Scope of Work

1. The Contractor must supply a proposal for the testing of the various wastewater as described below, with the dynamic filtration membrane processing technology. This technology must be versatile, and shall be able to be used with MF, NF and RO membranes. The Contractor must provide proof consisting of at least five case studies where this technology has been tested and installed in industrial applications in the world and has shown very successful results.
2. The testing will take place in two phases, first being laboratory testing to determine the optimal membrane to use and secondly pilot testing with a skid installed at the various sites.
3. The Contractor must provide a cost for the laboratory testing which will include the transportation of the water samples to the contractors location. A report must be produced detailing the tests experimental procedure/methodology, results and conclusions.
4. For the pilot scale tests, the candidate membrane of choice from the lab scale tests will be configured in an element stack of approximately 15-25 membranes.
5. However, the equipment must be mounted on a trailer, with all the cleaning equipment incorporated as well. The cleaning equipment must include the heaters for the CIP tank. The system must also be automated with loggers installed to log all the physical parameters (flow, pressure and temperature).
6. The contractor must also include resources for maintenance and operation. Chemicals required for the duration of the trial must also be provided by the contractor. The contractor must also supply all the spares required for the maintenance of the system, as well as the spares to address any defects on the system.
7. The Pilot test skid must be completely independent and must not require any utilities from the Employer, e.g. electrical supply, or compressed air supply. All equipment required to run the pilot test skid must be supplied by the contractor (compressor, generator, etc.). The equipment will be situated in a very isolated area, and hence the equipment must be lockable to keep it safe from harm or theft. The contractor must make allowance for this.
8. The water required to run the skid will be supplied from a nearby source, preferably within 500m, from a sump. The contractor must supply the pump, piping, valves and any other equipment required to supply the skid with the water, as well as to discharge the clean water back into the Eskom plant.
9. Membrane cleaning concepts that would be applicable to actual plant criteria must also evaluated.
10. In these tests, the following, as a minimum, will be tested and optimised:
    - Determine the optimum operating pressure
    - Pre-treatment optimisation
    - Determine flux rates and achievable concentration with a range of operating conditions;
    - Determine the maximum recovery
    - Determine the cleaning requirements and regime;
    - Determine required membrane area; and
    - Determine the degree of deterioration of membrane performance over time
11. The contractor must also provide a cost for the autopsy of the membrane if it is deemed necessary.

12. The contractor must also provide a cost for the laboratory testing of the daily samples.
13. A report must be produced detailing the tests experimental procedure/methodology, results and conclusions. The report must also contain information with regards to the sizing of the plant for each source water, the associated capital cost as well as operating and maintenance cost for the life cycle of the plant.

1 Description of the *service*

1.1 Executive overview

According to Eskom's Zero Liquid Effluent Discharge (ZLED) philosophy, no effluent is allowed to leave the sites. Impacted water is therefore utilised in an ever-cascading quality level until it reaches the ashing system where it is used for the slurrying and transportation of the ash and/or for dust suppression on the ash dump.

The Contractor must supply a proposal for the testing of the various wastewaters with dynamic filtration membrane processing technology. The testing will take place in two phases, first being laboratory testing to determine the optimal membrane to use and secondly pilot testing with a skid installed at the various sites.

1. Five streams will be considered for evaluation:
2. Wastewater which contains high levels of ash and oil (Tutuka Power Station)
3. Reverse Osmosis plant reject (Tutuka Power Station)
4. CCW for a sensitivity analysis) (Tutuka Power Station)
5. Ash water return (Duvha Power Station)
6. Flue Gas desulphurisation (FGD) bleedstream (Kusile Power Station)

1.2 *Employer*'s requirements for the *service*.

1.2.1 Technology to be tested

Research has developed new technologies, which have not been proven on Eskom waters. These systems are classified as dynamic filtration, which generates high shear rates more efficiently than cross-flow filtration. In dynamic filtration, shear rates are generated not by a pump, but by moving parts or vibrations. These movements create the membrane shear rate necessary to maintain the filtration by vibrating the membranes. This mode of operation allows high shear rates, of the order of $1–3\times10^5$ s^{-1} to be generated and increases both permeate flux and membrane selectivity. Vibrating modules (i.e., Shear-Enhanced Vibrating Membrane processing technology) consist of a stack of circular membranes oscillating around a vertical shaft at its resonant frequency.

The *Contractor* must supply a proposal for the testing of the various wastewater as described above, with the dynamic filtration membrane processing technology. This technology must be versatile, and shall be able to be used with MF, NF and RO membranes. The industrial membrane area per module must be more than 120m^2. The *Contractor* must provide proof consisting of at least three case studies, with water similar to the described streams, where this technology has been tested and installed in industrial applications in the world and has shown very successful results.

In a typical system, membranes are arranged in a plate and frame configuration. Different types of membranes (Microfiltration, Ultrafiltration, Nanofiltration, Reverse Osmosis) can be used in a module to achieve the required product quality. The system requires a pilot test protocol to obtain a right membrane material in combination with vibration to provide a stable flux.

The system must achieve high-energy efficiency by applying shear into a thin zone near the filter surface. This precise application of shear results in efficient energy conversion and very low power consumption. In these systems, nearly 99% of the total energy utilized is converted to shear at the

membrane surface. The disk stack of the unit is oscillated above a torsion spring that moves the stack back and forth. The oscillation produces a shear at the membrane surface of approximately 150,000 inverse seconds, which is much higher than conventional cross-flow systems. The shear waves produced by the membrane's vibration cause solids and foulants to be lifted off the membrane surface and remixed with the bulk material flowing through the membrane stack. The system proposed must be simple and compact. The system must not depend on feed flow to induce shearing forces, the feed slurry can become extremely viscous and still be successfully dewatered. The concentrate is essentially extruded between the vibrating disc elements and exits the machine once it reaches the desired concentration level. Thus, the system must be able to run in a single pass through the system, eliminating the need for costly working tanks, ancillary equipment and associated valving.

Membrane selection is the single most important parameter that affects the quality of the separation. Other important parameters that affect system performance are pressure, temperature, vibration amplitude, and residence time. All of these elements are optimized during testing.

The testing will take place in two phases, first being laboratory testing to determine the optimal membrane to use and secondly pilot testing with a skid installed at the various sites.

The *Contractor* must sign a Non-Disclosure Agreement with Eskom. All results emanating from the trial/test form a part of Eskom's Intellectual Property (IP) and cannot be shared or published without Eskom's permission."

1.2.2 Aim of the testing

The aim of the pilot testing is to determine if the system being tested, will be able to treat the various identified streams efficiently and effectively.
The primary aims of the treatment plant are as follows:
a) It must be cost effective;
b) It must be able to recover an economically feasible maximum amount of treated water suitable for reuse;
c) It must minimise treatment process complexity and footprint; and
d) it must minimise waste handling issues.

1.2.3 Parameters to be tested

The following key parameters will be tested and the acceptance criteria for the pilot tests must be as follows:

1. The permeate produced must be of raw water quality or better (for the specific station as detailed below).
2. A maximum recovery which can be achieved must be compared to the life cycle costs of the system (membrane replacement, energy, chemicals) for the most economical solution.
3. The cleaning frequency will be evaluated and used to determine life cycle costs.
4. Determine the degree of deterioration of membrane performance over time will be evaluated and used to determine life cycle costs.

1.2.4 Laboratory scale tests

The *contractor* will be responsible to firstly do laboratory tests at the *contractors* premises. If possible, Eskom will witness the tests. The costs for the transport of the samples as well as the testing and development of the report to be included. This must be done to optimise the following:

- operating pressure,
- the type of membrane to use,
- the shear rate,
- operating temperature
- pH conditions
- flux

The equipment for the laboratory scale tests must be supplied by the *Contractor*. The testing equipment typically consists of a

- feed tank,
- permeate tank,
- concentrate tank
- manual ball valves for isolation
- feed pump
- The membrane assembly with a:
    - driving system that generates vibration,
    - membrane module,
    - torsion spring which transfers vibration to the membrane module, and
    - system for controlling vibration.

This is a typical description, but the responsibility still lies with the *contractor* to decide on the equipment required for the laboratory testing.

The *Contractor* shall use a single membrane for each test. Various membranes are tested with each waste water source to determine which membrane will be optimal. Operating pressure must be varied during the test depending on the type of membrane used, and the shear rate must also be varied.
The apparatus must be able to vibrate the membrane with a frequency of up to 60Hz and a maximum vibratory amplitude of 25.4mm (1"). The vibratory amplitude at the rim of the membrane module must be varied to evaluate the effect of vibration. All the parameters which are changed (independent variables), as well as the dependent variables (those that will change) will be tested frequently (every 5-10 minutes).
During the test, operational and performance data shall be collected by the *contractor*. An example of the variables are as follows. But the responsibility will belong to the contractor to decide on the procedure for testing.

Variables

Independent variables
- Type of membrane used
- Feed concentration

Dependent variables
- Change in flux
- Concentration of the reject stream
- Concentration of the permeate
- Removal percentage

Controlling Variables
- The feedwater pressure

The procedure which will be required for testing must be supplied to the *Employer* for acceptance. The *Contractor* must provide a cost for the laboratory testing which shall include the transportation of the water samples to the *contractors* location. A report must be produced detailing the tests experimental procedure/methodology, results and conclusions.

1.2.5 Pilot scale tests

For the pilot scale tests, the candidate membrane of choice from the lab scale tests will be configured in an element stack of approximately 15-25 membranes. However, the equipment must be mounted on a trailer, with all the cleaning equipment incorporated as well. The cleaning equipment must include the heaters for the CIP tank. The system must also be automated with loggers installed to log all the physical parameters (flow, pressure and temperature). The *Contractor* must also include resources for maintenance and operation. Chemicals required for the duration of the trial must also be provided by the *Contractor*. The *Contractor* must also supply all the spares required for the maintenance of the system, as well as the spares to address any defects on the system. These spares must be readily available within 24hrs.

The Pilot test skid must be completely independent and must not require any utilities from the *Employer*, e.g. electrical supply, or compressed air supply. All equipment required to run the pilot test skid must be supplied by the *contractor* (compressor, generator, etc.). The equipment will be situated in a very

isolated area, and hence the equipment must be lockable to keep it safe from harm or theft. A new membrane needs to be installed at the start of testing for each new stream as a minimum. If replacement membranes are required during the testing, the *contractor* must make allowance for this as well.

The *Contractor* will provide a cost for the disconnection, transport and reconnection of the pilot plant as it is moved from station to station.

The water required to run the skid will be available from a nearby source, preferably within 500m. The *Contractor* must supply the pump, piping, valves and any other equipment required to supply the skid with the water, as well as to discharge the clean water back into the Eskom plant.

The testing methodology which will be required for testing must be supplied to the *Employer* for acceptance. The methodology should describe if it is required to do the test either during normal working hours or on a 24 hour, 7 days a week operation. This methodology must prove that the plant will simulate operational conditions and that the interruption in operation will not alter the results. The contractor must allow for at least one month of 24 hour operation and the rest of the testing time can be on an 8 hr day – Monday to Friday. However, if the contractor requires testing to be 24 hours a day-7 days a week, then operational costing must be allowed for this.

Membrane cleaning concepts that would be applicable to actual plant criteria must also evaluated. The *contractor* must evaluate the efficacy of using standard commercially available cleaning chemicals versus proprietary chemicals.

In these tests, the following, as a minimum, will be tested and optimised:

- Determine the optimum operating pressure.
- Pre-treatment optimisation.
- Determine flux rates and achievable concentration with a range of operating conditions.
- Determine the maximum recovery.
- Determine the cleaning requirements and regime as well as optimisation of the cleaning protocols and chemicals.
- Determine required membrane area; and
- Determine the degree of deterioration of membrane performance over time.

The *Contractor* must also provide a cost for the autopsy of the membrane.

A report must be produced detailing the tests experimental procedure/methodology, results and conclusions. Monthly reports must be provided as the tests are ongoing. After the completion of the tests on each source water, a draft report must be submitted for that specific source water. The report must also contain information with regards to the sizing of the plant for each source water, the associated capital cost as well as operating and maintenance cost for the life cycle of the plant. At the end of all the tests, a final report must be submitted no later than a month after the conclusion of the final tests. This document must consolidate all the information for the lab scale tests, pilot scale tests as well as results of the autopsy.

1.2.6 Various Feedwaters which will be tested

a. Wastewater which contains high levels of ash and oil

The dirty water dams receive the wastewater from the station. This includes all drains from the water and steam circuit, drains from the CW pipework in the units, floor-washing effluent, etc. These drains are contaminated with ash when the stations are forced to implement emergency floor ashing to clear the boiler throat prior to shutting down the unit to repair the defect. The ash is washed into the station drains and ends up in these dirty water dams. In addition to this, the water is contaminated with oil from leaks which exist on the plant. This is also washed into the station drains. The design of the system is such that this water must be treated by an oil and grit system. However, this system is only designed for certain levels of oil and grit and is usually overloaded, and hence it is not effective. As part of the ZLED philosophy, the water from this system must be returned to the cooling water system for further treatment. This excess ash then impacts the cooling water treatment system and causes frequent failures on the clarifiers bridges and stirrers.

A solution is required for this dirty water dam water which will remove all the ash and oil from the water and produce water which is of a raw water quality or better. This analysis is the dissolved species. The intention is to test the capability of the technology with regards to the removal of ash and oil. At the time of testing, the Employer will add these components to the water supply if the levels.

The typical analysis of raw water quality is as per Table 1 and Figures 1-15 below: Table 1: Raw Vaal water supplied to Tutuka Power Station

Parameter	Unit	Minimum	Maximum	Average	95th percentile
Conductivity	µS/cm	3.2	433.0	257.6	368.0
pH		4.3	9.9	7.5	8.9
m-alkalinity as $CaCO_3$	mg/kg	15.0	181.5	78.1	111.6
p-alkalinity as $CaCO_3$	mg/kg	0.0	19.1	0.4	0
Ca Hardness as $CaCO_3$	mg/kg	7.7	78.4	29.4	57.3
Mg Hardness as $CaCO_3$	mg/kg	3.8	129	43	103
Chloride	mg/kg	0.4	48	14.7	23
Potassium	mg/kg	1.7	11.8	4.1	10.0
Phosphate	mg/kg	0.0	2.0	0.7	2.0
Silicate	mg/kg	0.0	51.7	18.6	41.8
Sulphate	mg/kg	0.2	46.1	24.3	42.2
Sodium	mg/kg	5.4	32.2	16.2	29.5
Total organic carbon as C	mg/kg	0.2	68.9	18.8	38.9
Total hardness as $CaCO_3$	mg/kg	4.6	170.0	55.1	123.8
Turbidity	NTU	0	155	30.1	58.3

