1.00 mg/L                            |
|                   | Treated Water | Hardness, total  | Grab           | Daily                                         | 28                                   | 0                                           | <250.00 mg/L                         |
|                   | Treated Water | Hydrogen Sulfide | Grab           | Daily                                         | 28                                   | 0                                           | 0.05 mg/L                            |
|                   | Treated Water | Sodium           | Grab           | Daily                                         | 28                                   | 0                                           | 200.00 mg/L                          |
|                   | Treated Water | Sulfate          | Grab           | Daily                                         | 28                                   | 0                                           | 200.00 mg/L                          |
|                   | Treated Water | Zinc             | Grab           | Daily                                         | 28                                   | 0                                           | 5.00 mg/L                            |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/Stream   | Parameter           | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------|---------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                     |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Acrylamide          | Grab           | Daily                                         | 28                                   | 0                                           | 0.0005 mg/L                          |
|                   | Treated Water | Epichlorohydrin     | Grab           | Daily                                         | 28                                   | 0                                           | 0.0004 mg/L                          |
|                   | Treated Water | Bromate             | Grab           | Daily                                         | 28                                   | 0                                           | 0.01 mg/L                            |
|                   | Treated Water | Chlorite            | Grab           | Daily                                         | 28                                   | 0                                           | 0.70 mg/L                            |
|                   | Treated Water | Chlorate            | Grab           | Daily                                         | 28                                   | 0                                           | 0.70 mg/L                            |
|                   | Treated Water | Dibromoacetonitrile | Grab           | Daily                                         | 28                                   | 0                                           | 0.07 mg/L                            |
|                   | Treated Water | Dichloroacetate     | Grab           | Daily                                         | 28                                   | 0                                           | 0.05 mg/L                            |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/Stream   | Parameter                   | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------|-----------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |               |                             |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water | Dichloroacetonitrile        | Grab           | Daily                                         | 28                                   | 0                                           | 0.02 mg/L                            |
|                   | Treated Water | Monochloroacetate           | Grab           | Daily                                         | 28                                   | 0                                           | 0.02 mg/L                            |
|                   | Treated Water | Trichloroacetate            | Grab           | Daily                                         | 28                                   | 0                                           | 0.20 mg/L                            |
|                   | Treated Water | 2,4,6-trichlorophenol       | Grab           | Daily                                         | 28                                   | 0                                           | 0.20 mg/L                            |
|                   | Treated Water | Bromoform                   | Grab           | Daily                                         | 28                                   | 0                                           | 0.10 mg/L                            |
|                   | Treated Water | Bromodichloromethane (BDCM) | Grab           | Daily                                         | 28                                   | 0                                           | 0.06 mg/L                            |
|                   | Treated Water | Chloroform                  | Grab           | Daily                                         | 28                                   | 0                                           | 0.30 mg/L                            |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/Stream      | Parameter                              | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|------------------|----------------------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |                  |                                        |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
|                   | Treated Water    | Dibromochloromethane (DBCM)            | Grab           | Daily                                         | 28                                   | 0                                           | 0.10 mg/L                            |
|                   | Treated Water    | Total trihalomethanes                  | Grab           | Daily                                         | 28                                   | 0                                           | 1.00 mg/L                            |
|                   | Treated Water    | Gross alpha activity (excluding radon) | Grab           | Daily                                         | 28                                   | 0                                           | 0.50 Bq/L                            |
|                   | Treated Water    | Gross beta                             | Grab           | Daily                                         | 28                                   | 0                                           | 1.00 Bq/L                            |
|                   | Treated Water    | Radon                                  | Grab           | Daily                                         | 28                                   | 0                                           | 11.00 Bq/L                           |
| Solids Treatment  | Dewatered Sludge | % DS                                   | Grab           | Daily                                         | 28                                   | 0                                           | Minimum 18%                          |
| Solids Treatment  | Dewatered Sludge | Volume                                 | Grab           | Daily                                         | 28                                   | 0                                           | Refer to Performance guarantee       |



## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location      | Item/Stream | Parameter                    | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|------------------------|-------------|------------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                        |             |                              |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
| Liquid Treatment Line  | Power       | Power/Electrical Consumption | Reading        | Daily                                         | 28                                   | 0                                           | Refer to Performance Guarantee       |
| Solids Treatment Plant | Power       | Power/Electrical Consumption | Reading        | Daily                                         | 28                                   | 0                                           | Refer to Performance Guarantee       |
| Liquid Treatment Line  | Chemical    | Chemical Consumption         | Reading        | Daily                                         | 28                                   | 0                                           | Refer to Performance Guarantee       |
| Solids Treatment Plant | Chemical    | Chemical Consumption         | Reading        | Daily                                         | 28                                   | 0                                           | Refer to Performance Guarantee       |
| Whole Plant            | Manning     | Man Hours                    | Monitoring     | Daily                                         | 28                                   | 0                                           | Refer to Performance Guarantee       |

## Section 5 – Employer's Requirements – Kaliwa RWTL and WTP

| Sampling Location | Item/Stream         | Parameter                                  | Type of Sample | Sampling and Testing during the Guarantee Run |                                      |                                             |                                      |
|-------------------|---------------------|--------------------------------------------|----------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|--------------------------------------|
|                   |                     |                                            |                | Frequency                                     | No. of Samples or Calculations Taken | No. of Samples Allowed to fail <sup>1</sup> | Required Values/ Acceptance Criteria |
| Whole Plant       | Power               | Base Power (not influenced by flow)        | Reading        | Daily                                         | 28                                   | 0                                           | Refer to Performance Guarantee       |
| Environmental     | Operation           | Occupational Noise Levels                  | Site Survey    | Weekly                                        | 4                                    | 0                                           | Refer to Performance Guarantee       |
| Environmental     | Wastewater          | Refer to DAO 2021-19 parameters and limits | Grab           | Weekly                                        | 4                                    | 0                                           | Subclause 11.5                       |
| Treatment Plant   | Process Reliability | Plant down time                            | Monitoring     | 24-hour duration                              | Running hours/day                    | -                                           | 99.9%                                |
| Treatment Plant   | Electrical Controls | Plant down time                            | Monitoring     | 24-hour duration                              | Running hours/day                    | -                                           | 99.9%                                |
| Treatment Plant   | PLC Reliability     | Plant down time                            | Monitoring     | 24-hour duration                              | Running hours/day                    | -                                           | 99.9%                                |

- 21.2.11 The Contractor shall submit a summary of the test results available at the end of each 7-day period to the Engineer, and notify the Engineer within seven (7) days of the date of sampling of any failed tests.
- 21.2.12 In case of failure the Contractor shall rectify any defects and may request for a repeated Guarantee Run until 28 days of fault free operation is demonstrated.
- 21.2.13 Within fourteen (14) days after the successful completion of the 28-day Guarantee Run the Contractor shall submit a Guarantee Run Report. The report will summarize the methodology; calculations and results of all the tests carried out during the period, consumption of all guaranteed consumables during the stage and will include a schedule of identified failures.
- 21.2.14 Upon successful completion of the PPP, the Taking Over Certificate shall be issued to the Contractor. This milestone marks the date of completion and the start of the Defects Notification Period.
- 21.2.15 The Contractor shall rectify any defects during the 1-year Defects Notification Period and shall provide a root-cause analysis report for every incident of breakdown. If the defective equipment or component cannot be repaired within a week from the day of breakdown, it shall be the Contractor's responsibility to provide a service unit so as not to disrupt plant operations until the repaired unit is successfully put back online.

## 22 Training

### 22.1 Training Sessions

22.1.1 The Contractor shall prepare a detailed plan for the necessary training during the performance of the Works; and submit to the Engineer for obtaining the Notice of No Objection. The detailed training plan shall be submitted by the Contractor to the Engineer within twenty-eight (28) days prior to the start date of the proposed training period. The accepted training plan must be in place at least one (1) week before any training sessions.

22.1.2 The Contractor's training shall enable their personnel & sub-Contractors and the Employer's staff to operate the Raw Water Transmission Line and Water Treatment Plant safely and efficiently.

22.1.3 The Contractor's training plan shall include as a minimum the following:

- 1 Details of the training for operation, maintenance,
- 2 Details of the training for troubleshooting for process and equipment
- 3 Curriculum
- 4 Qualified resource person and schedule to be approved by Employer prior commissioning. The Contractor should provide the qualifications of the trainers and demonstrate their experience and capacity to provide formal training as required.