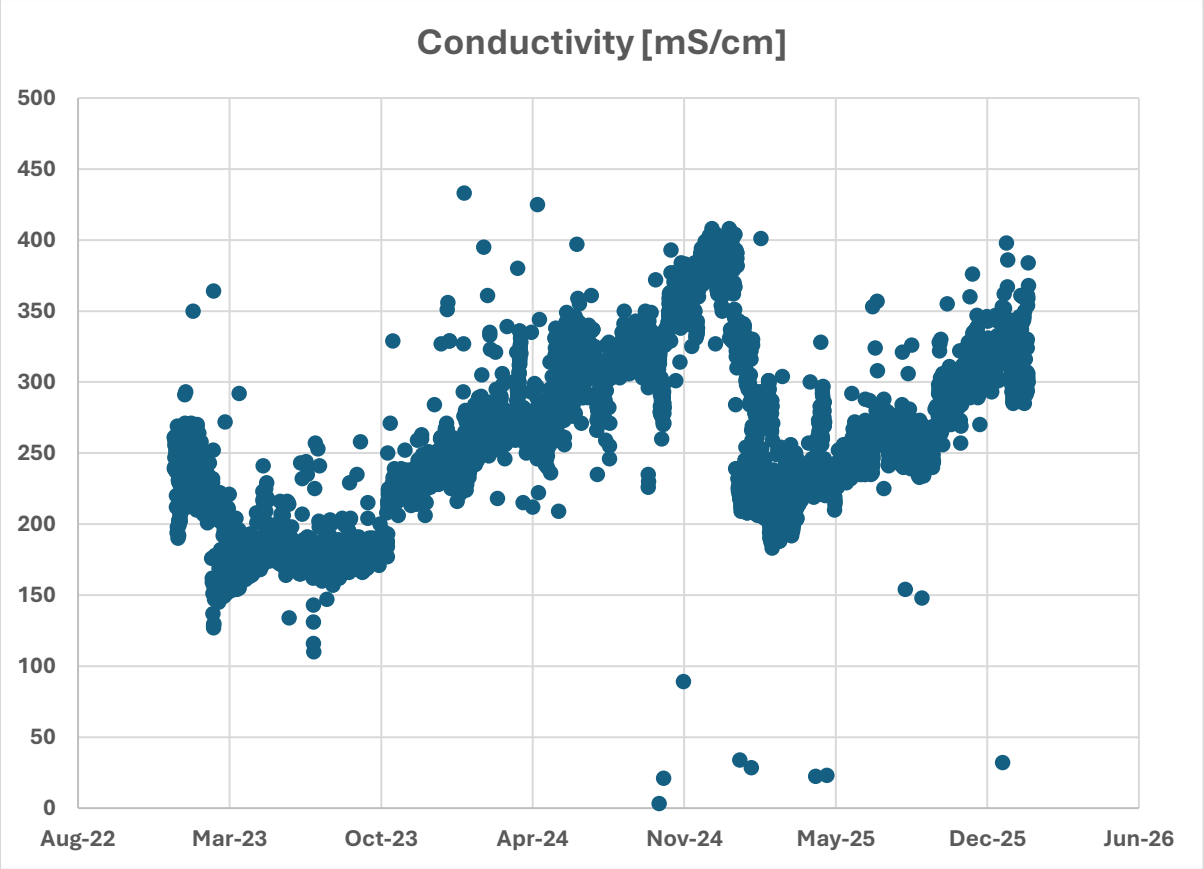

Figure 1: Raw water conductivity at Tutuka Power Station

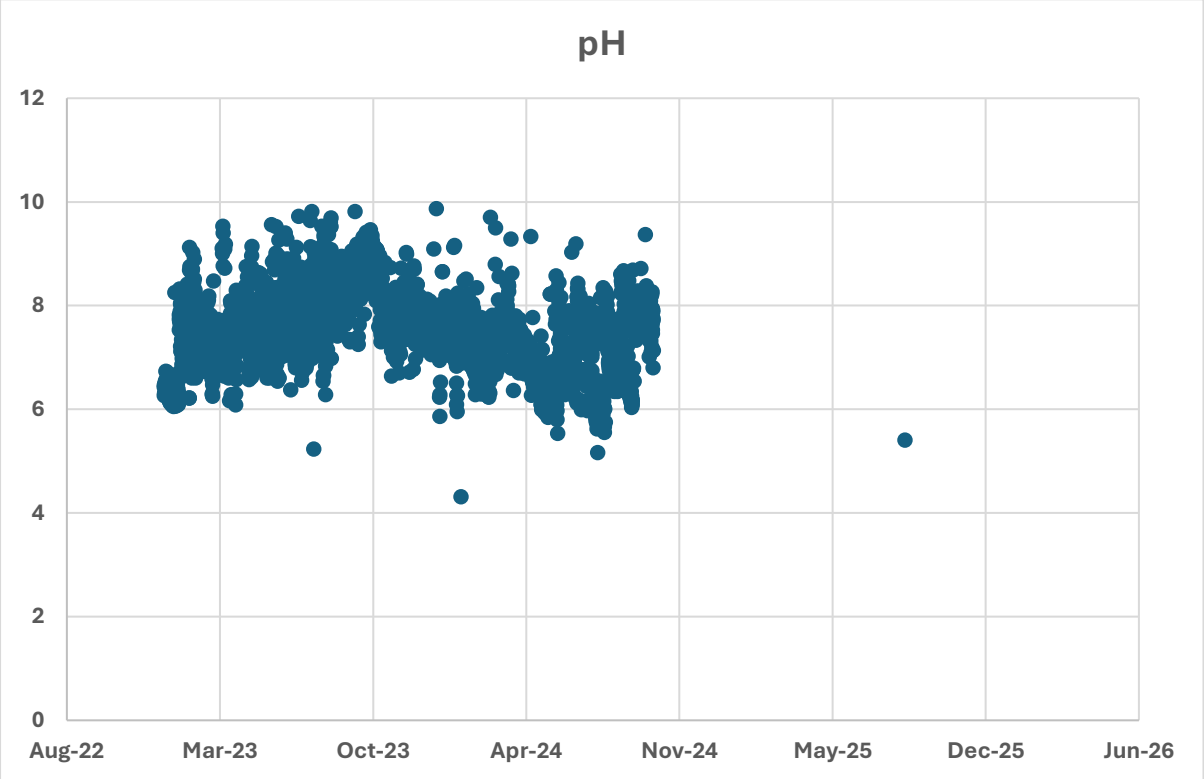

Figure 2: Raw water pH at Tutuka Power Station

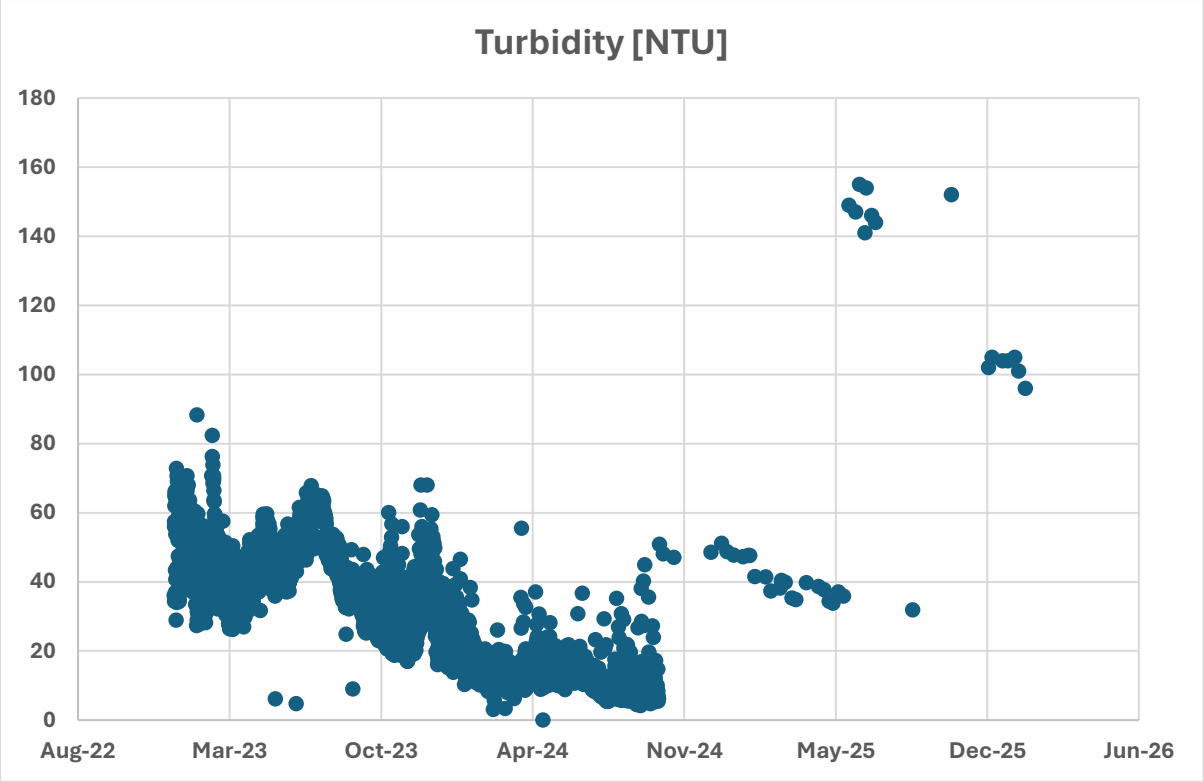

Figure 3: Raw water turbidity at Tutuka Power Station

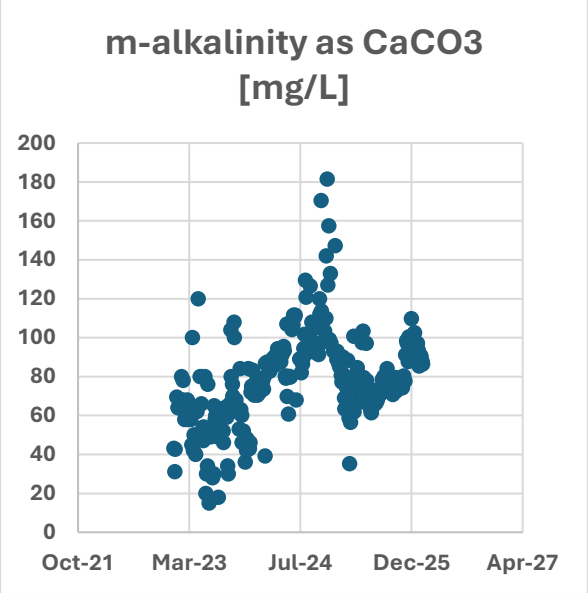

Figure 4: Raw water m-alkalinity

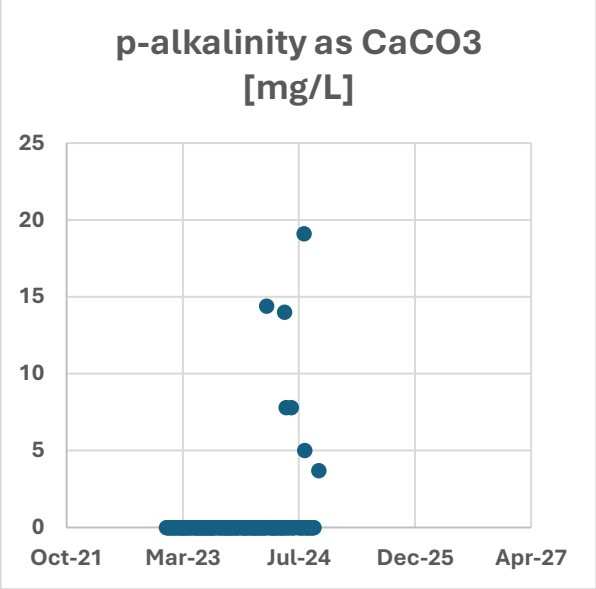

Figure 5: Raw water P-alkalinity

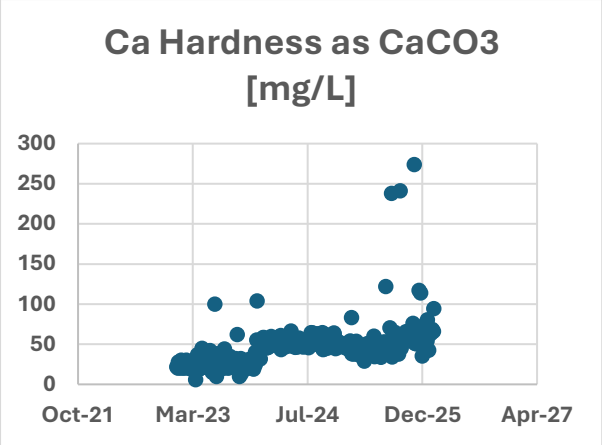

Figure 6: Raw water Ca hardness

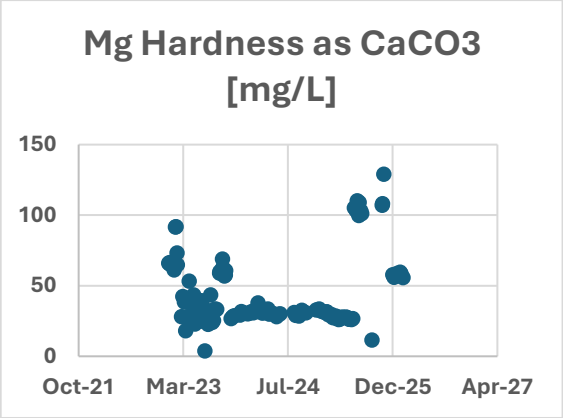

Figure 7: Raw water Mg hardness

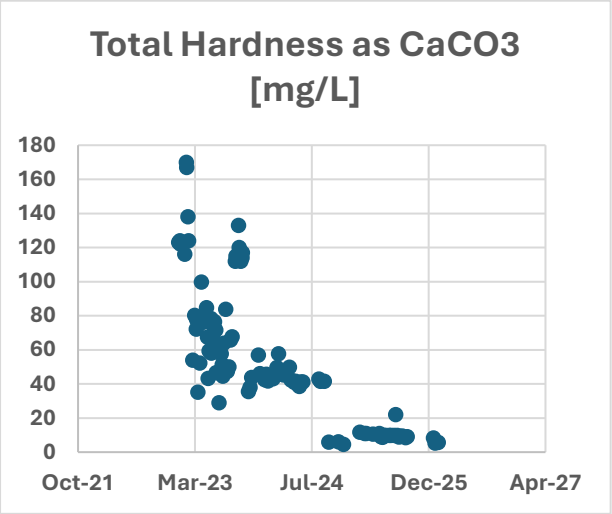

Figure 8: Raw water total hardness

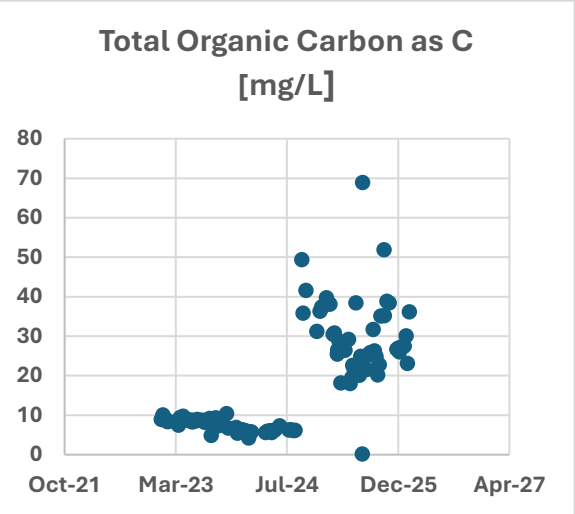

Figure 9: Raw water Total organic carbon

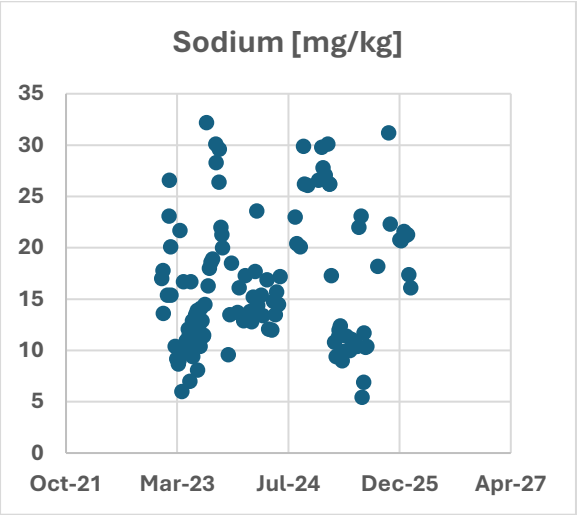

Figure 10: Raw water sodium

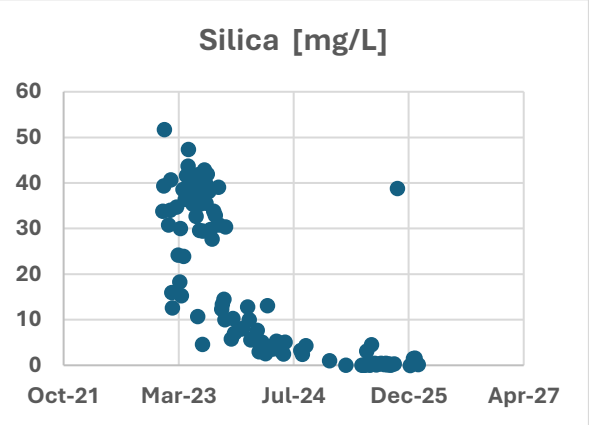

Figure 11: Raw water silica

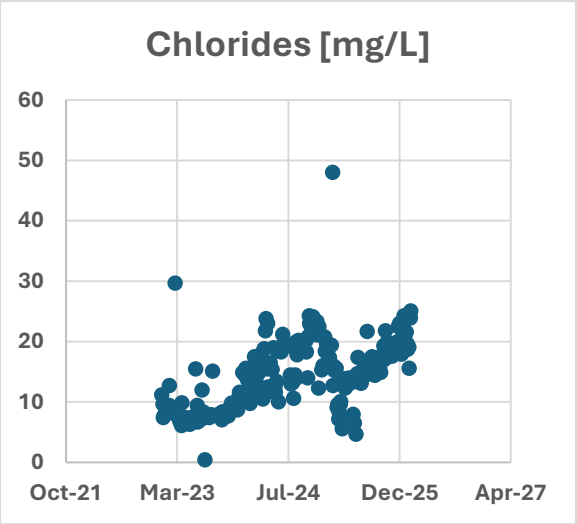

Figure 12: Raw water Chlorides

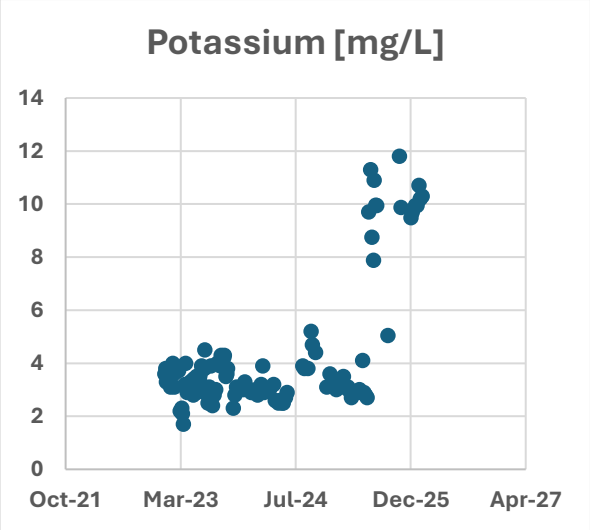

Figure 13: Raw water Potassium

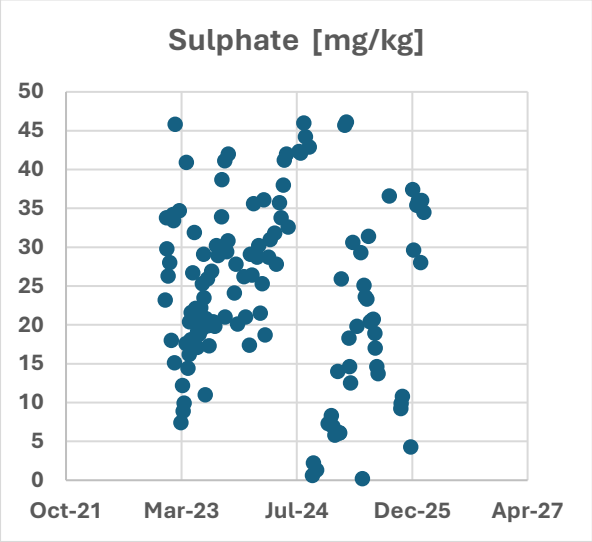

Figure 14: Raw water sulphate

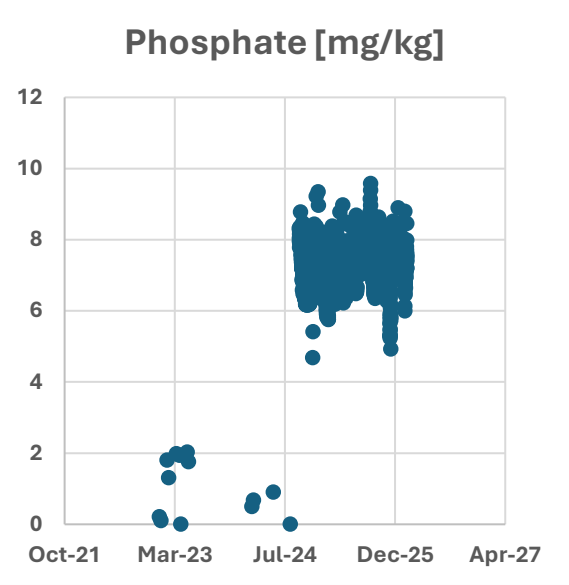

Figure 15: Raw water phosphate

The typical range of water quality in the dirty water dams is as indicated in the Table 2 and Figures 16 to 25 below:

Table 2: Wastewater which contains high levels of ash and oil (Dirty Water Dam recovery - Tutuka Power Station)

Parameter	Unit	Range	Average	95th percentile
pH	-	3.5 - 10.9	9.0	9.7
Conductivity	µS/cm	292 – 33564	9646.4	25237.9
Turbidity	NTU	1.3 – 343.0	17.9	37.9
Calcium Hardness as $CaCO_3$	mg/kg	25 – 1431.0	166.0	359.3
Magnesium Hardness as $CaCO_3$	mg/kg	26.1 – 1191	265.3	923.4

Total Hardness as $CaCO_3$	mg/kg	53.7 – 1309.0	374.2	1237.5
m-alkalinity	mg/kg	20.4 – 866.0	272.6	609.9
p-alkalinity	mg/kg	0 – 582.6	39.8	153.4
Sodium	mg/kg	58.8 - 10180	1877.3	5535.2
Potassium	mg/kg	6.9 - 214	58.7	174.7
Chloride	mg/kg	51.9 - 7726	1215.4	4645.6
Silica as SiO_2	mg/kg	0.1 – 33.9	15.1	29.4
Sulphate	mg/kg	5.6 -17000	3250.1	9396.8
FOG	mg/kg	100-5000	4682	4754

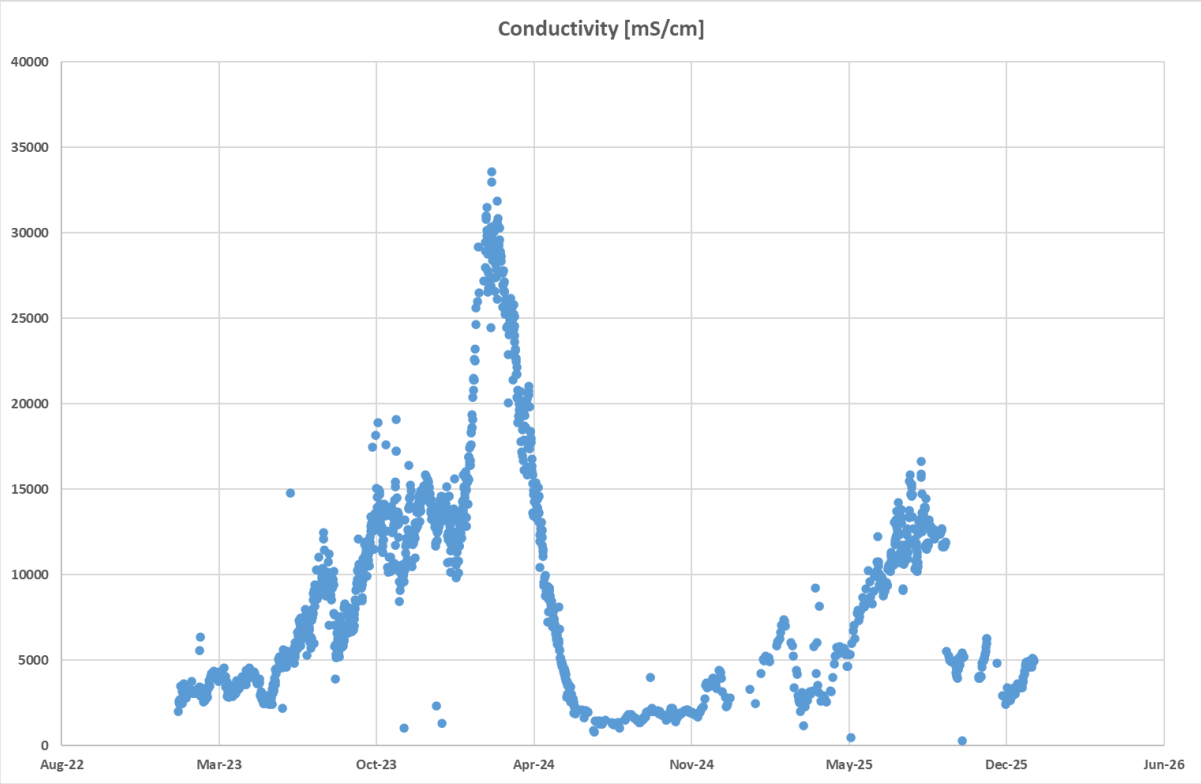

Figure 16: Dirty water dam recovery conductivity at Tutuka Power Station

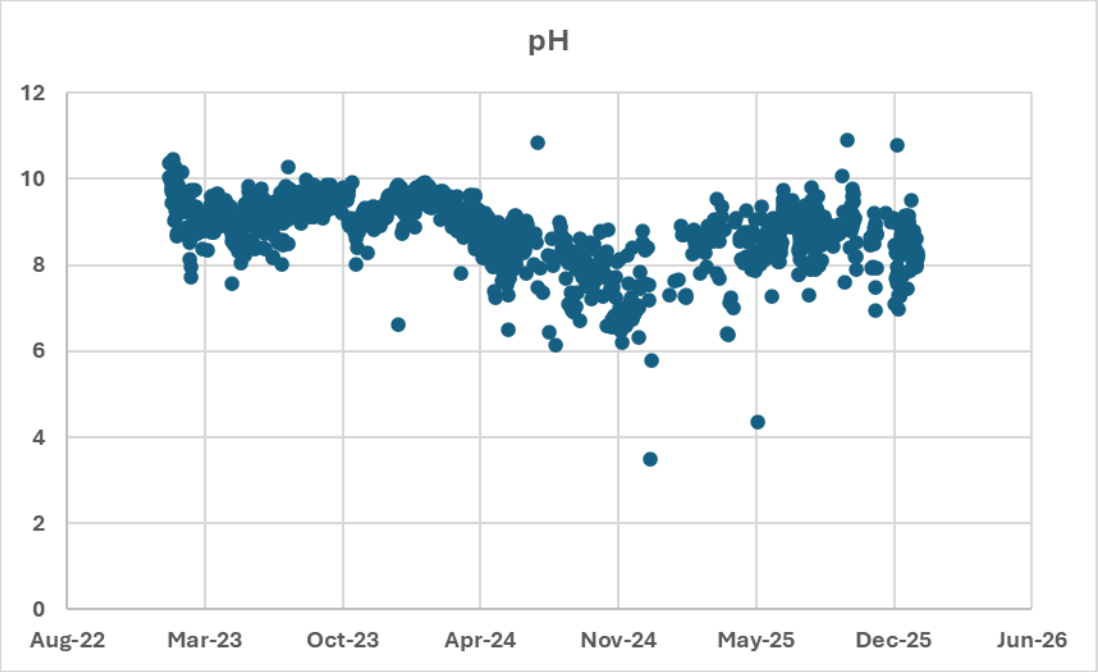

Figure 17: Dirty water dam recovery pH at Tutuka Power Station

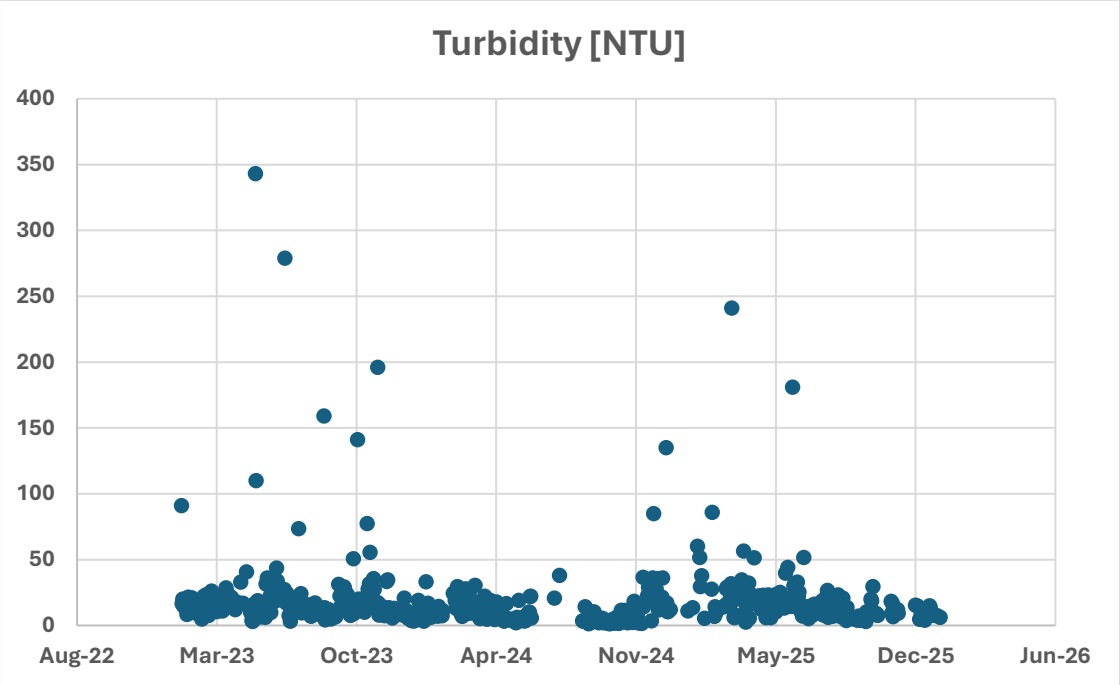

Figure 18: Dirty water dam recovery turbidity at Tutuka Power Station

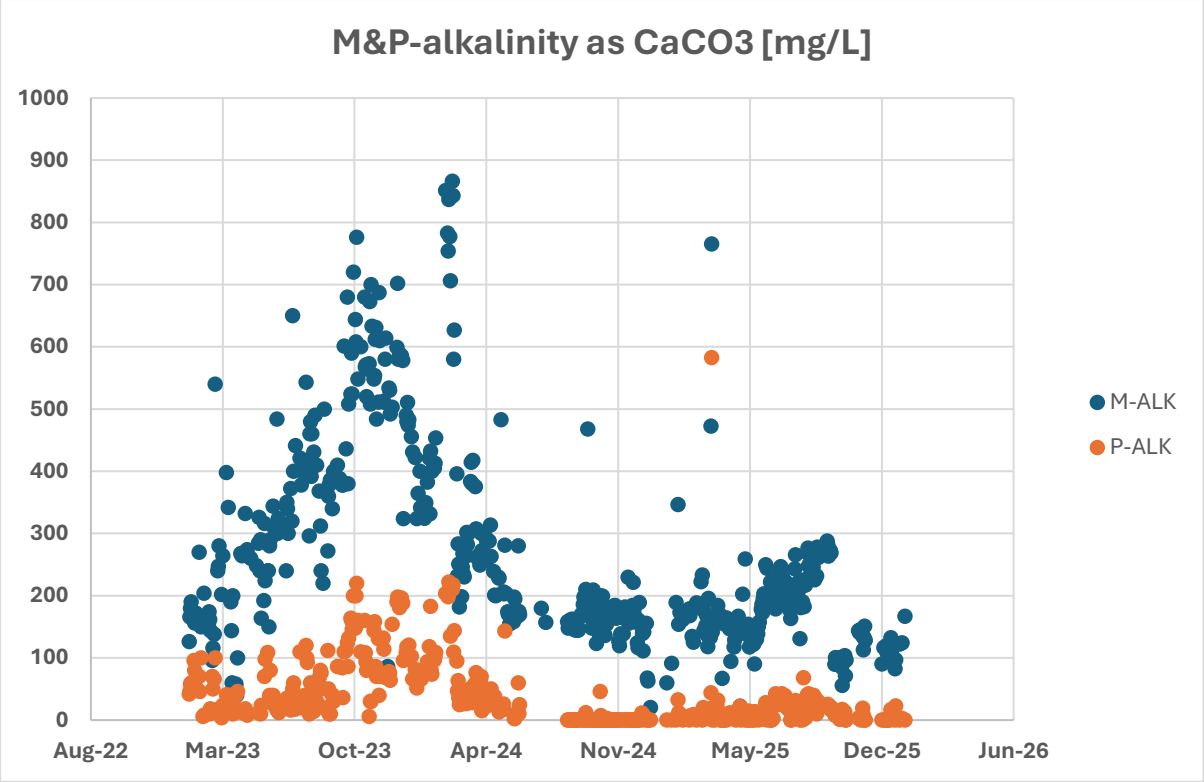

Figure 19: Dirty water dam recovery M&P alkalinity at Tutuka Power Station

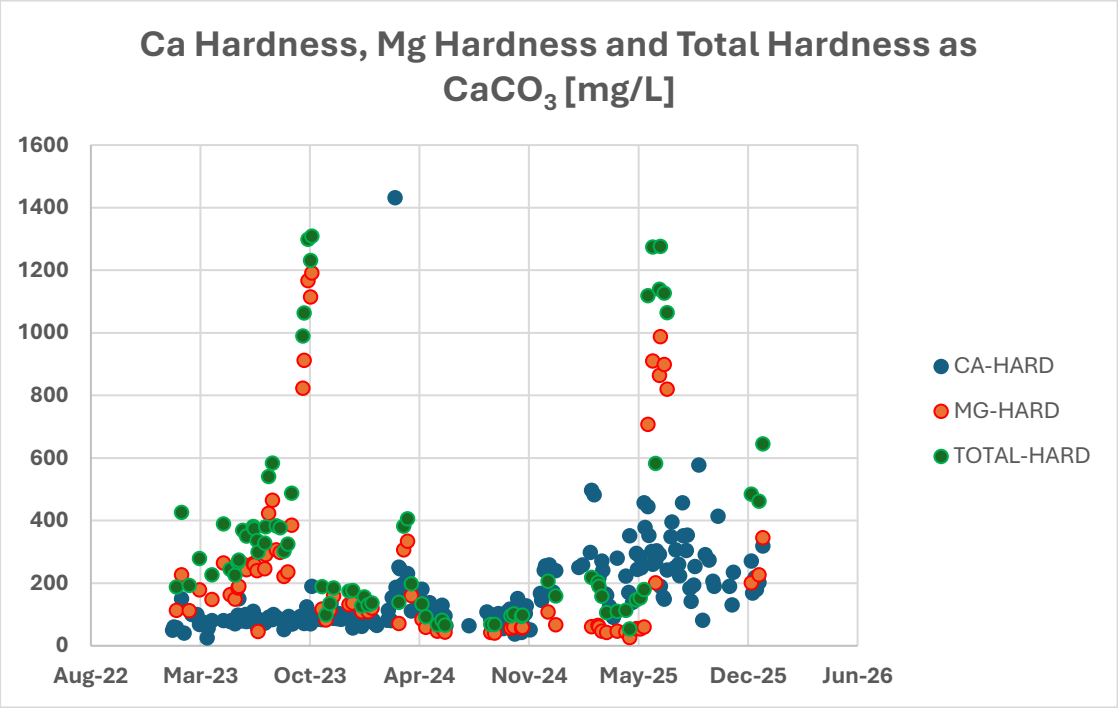

Figure 20: Dirty water dam recovery Calcium, magnesium and total hardness at Tutuka Power Station

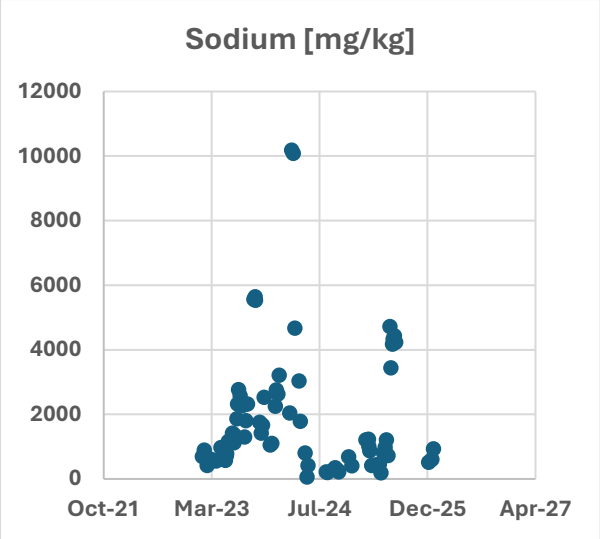

Figure 21: Dirty water recovery Sodium

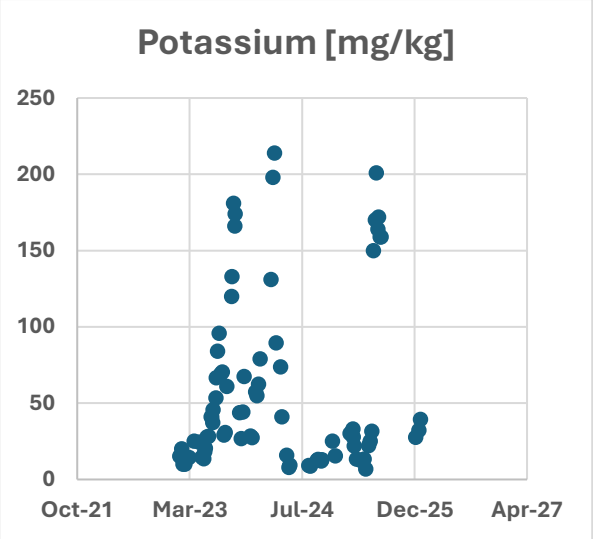

Figure 22: Dirty water recovery Potassium

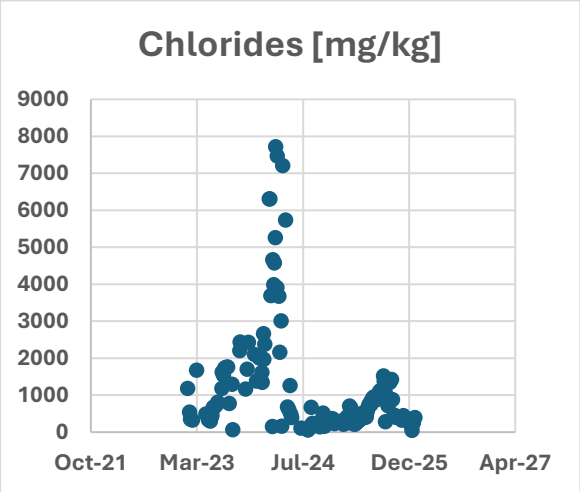

Figure 23: Dirty water recovery chlorides

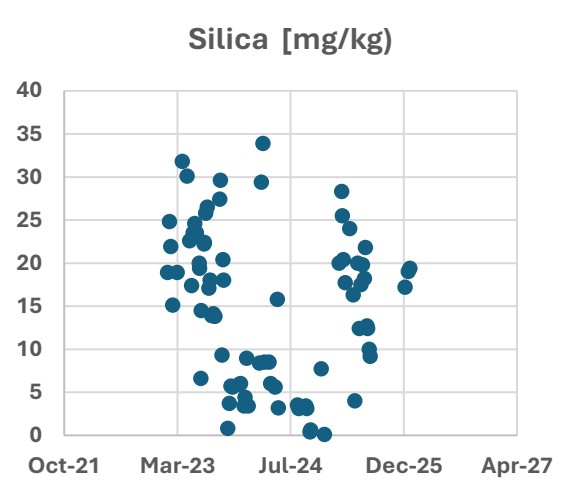

Figure 24: Dirty water recovery silica

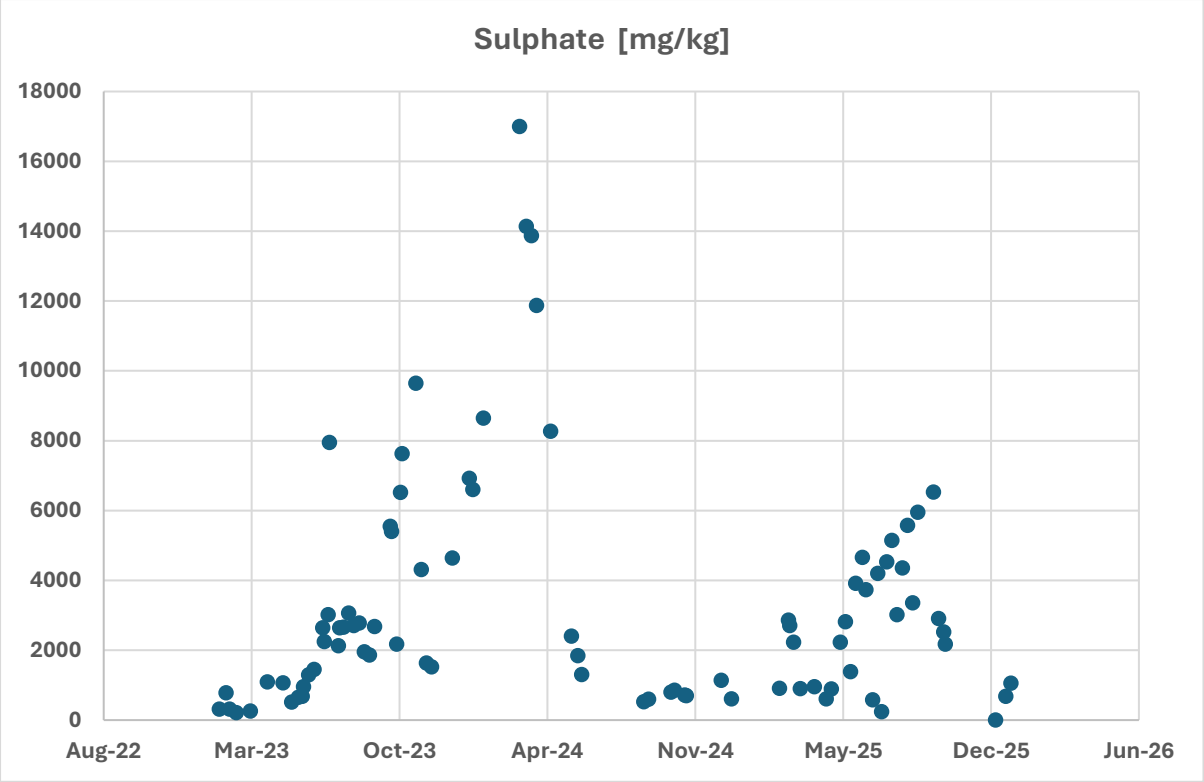

Figure 25: Dirty water recovery Sulphate

The water that is recovered must be of a quality similar to raw water quality in Table 1 or better. The water to be treated (i.e. the DWD recovery stream) is predominantly a mixture of clay, sand and coal in water. The indicative dry base ash of a DWD sample is 63%. The typical particle size of the solids in the water is between 0.25 µm – 794.33 µm.

b. Ash water – high pH

Many of the stations have problems with very high levels of water in the ash system. Reverse osmosis plants have been built at some of the stations to treat this water. These reverse osmosis plants are problematic as a result frequent scaling. A solution is required for the treatment of this high salinity, high pH water. The intention is to test the capability of the technology with regards to the removal of ash. At the time of testing, the Employer will add these components to the water supply if the levels are too low.