22.1.4 The Contractor shall arrange all of the Employer's staff to be trained a general overview of the transmission line and plant together with instruction on fault diagnosis, alarms and control system interrogation, breakdown maintenance and routine maintenance. The training shall enable a detailed understanding to be gained of how the process operates and the engineering involved.

### 22.2 Training Requirements:

22.2.1 The training requirements are identified in the table below:

| Programme Date                                                                   | Training Type                                                                                                                                                                              | Duration                     |
|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| During Tests on Completion (Pre-commissioning and process commissioning stages): | Initial training on the process and Hands-on training of the Employer's Operation and Maintenance Personnel (including safety reminder related to operations and maintenance of equipment) | 10 days of hands-on training |
|                                                                                  | A formal training session for onsite operations staff and process managers on general operation of the RWTL and WTP;                                                                       | 2 days                       |

| Programme Date                                        | Training Type                                                                                        | Duration |
|-------------------------------------------------------|------------------------------------------------------------------------------------------------------|----------|
| During Tests on Completion<br>(Process Proving Stage) | Structured training, including the hands-on training of Employer’s Operation & Maintenance Personnel | 4 weeks  |
|                                                       | Shadowing/mentoring of Employer’s Operations & Maintenance Personnel                                 | 8 weeks  |

22.2.2 The structured training should cover following areas and aspects of the operation and maintenance of the plant:

22.2.2.1 Inlet works (RWTL);

22.2.2.2 Treatment process;

22.2.2.3 Chemical Dosing Process;

22.2.2.4 Sludge treatment process;

22.2.2.5 SCADA operation, Instrumentation and control;

22.2.2.6 Plant Operation and Equipment Maintenance;

22.2.2.7 Process Trouble shooting;

22.2.2.8 Laboratory operation and water sampling and analysis;

22.2.2.9 Fixed and Portable Lifting Facilities.

22.2.3 Training for each element shall take at least 2 days. If deem necessary by the Employer, the training of each element can take more than two (2) days and shall be informed to the Contractor at least seven (7) days prior to the start date. Training on the equipment shall be carried out by the equipment suppliers.

22.2.3.1 A roll-out of the Hazard Identification, Risk Assessment and Control for transmission line and plant operation and maintenance, chemical safety and spill response procedure and emergency planning and preparedness response procedure must be conducted.

22.2.3.2 Training dates shall be identified in the program. The Contractor shall provide a choice of two (2) suitable dates for the initial training sessions.

22.2.3.3 The follow-up monitoring period is intended to consolidate the initial training. This secondary period shall consist of eight (8) weeks of close supervision by the Contractor of the Employer’s operations staff. It shall be undertaken during the latter stages of the Process Proving Period. This monitoring shall be carried out by one of the staff members who implemented the earlier training sessions.

## **22.3 Training Methods**

- 22.3.1 The training shall be based on details defined in the Contractor's Training Plan.
- 22.3.2 The method of training delivery shall be structured to include theory, group discussion and part practical elements supported by visual aids, demonstrations and appropriate assessments.
- 22.3.3 The Contractor shall ensure the participation of the manufacturer representatives during the Process Proving. The representatives shall conduct training on how to troubleshoot, maintain and replace critical spare parts.
- 22.3.4 The training shall be appropriate to the discipline of the delegate and the RWTL and WTP and equipment being demonstrated, with different levels of personnel being trained. As a minimum, management, supervisory, process, operations and maintenance personnel shall be trained.
- 22.3.5 The training shall be monitored continuously and each delegate shall be required to demonstrate their competence. In order to achieve an acceptable standard of competence, a two-step assessment program shall be provided:
  - 22.3.5.1 Group tasks in which delegates shall be given a task that will require them to use the knowledge learned during the session, to feed back and demonstrate understanding.
  - 22.3.5.2 Training task book, which will require individual assessment (verbal and practical). Each section must be signed off by the Contractor confirming that the delegate is competent in the areas of training covered. Each section of the task book will relate to a session undertaken during the training.
- 22.3.6 A comprehensive overall Training Manual shall be produced by the Contractor, covering all of the related training matters discussed during the training sessions. The Training Manual shall be submitted by the Contractor for formal review and acceptance of the Engineer and Employer. The accepted training manual must be in place at least one (1) week prior the start of any training session. The Contractor should provide the qualifications of the trainers and demonstrate their experience and capacity to provide formal training as required.