The typical water quality for treatment from the ash dams at Duvha is as indicated in the Figures 26-32 and Table 3 below:

Table 3: Ash water return (Duvha Power Station)

Parameter	Unit	Range	Average	95th percentile
pH	-	7.99 – 12.48	11.14	12.12
Conductivity	µS/cm	760 - 4707	2171.78	3626.15
Turbidity	NTU	0.251-12.3	2.61	6.8
Calcium Hardness as $CaCO_3$	mg/kg	260-1784	853.1	1410.2
Magnesium Hardness as $CaCO_3$	mg/kg	10 – 600	168.32	224.8

Parameter	Unit	Range	Average	95th percentile
Total Hardness as $CaCO_3$	mg/kg	397 – 1970	1013.587	1556.1
m-alkalinity	mg/kg	32.3 – 741.8	236.2	562.08
p-alkalinity	mg/kg	16.1 – 727.5	219.92	544.69
Sodium	mg/kg	46.77 – 277	146.69	191.85
Ammonium	mg/kg	0 – 0.85	0.17	0.35
Nitrate	mg/kg	0 – 42.4	4.73	13.9
Phosphate	mg/kg	0.005 – 5.6	0.91	4.3
Potassium	mg/kg	4,94 – 315	37.64	43.76
Chloride	mg/kg	0.63 – 307	96.07	165.2
Fluoride	mg/kg	0 – 112	1.29	2.49
Sulphate	mg/kg	330 – 1724	682.76	994.2
TOC as C	mg/kg	0.762 – 12.8	2.14	3.29

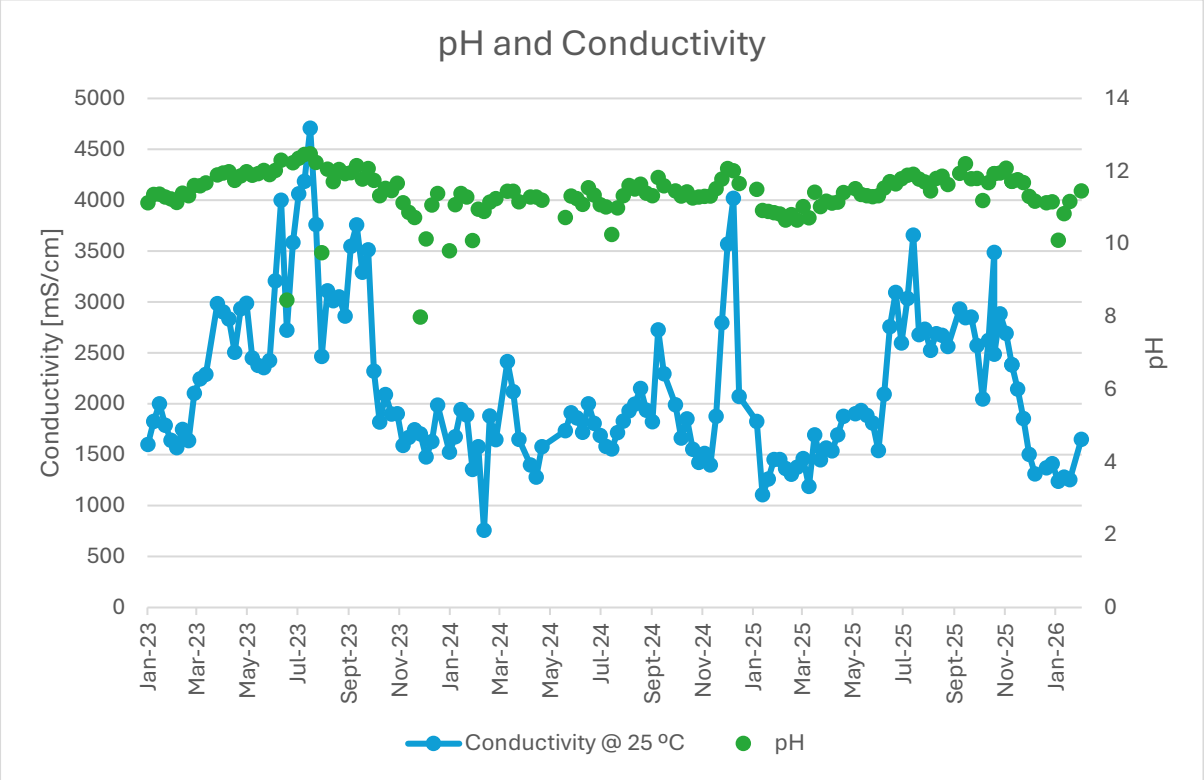

Figure 26: Duvha Ash Water pH and Conductivity

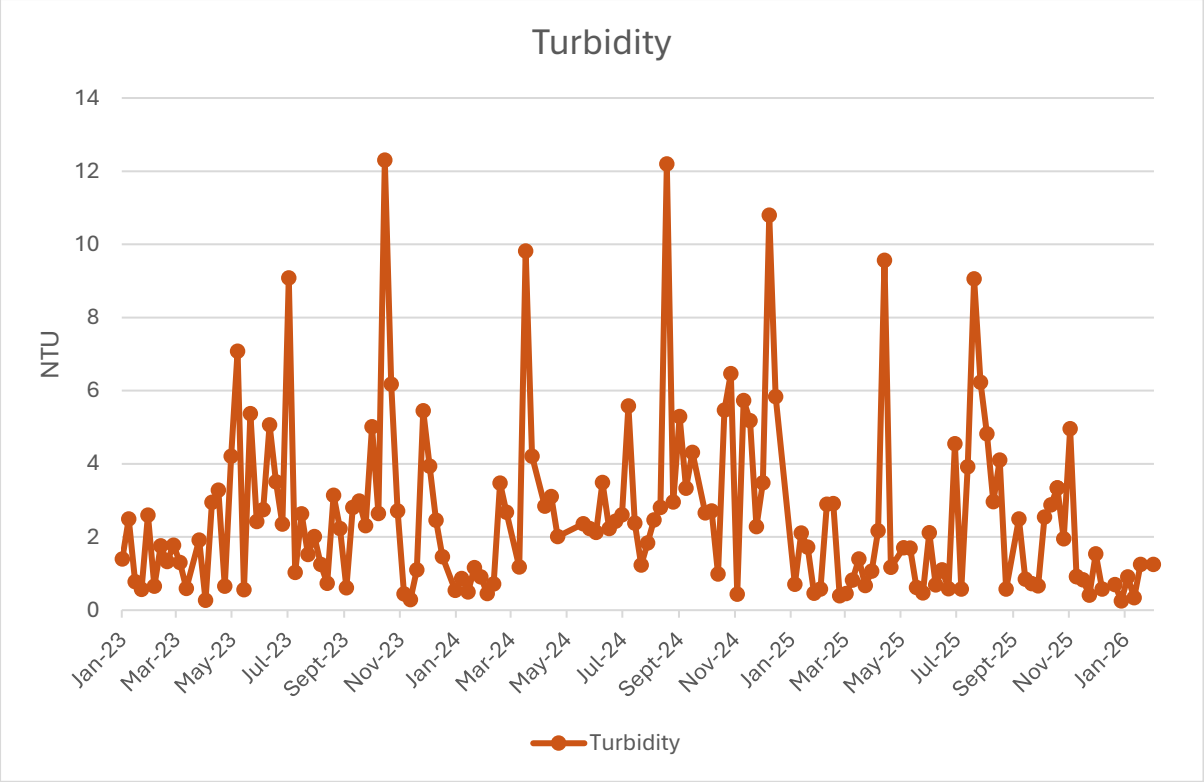

Figure 27: Duvha Ash Water Turbidity

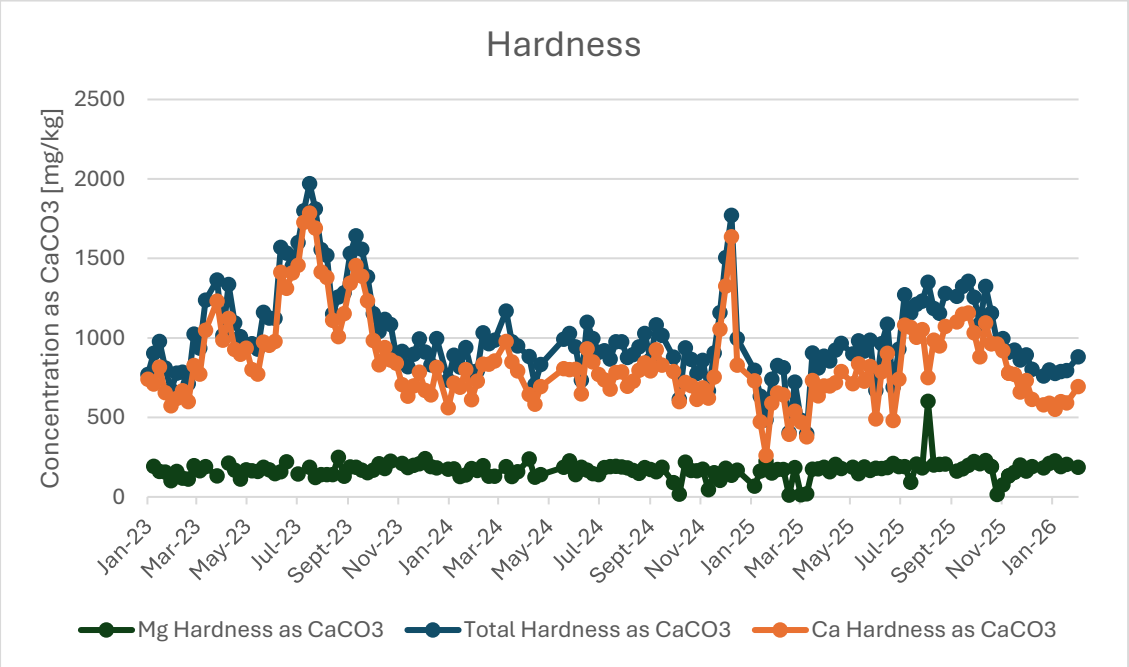

Figure 28: Duvha Ash Water Hardness

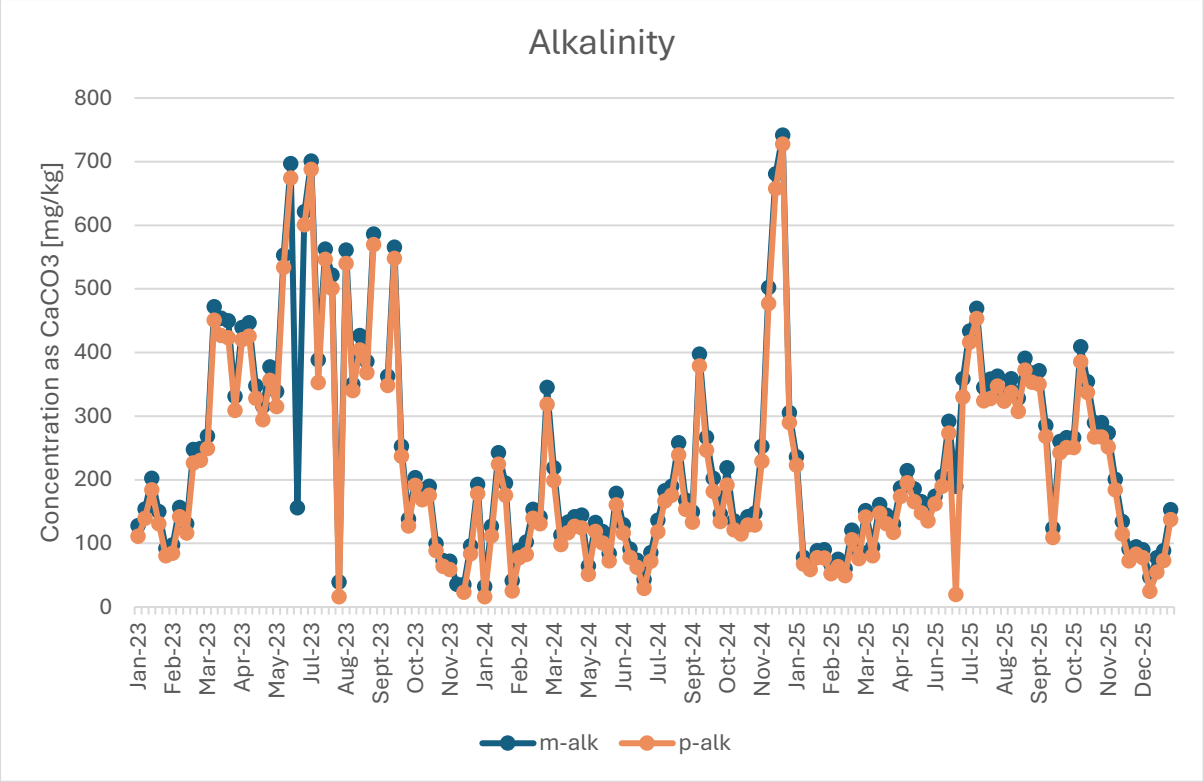

Figure 29: Duvha Ash Water Alkalinity

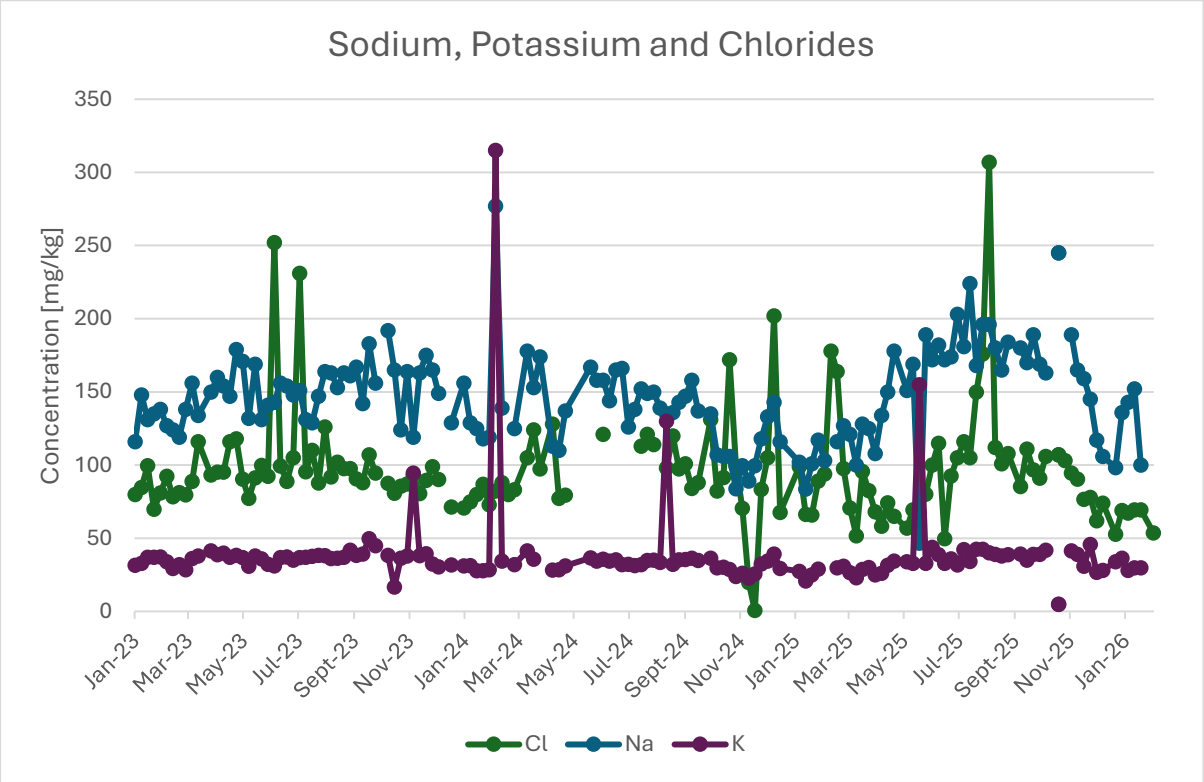

Figure 30: Duvha Ash Water Sodium, Chlorides and Potassium

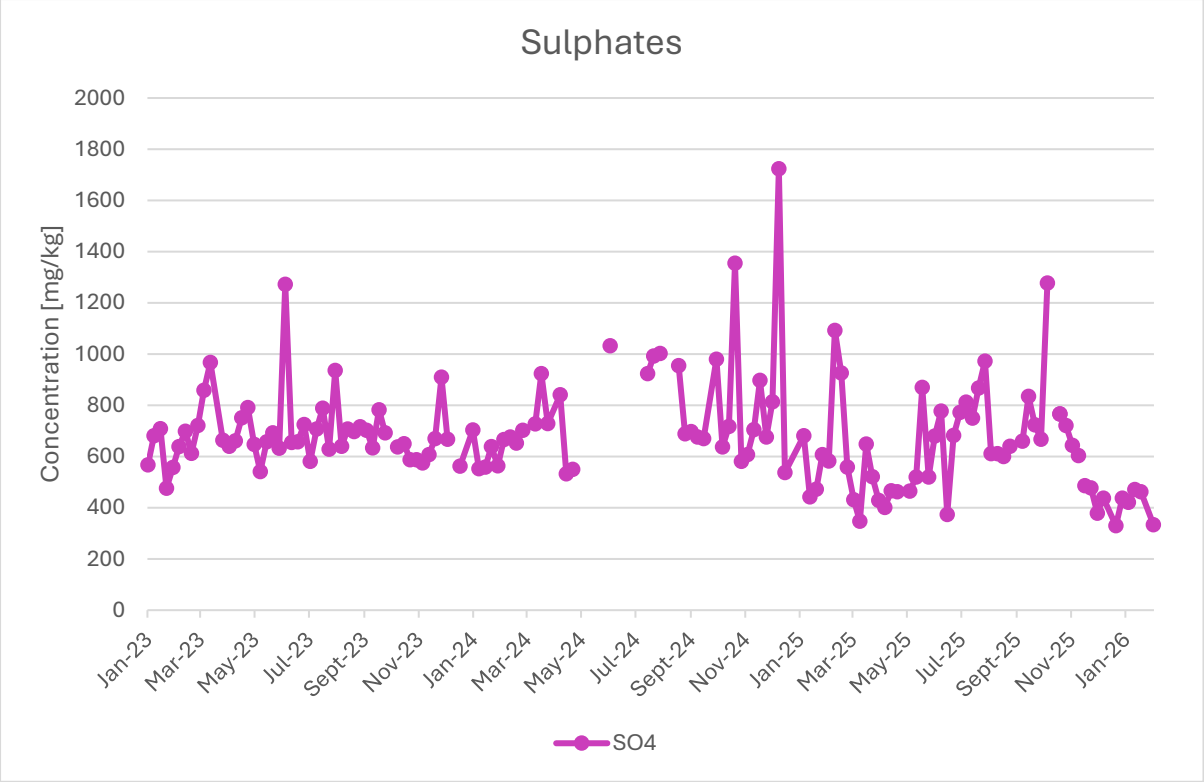

Figure 31: Duvha Ash Water Sulphates

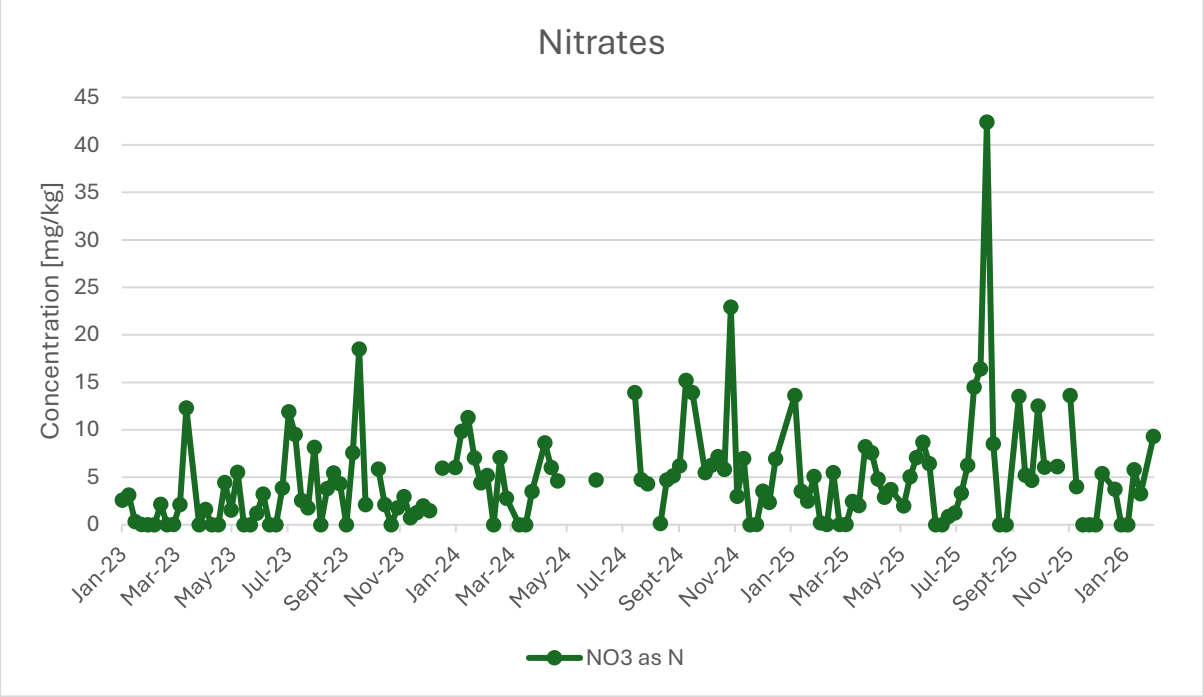

Figure 32: Duvha Ash Water Nitrates

c. FGD bleedstream

In a drive to reduce the particulate emissions at the newly built power stations, flue gas desulphurisation plants have been built at Kusile and the intention is for another to be built at Medupi. However, the bleedstream from this water has to be treated further. Thermal crystallisation is one of the techniques being utilised to treat this water. This plant has been installed at Kusile. However, it is a very cost

intensive plant with extremely high capital and operating costs. An alternative solution must be investigated which could treat this water.
The typical range of water quality for treatment is not known as yet since the analysis of these streams are still in progress. However, the chemical analysis as per the design is in the table below. The table below refers to the design parameters for the plant.

Table 4: Designed chemical parameters for the Bleedstream from the FGD plant (Kusile Power Station)

PARAMETER	CONCENTRATION [mg/L ion] BEFORE PRE-TREATMENT
Chloride	30,000
Sulfate	1,500 - 8,000
Sulfite	<20
Nitrate	100 – 1,500
Fluoride	30 – 200
Calcium	4,000 – 20,000
Magnesium	200 – 5,600
Sodium	75 – 1,200
Iron	30 – 400
Aluminum	50 – 800
Arsenic	0.05 – 3.0
Boron	20 – 40
Boron (as HBO_3)	
Cadmium	0.04 – 0.5
Cobalt	0.05 – 0.4
Chromium Total	0.3 – 5.0
Copper	0.1 – 0.85
Mercury	0.05 – 0.8
Nickel	0.2 – 6.0
Lead	0.1 – 3.0
Selenium	0.2 – 1.0
Vanadium	0 – 2.4
Zinc	5 – 10
Ammonium	<10 – 100
Ammonia	
COD	100 – 150
pH	4 – 7
TSS	300 – 10,000
Bicarbonate	
Silica	
TOC	

However, the samples from the plant have been tested and certain parameters are less than the designed parameters. Refer to the table below for the last set of samples. Since the intention is to test the water to the design parameters of the plant, the contractor must make allowance for recycle of the concentrate stream in order to cycle up the ions.

Table 5: Chemical operational parameters for the Bleedstream from the FGD plant (Kusile Power Station)

PARAMETER	UNITS	CONCENTRATION [mg/L ion] BEFORE PRE-TREATMENT
Total Alkalinity (pH>4.5)	mg CaCO3/L	60.2
Bicarbonate Alkalinity	mg CaCO3/L	60.2
Carbonate Alkalinity	mg $CaCO_3$/L	0.00

M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	60.2
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	0.00
Conductivity (Laboratory)	mS/cm	2560
pH (Laboratory)		6.69
Total Hardness	mg $CaCO_3$/L	13215
Calcium Hardness	mg $CaCO_3$/L	2068
Magnesium Hardness	mg $CaCO_3$/L	11147
Total Dissolved Solids (TDS)	mg/L	17779
Suspended Solids (TSS)	mg/L	5528
Temperature	°C	21.0
Chemical Oxygen Demand (COD)	mg O_2/L	4000
Ammonia and Ammonium	mg N/L	
Calcium	mg Ca/L	828
Chloride	mg Cl/L	1004
Magnesium	mg Mg/L	2707
Nitrate and Nitrite (TON)	mg N/L	4.14
Potassium	mg K/L	136
Sodium	mg Na/L	1369
Silicon	mg Si/L	34.5
Sulphate	mg SO_4/L	9008
Aluminium	mg Al/L	1.33
Antimony	mg Sb/L	
Arsenic	mg As/L	0.06
Barium	mg Ba/L	0.10
Beryllium	mg Be/L	0.01
Boron	mg B/L	68.8
Bromide	mg Br/L	
Cadmium	mg Cd/L	0.002
Chromium	mg Cr/L	0.01
Cobalt	mg Co/L	0.10
Copper	mg Cu/L	0.01
Fluoride	mg F/L	71.7
Iron	mg Fe/L	0.09
Lead	mg Pb/L	0.23
Lithium	mg Li/L	6.86
Total Manganese	mg Mn/L	
Manganese	mg Mn/L	2317
Mercury	mg Hg/L	0.003
Molybdenum	mg Mo/L	0.08
Nickel	mg Ni/L	0.84
Selenium	mg Se/L	1.21
Strontium	mg Sr/L	1.29
Tin	mg Sn/L	0.04
Vanadium	mg V/L	0.96

Zinc	mg Zn/L	0.41

d. Effluent from the Spiral Reverse Osmosis plant

The resin regeneration and reverse osmosis effluent is sent to the neutralisation sump. From this sump it is further sent for co-disposal with the ash. Legislation passed in 2013, states that brine with a high salt content (TDS>5%), cannot be co-disposed with the ash from 2021 onwards.

Hence, a solution is required to treat this water instead of the co-disposal with ash.

The typical range of water quality for treatment of the SRO brine is as per table and Figures 40-52 below when the plant was last in service.

Table 6: SRO brine (Tutuka Power Station)

		Tutuka SRO brine		
Parameter	**Unit**	**Range**	**Average**	**95th percentile**
pH	-	2.5 - 9.1	6.9	8
Conductivity	µS/cm	5.6 – 35373	29393	34192.8
Turbidity	NTU	0.2 – 2.7	0.7	1.3
Calcium Hardness as $CaCO_3$	mg/kg	20 - 1580	828	1560.7
Magnesium Hardness as $CaCO_3$	mg/kg	61.4 - 5178	2515.8	5155.9
Total Hardness as $CaCO_3$	mg/kg	109 - 6678	3343.8	6065.2
m-alkalinity	mg/kg	0 – 968.2	351.7	793.1
p-alkalinity	mg/kg	0 – 32.5	0.6	0
Sodium	mg/kg	172 - 13500	5103.9	8593.4
Potassium	mg/kg	11.6 - 709	287.5	450.3
Chloride	mg/kg	0 - 5463	3700.3	5201.2
Sulphate	mg/kg	559 - 106840	34744.2	98032.5
Silica as SiO2	mg/kg	1.9 - 85	46.9	83
COD	mg/kg	633 -2302	1073.1	1955.2

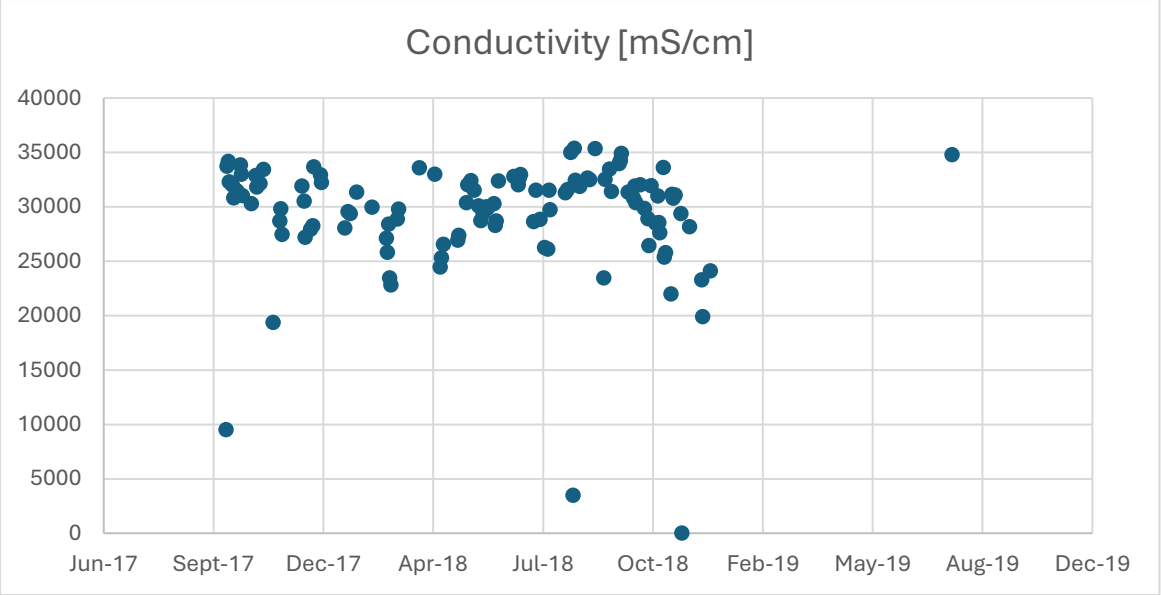

Figure 33: Tutuka SRO brine conductivity

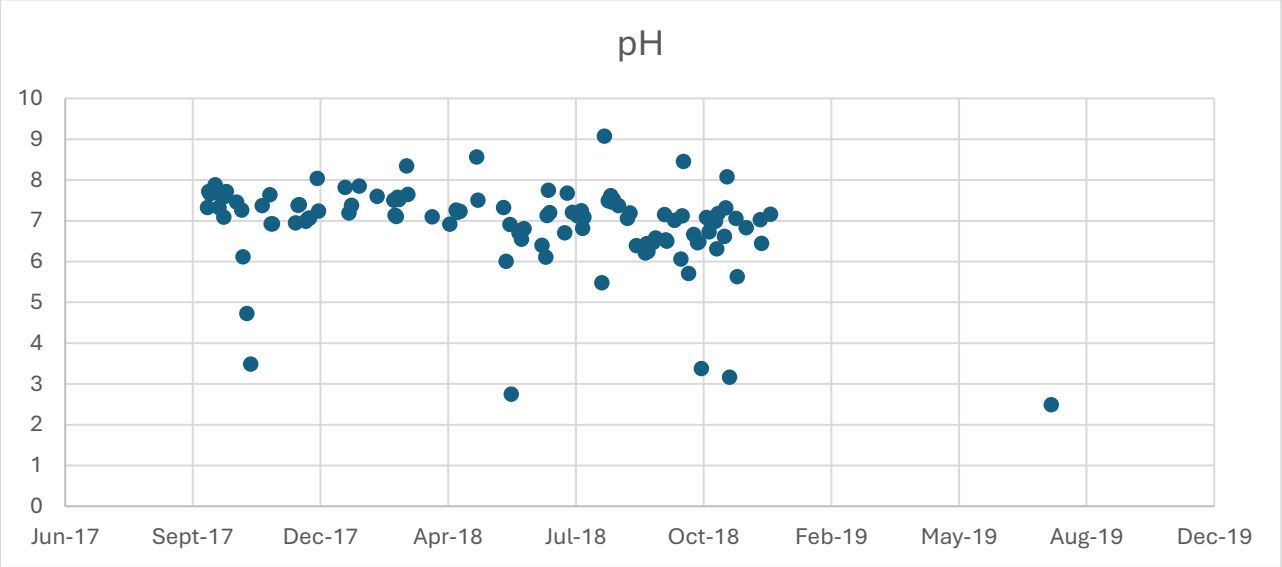

Figure 34: Tutuka SRO brine pH

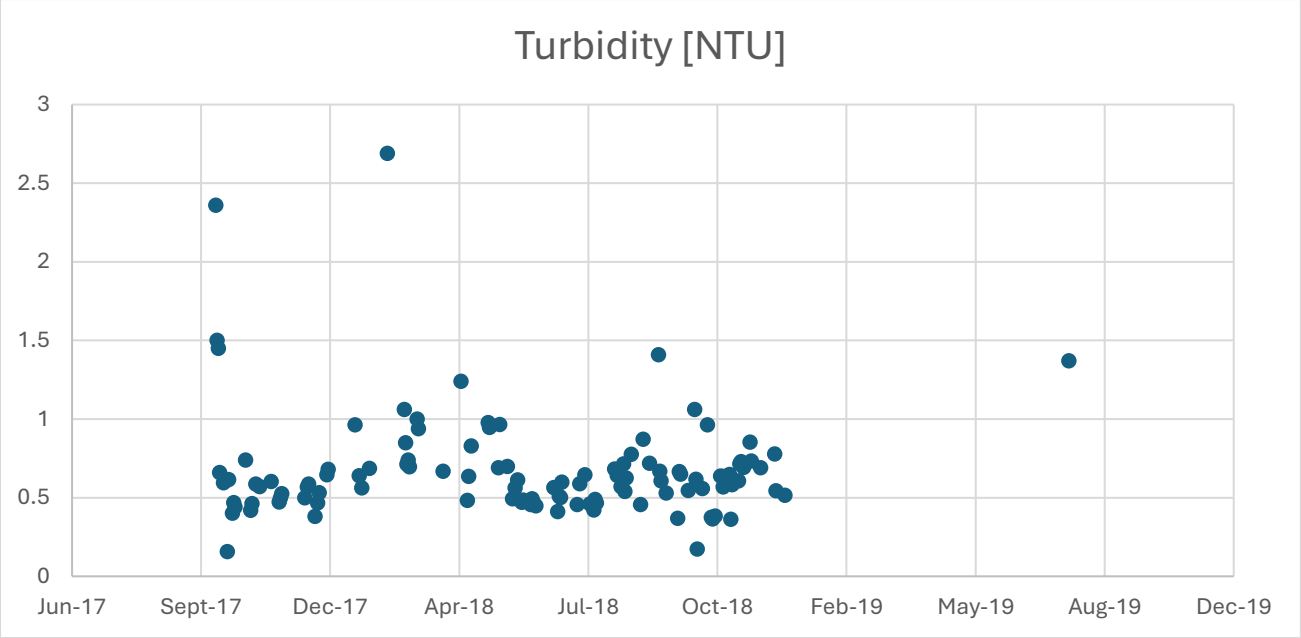

Figure 35: Tutuka SRO brine turbidity

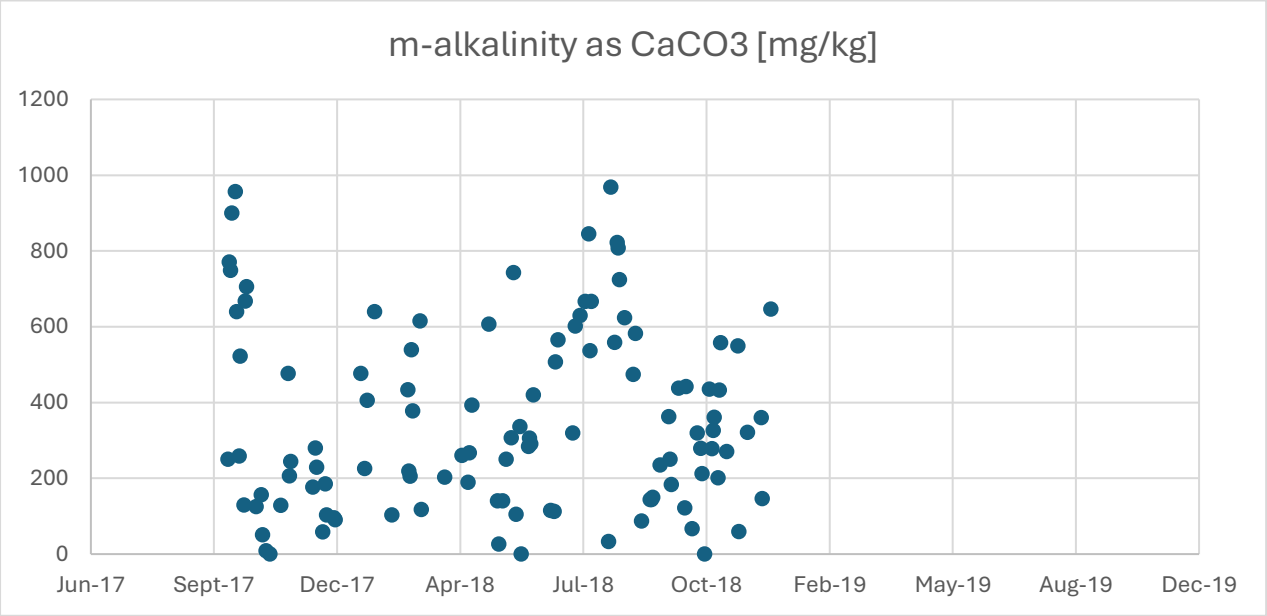

Figure 36: Tutuka SRO brine m-alkalinity

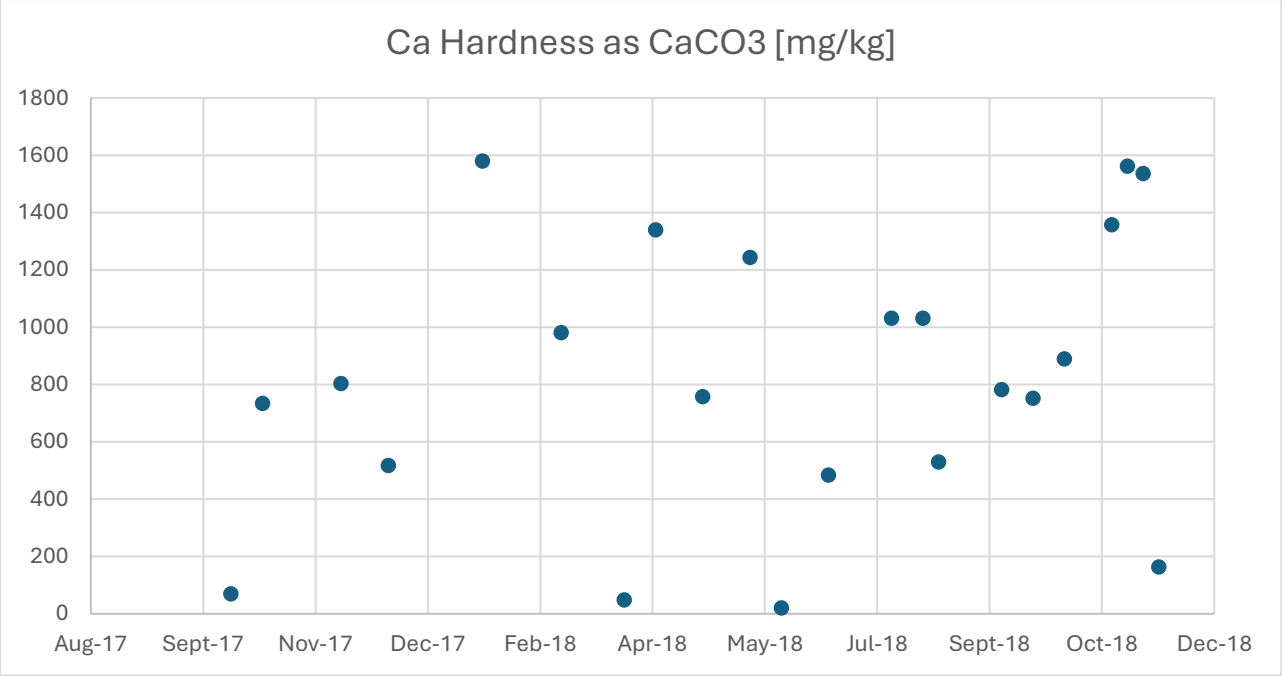

Figure 37: Tutuka SRO Calcium hardness

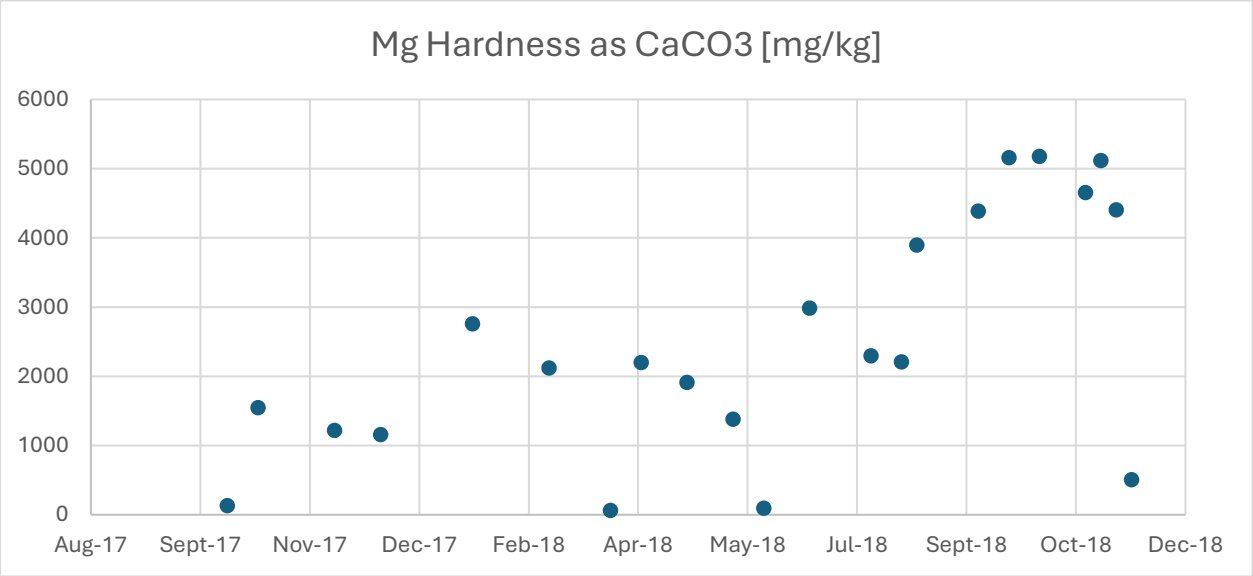

Figure 38: Tutuka SRO brine magnesium hardness

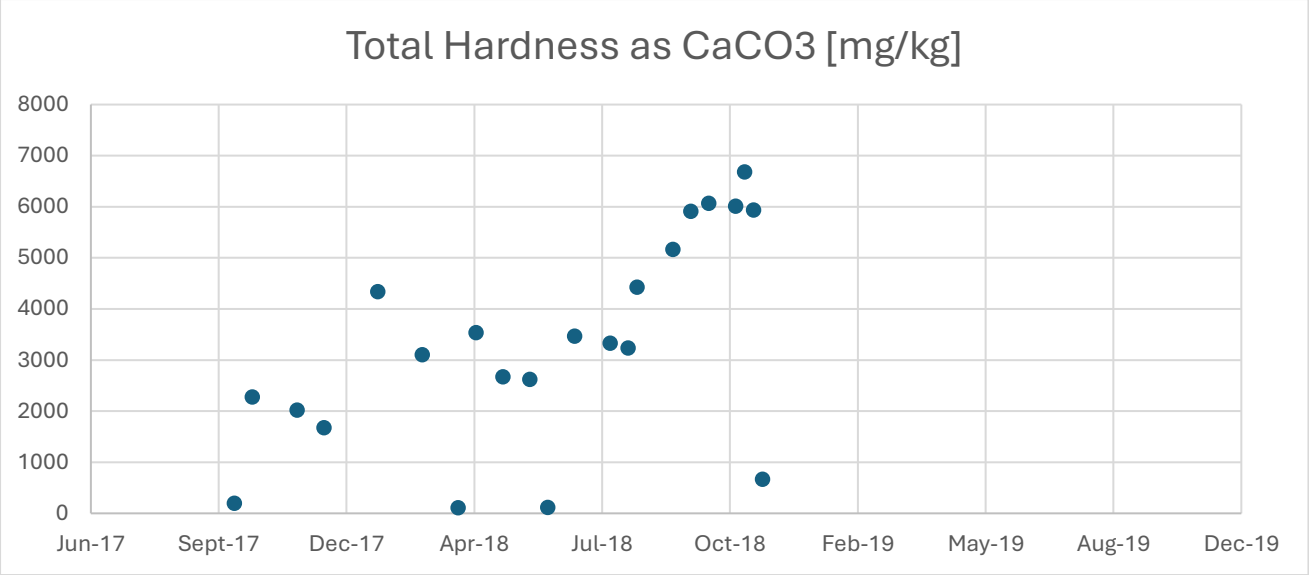

Figure 39: Tutuka SRO total hardness

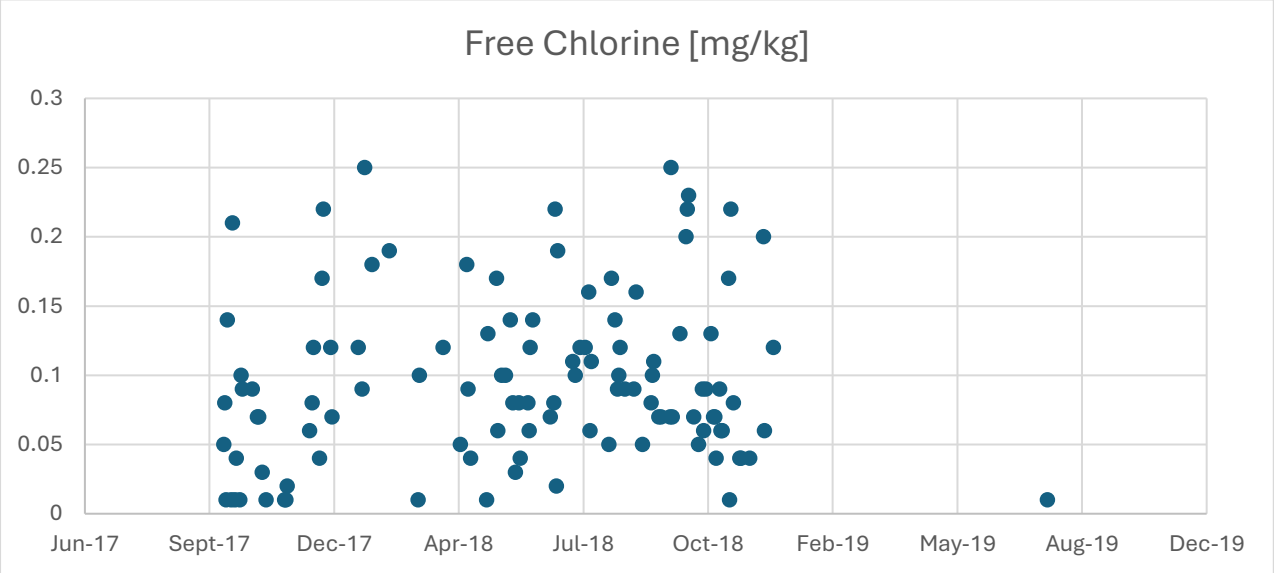

Figure 40: Tutuka SRO brine Free chlorine

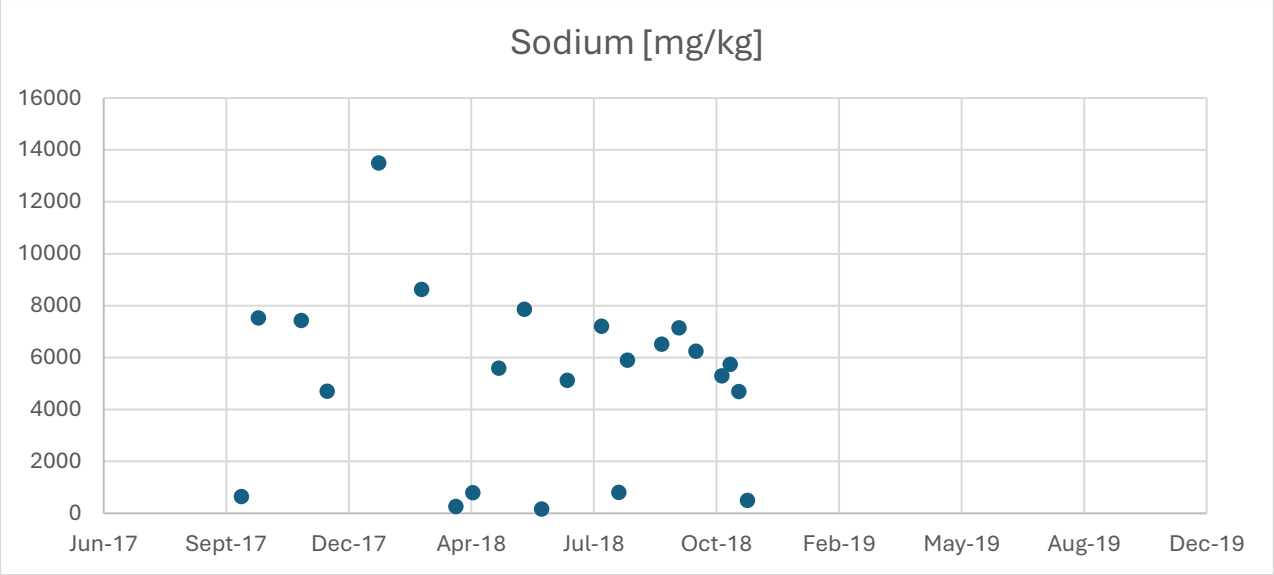

Figure 41: Tutuka SRO sodium concentration

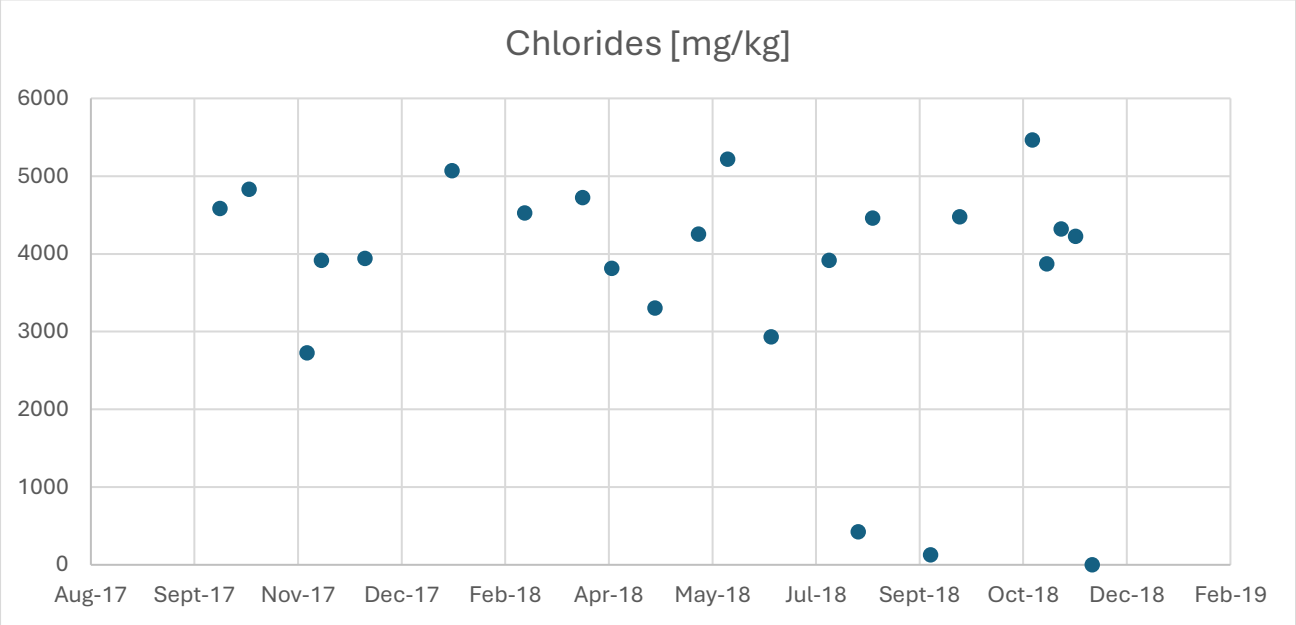

Figure 42: Tutuka SRO chlorides concentration

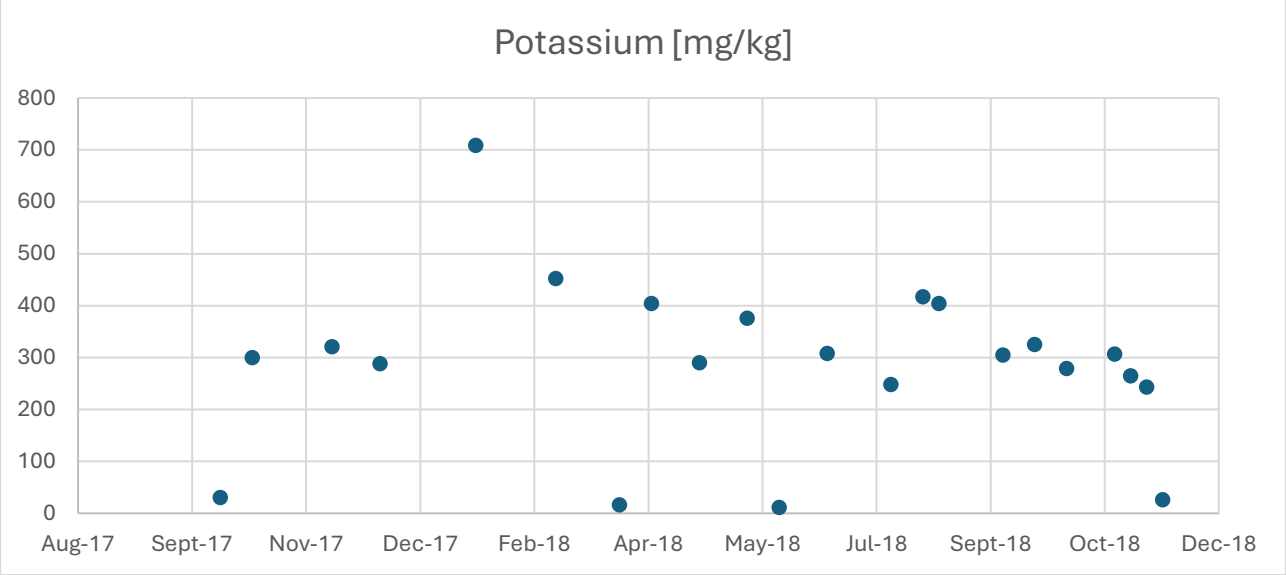

Figure 43: Tutuka SRO potassium concentration

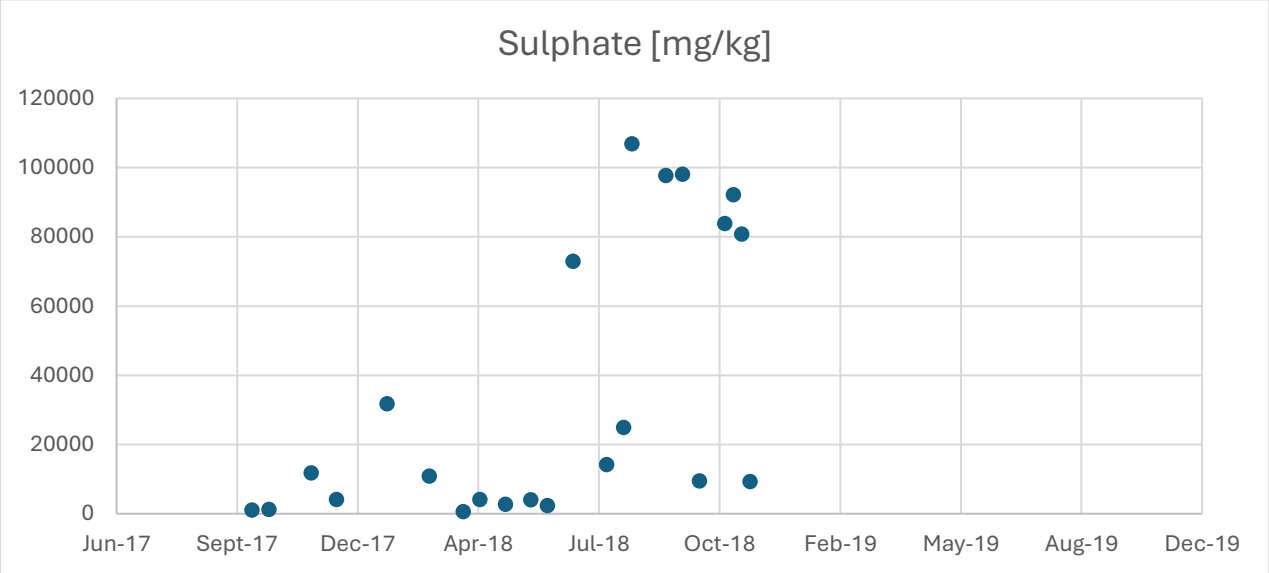

Figure 44: Tutuka SRO sulphate concentration

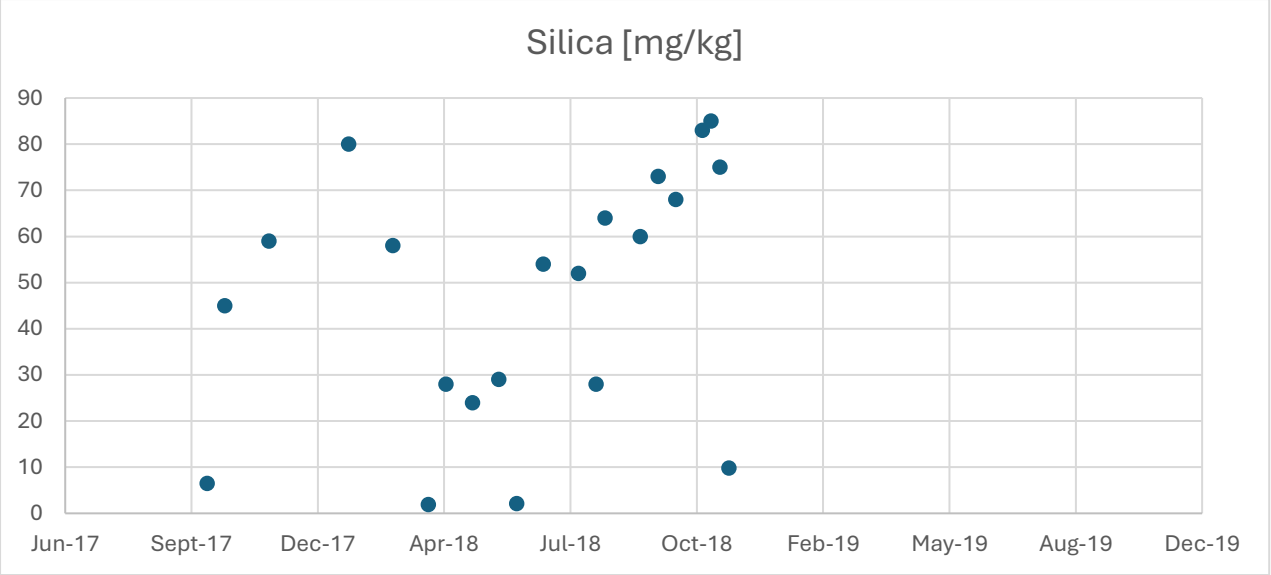

Figure 45: Tutuka SRO silica concentration

e. Concentrated Cooling Water (CCW) sidestream / blowdown

Water from the concentrated cooling water system is blown down when the water quality is out of specification with respect to the limits in the Eskom Cooling Water Chemistry standard. There are times when the water cannot be blown down because of high water levels in the ash system. The water then concentrates out of specification which exacerbates the scaling potential of the water and results in scaling of the cooling water system. Currently, lime softening treatment has been employed at many stations to treat the concentrated cooling water on a side stream. These plants have however been found to be problematic and are often out of service. Since this water is not as saline as the other waters being tested, this stream will be tested for sensitivity analysis purposes.

The typical range of water quality for treatment from the CCW at Tutuka is as indicated in the tables and figures below:

Table 7: Concentrated Cooling water (Tutuka Power Station)

		Tutuka CW East		
Parameter	**Unit**	**Range**	**Average**	**95th percentile**
pH	-	6.69 – 12.01	8.86	9.61
Conductivity	µS/cm	12.8 - 52700	12431.72	38210
Turbidity	NTU	2.38 - 270	46.86	121
CCPP as $CaCO_3$	mg/kg	4.7 – 170	45.16	93.25
Calcium Hardness as $CaCO_3$	mg/kg	0 –1951	302.45	895.15
Magnesium Hardness as $CaCO_3$	mg/kg	0.9 – 2990	206.33	370.06
Total Hardness as $CaCO_3$	mg/kg	37.7 - 2890	625.83	1887
m-alkalinity	mg/kg	28.7 – 1894	405.58	1043.9
p-alkalinity	mg/kg	0 – 601	44.41	212.38

		Tutuka CW East		
Sodium	mg/kg	22.9 - 5816	1519.51	5198
Potassium	mg/kg	5 - 325	97.62	262.9
Chloride	mg/kg	20.2 – 5080	642.38	1809
Sulphate	mg/kg	41.3 – 9179	1874.33	5049.45
Nitrates	mg/kg	0.53 – 35.1	11.78	29.82
Phosphates	mg/kg	0.01 – 2430	110.63	571
Silicate at SiO_2	mg/kg	0.01 - 132	36.16	87.6
TOC	mg/kg	0.03 - 106	30.66	76.46

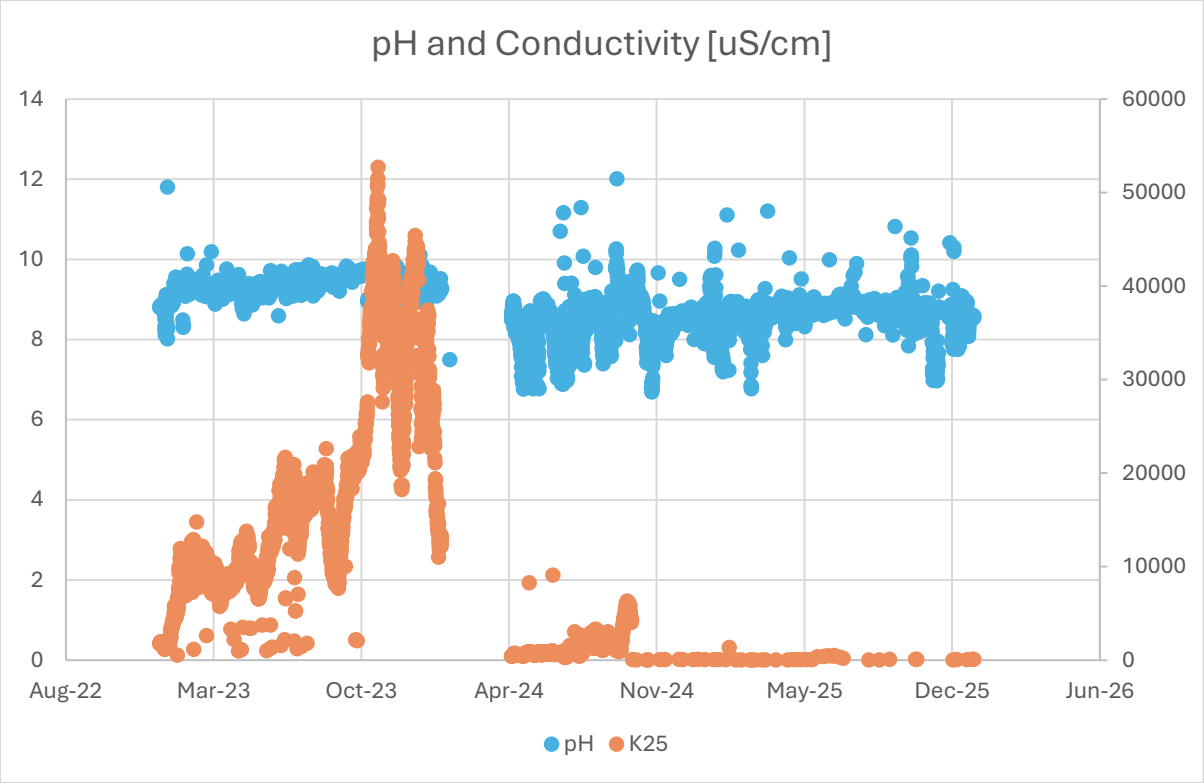

Figure 46: Tutuka Cooling water East pH and Conductivity

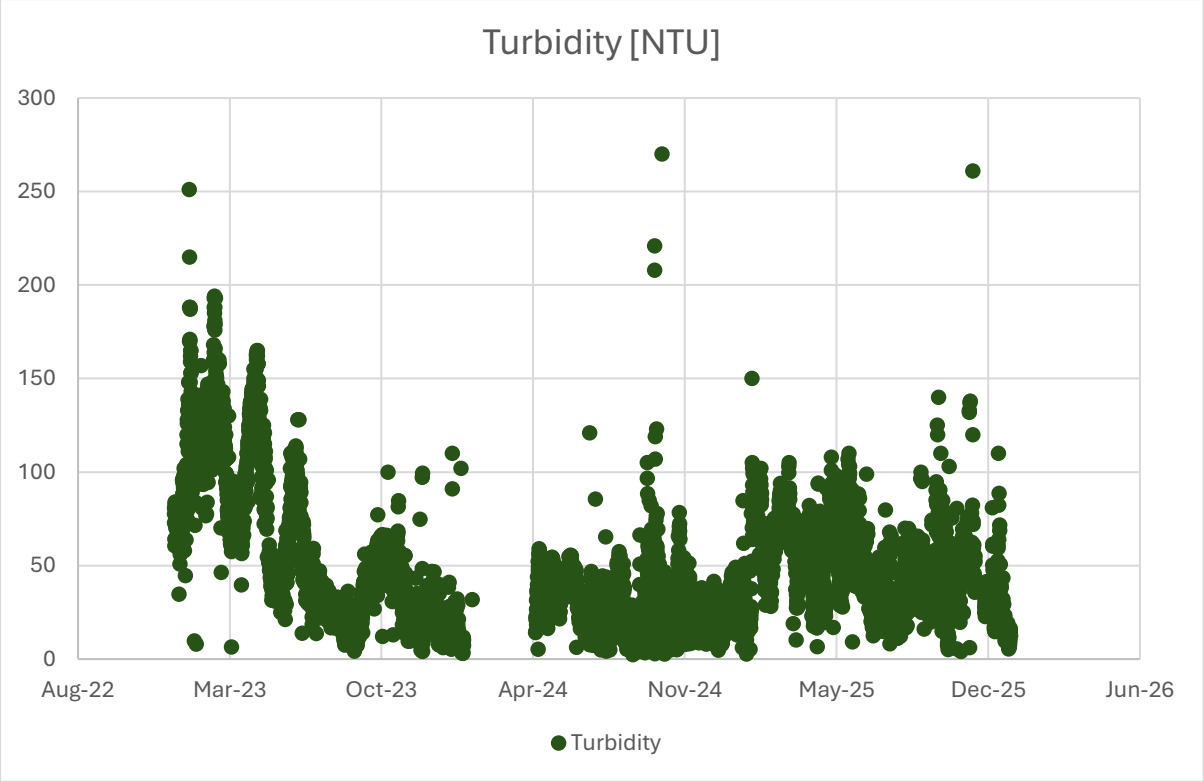

Figure 47: Tutuka Cooling water East Turbidity

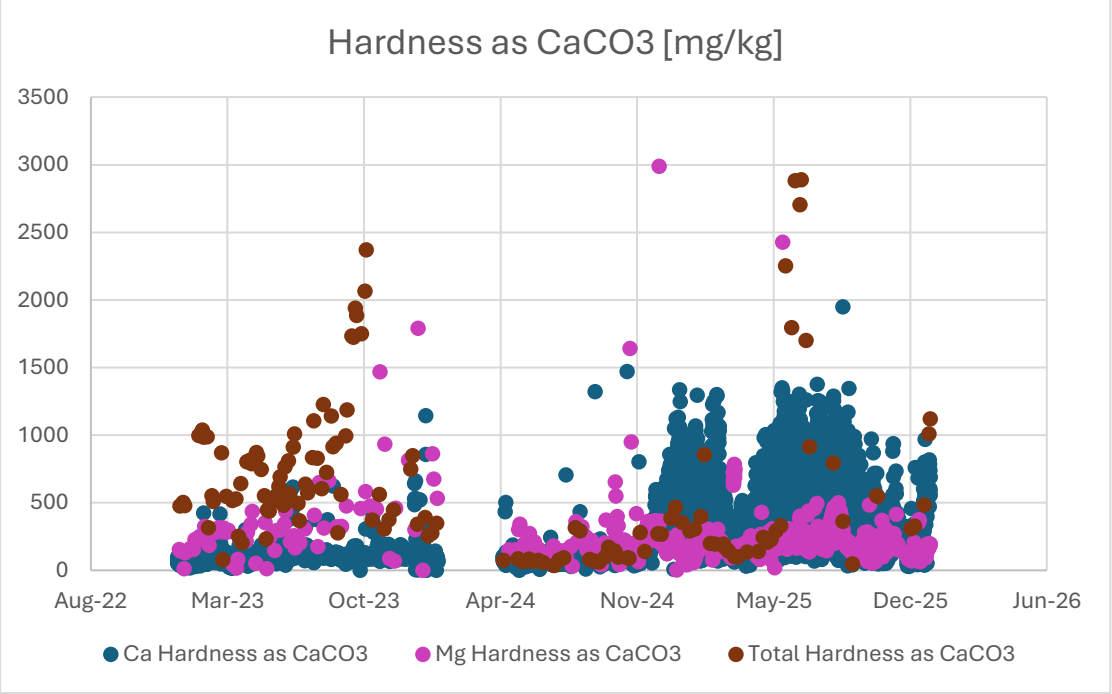

Figure 48: Tutuka Cooling water East Hardness

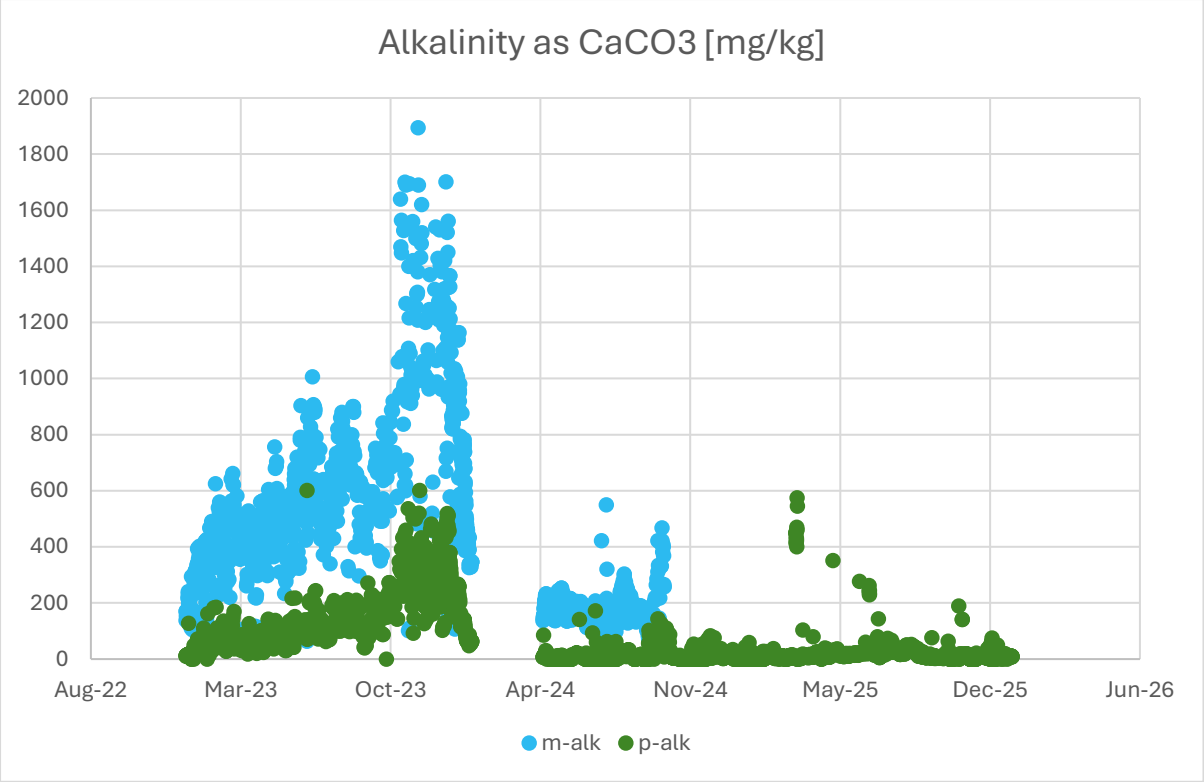

Figure 49: Tutuka Cooling water East Alkalinity

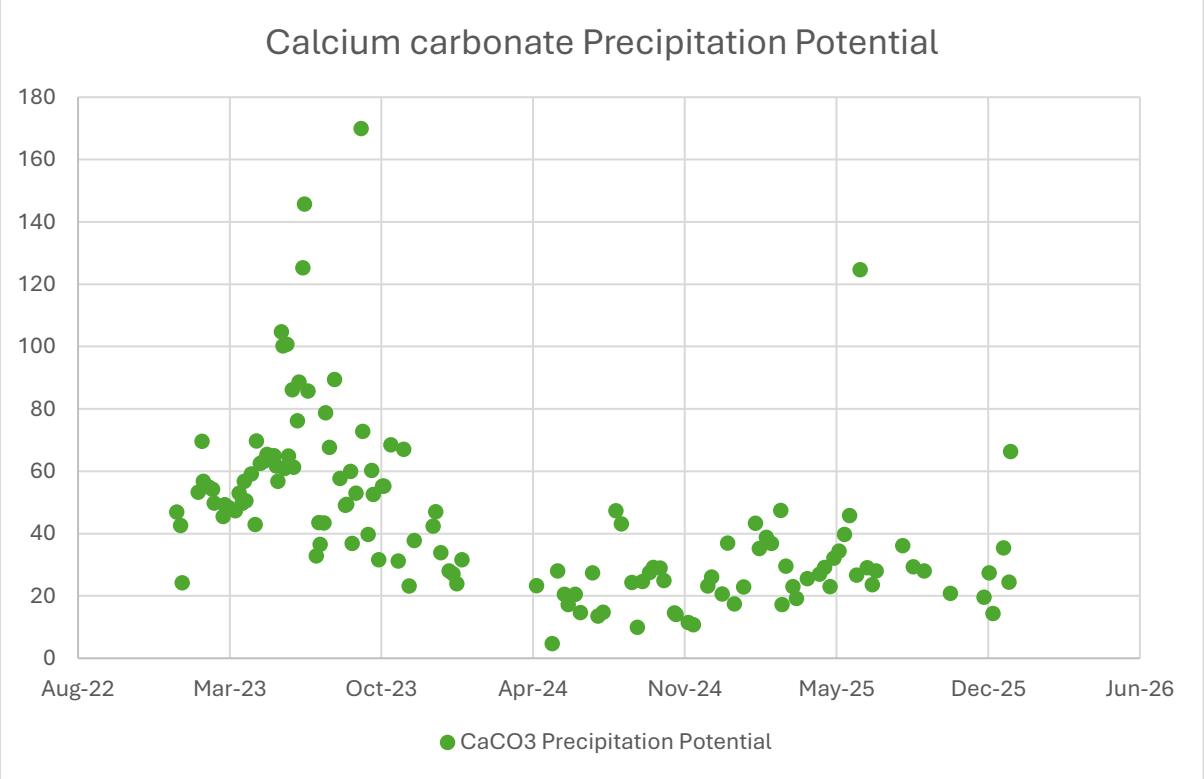

Figure 50: Tutuka Cooling water East Calcium carbonate precipitation potential

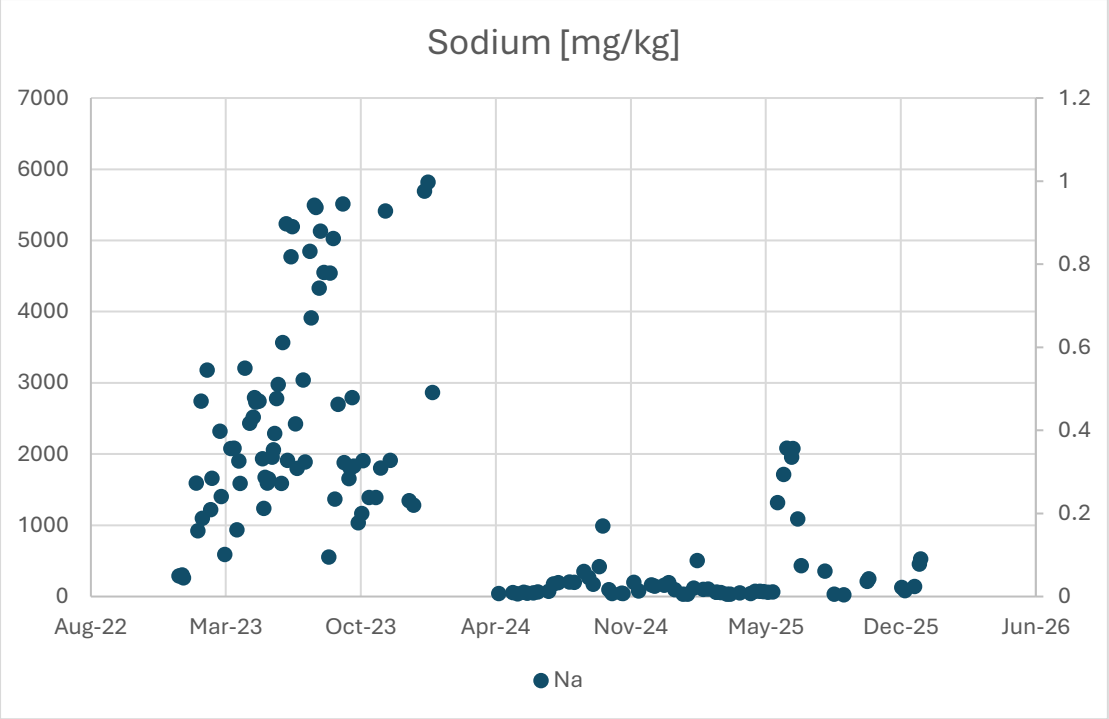

Figure 51: Tutuka Cooling water East Sodium

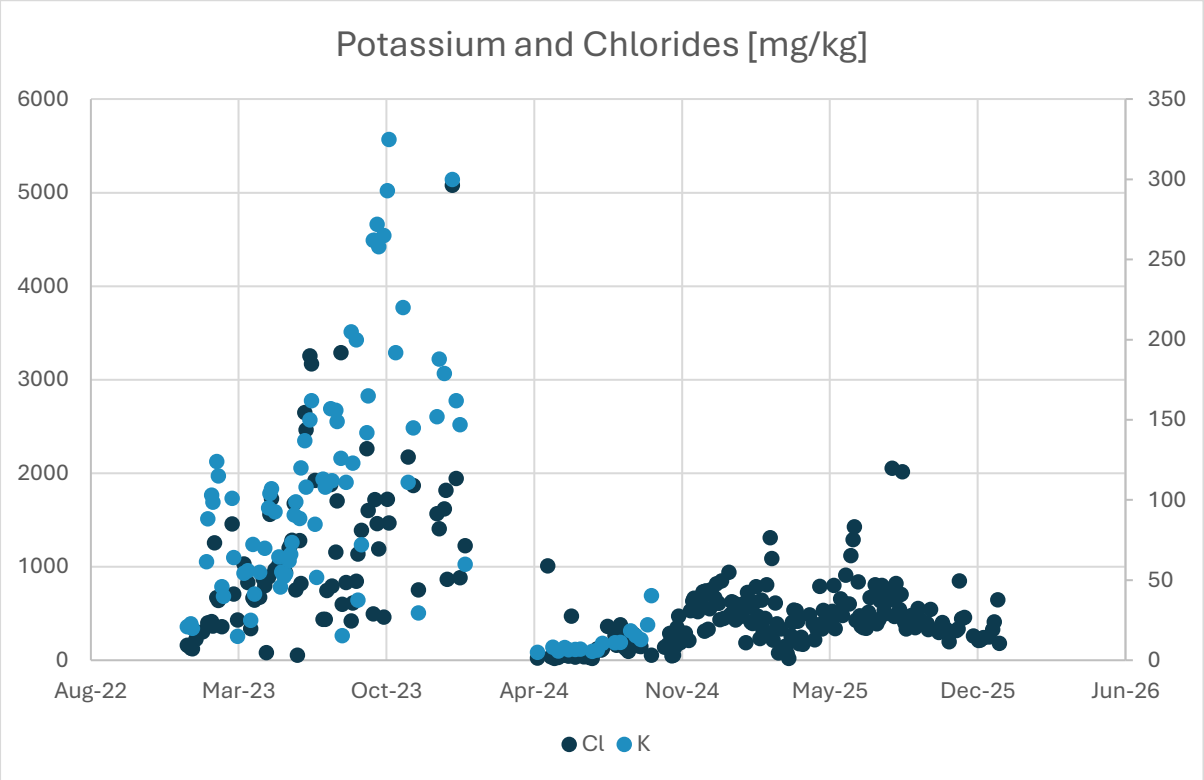

Figure 52: Tutuka Cooling water East Chlorides and Potassium

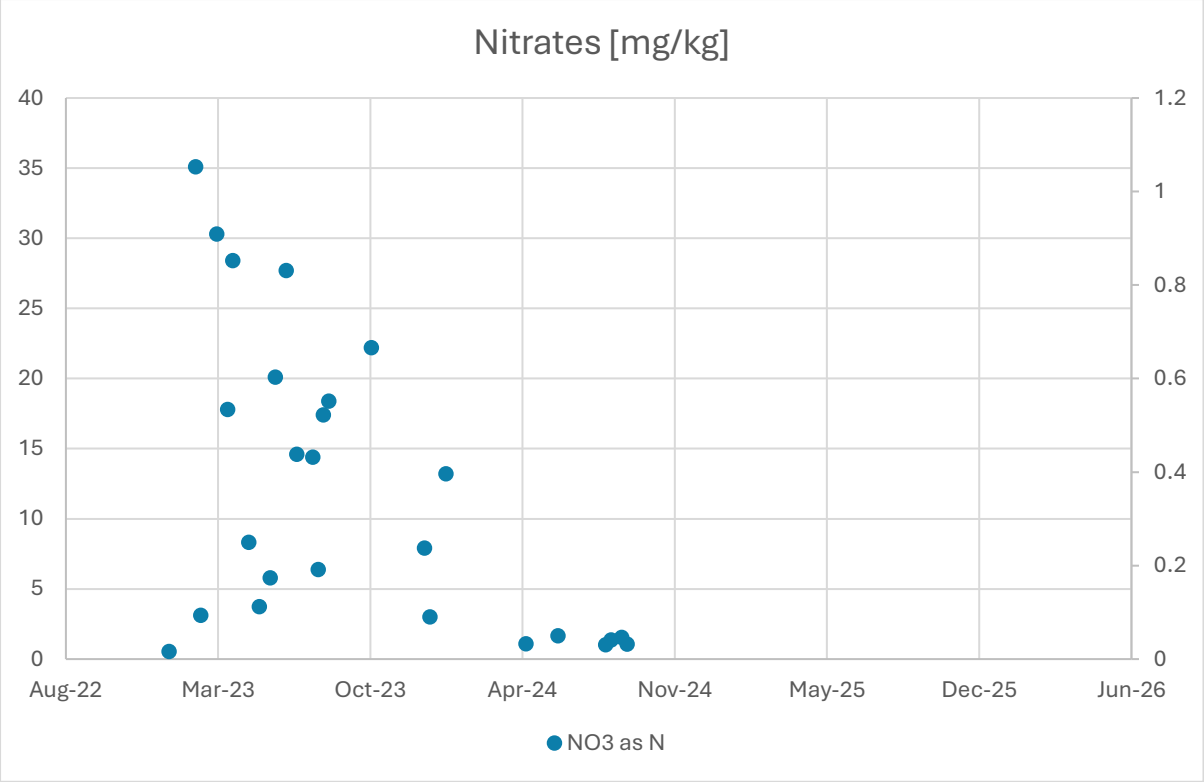

Figure 53: Tutuka Cooling water East Nitrates

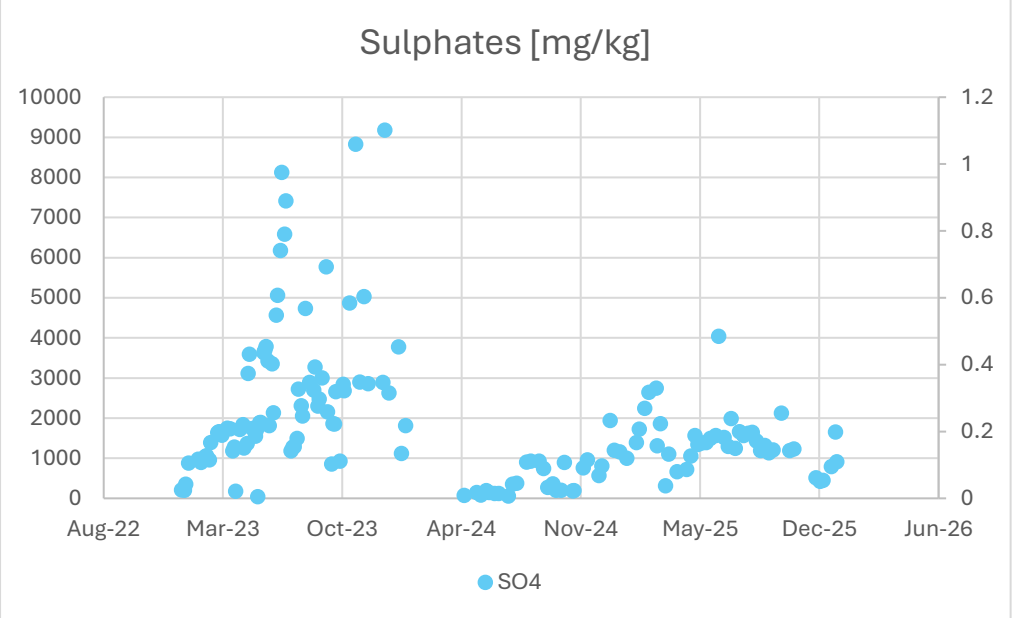

Figure 54: Tutuka Cooling water East Sulphates

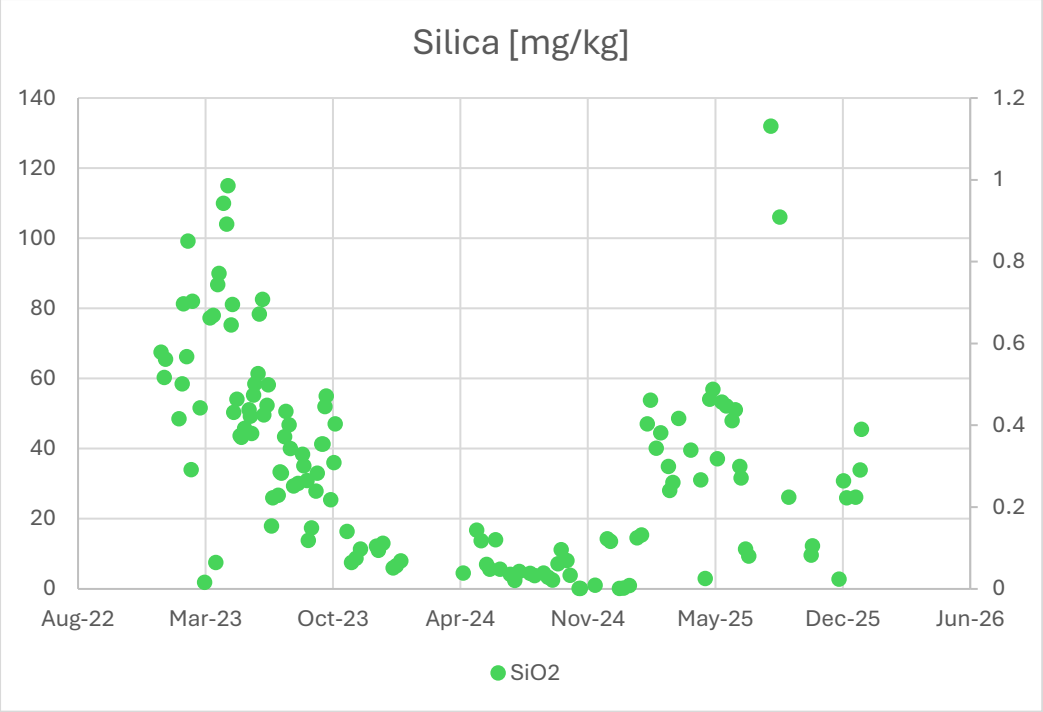

Figure 55: Tutuka Cooling water East Silicates

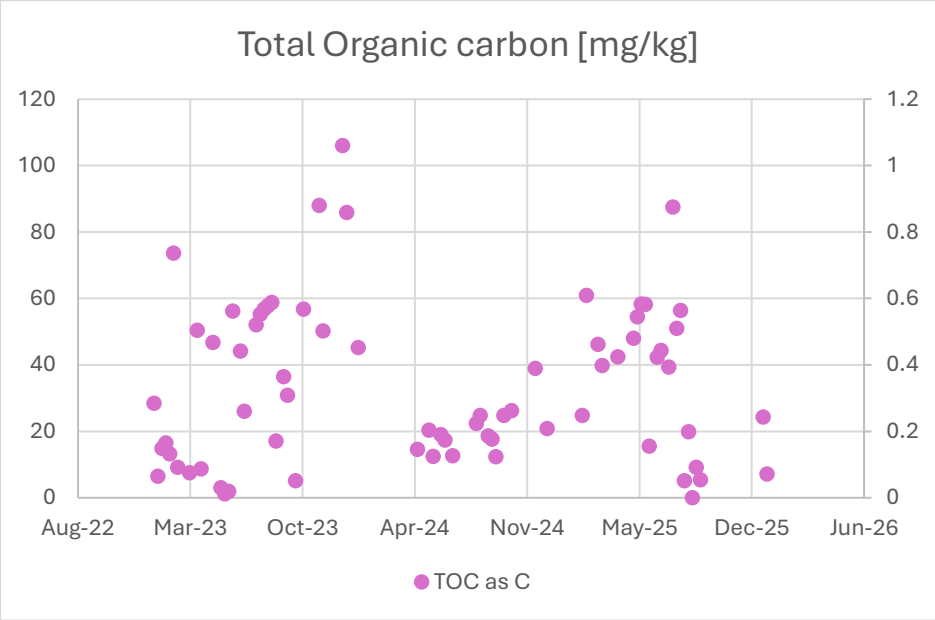

Figure 56: Tutuka Cooling water East Total organic carbon

2 PLANT BATTERY LIMITS

The plant battery limits will be different for the different source waters to the plant.

a. Wastewater which contains high levels of ash and oil (Tutuka Power Station)

The source water to the plant will be taken from the sump, which normally feeds the submersible pumps. The permeate will be collected in a tank and will be re-used for the cleans. The rest of the permeate will be fed back to the sump which feeds the clean water return pumps. The concentrate produced will be collected and discharged as per the procedure on the station when dredging the dams, or into the brine concentrate sump. The Employer will use the analysis of the brine (concentrate) stream to decide where it must be discharged.

Submersible pump house

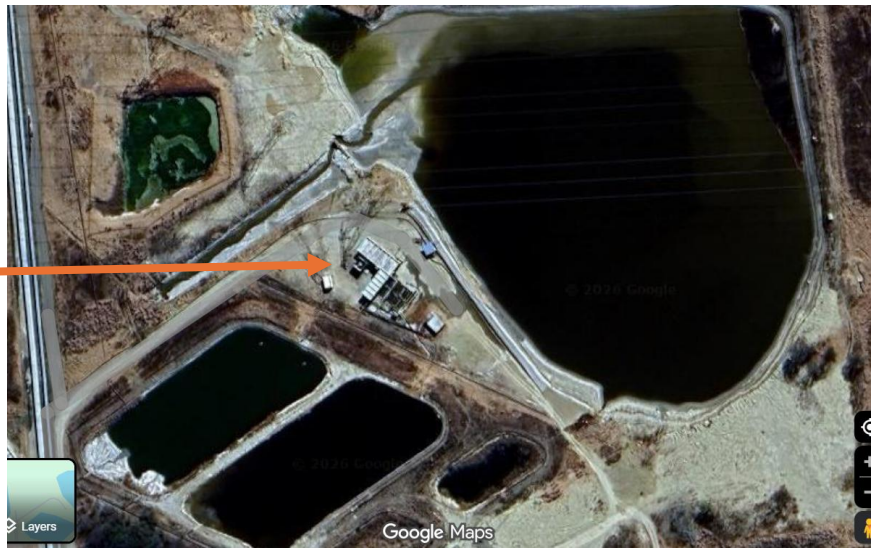

Figure 57: Google map of the Dirty water dams at Tutuka



Figure 58: Picture of the Submersible screw pump house at the Dirty water dams at Tutuka

- A google maps screenshot of the area is as per Figure 57.
- The link for the google maps location for the low level dams is as follows: https://www.google.com/maps/place/26%C2%B046'13.7%22S+29%C2%B021'30.7%22E/@-26.7704789,29.3559445,17z/data=!3m1!4b1!4m4!3m3!8m2!3d-26.7704789!4d29.3585194?hl=en&entry=ttu&g_ep=EgoyMDI2MDUyMC4wIKXMDSoASAFQAw%3D%3D

b. Ash water return (Duvha Power Station)

The source water will be taken directly from the AWR dam. The permeate will be collected in a tank and will be re-used for the cleans. The rest of the permeate will be fed back to the dam for the period of the test. The Employer will use the analysis of the brine (concentrate) stream to decide where it must be discharged.

- This source is still available from either the low-level dams or the high-level dams. Alternatively, the water supply can be taken from the AWR pumps or the Sluice booster pumps as per Figure 59: Schematic of the AWR system at Duvha.
- The link for the google maps location for the low-level dams is as follows: https://maps.app.goo.gl/a1aNdULu63s3Umcb8. A google maps screenshot of the area is as per Figure 60 below.
- The link for the google maps location for the high-level dams is as follows: https://maps.app.goo.gl/wik5ZMVfFbcxT4TZ8. A google maps screenshot of the area is as per Figure 61 below.

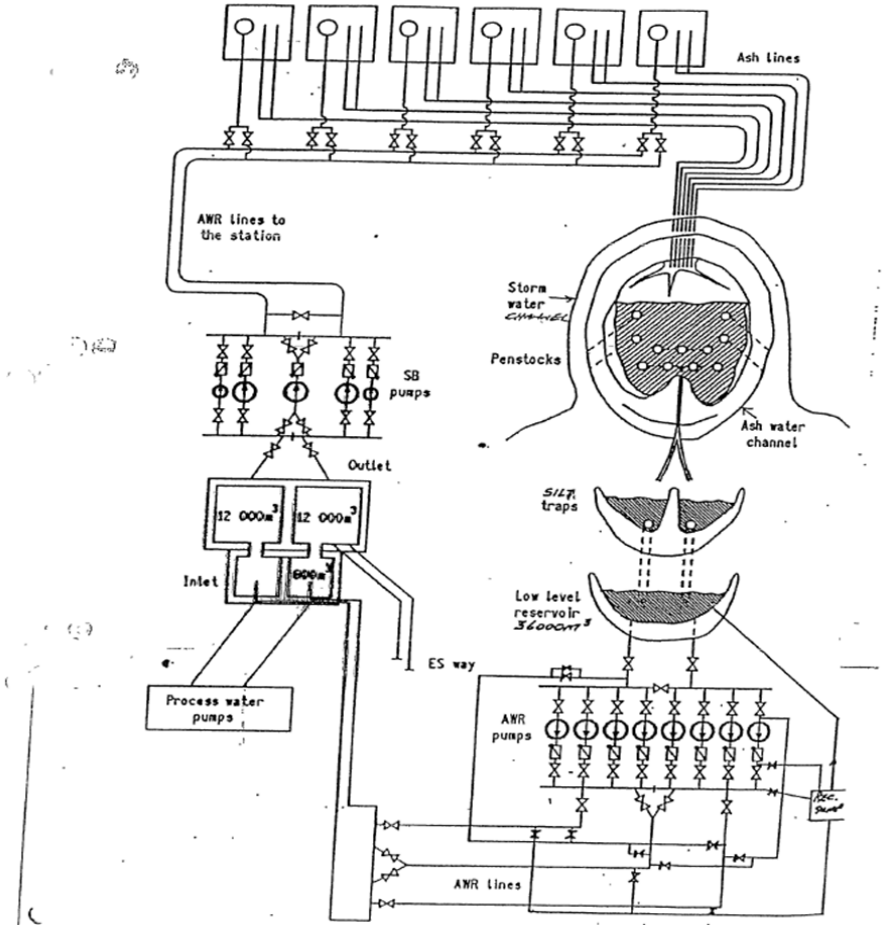

Figure 59: Schematic of the AWR system at Duvha

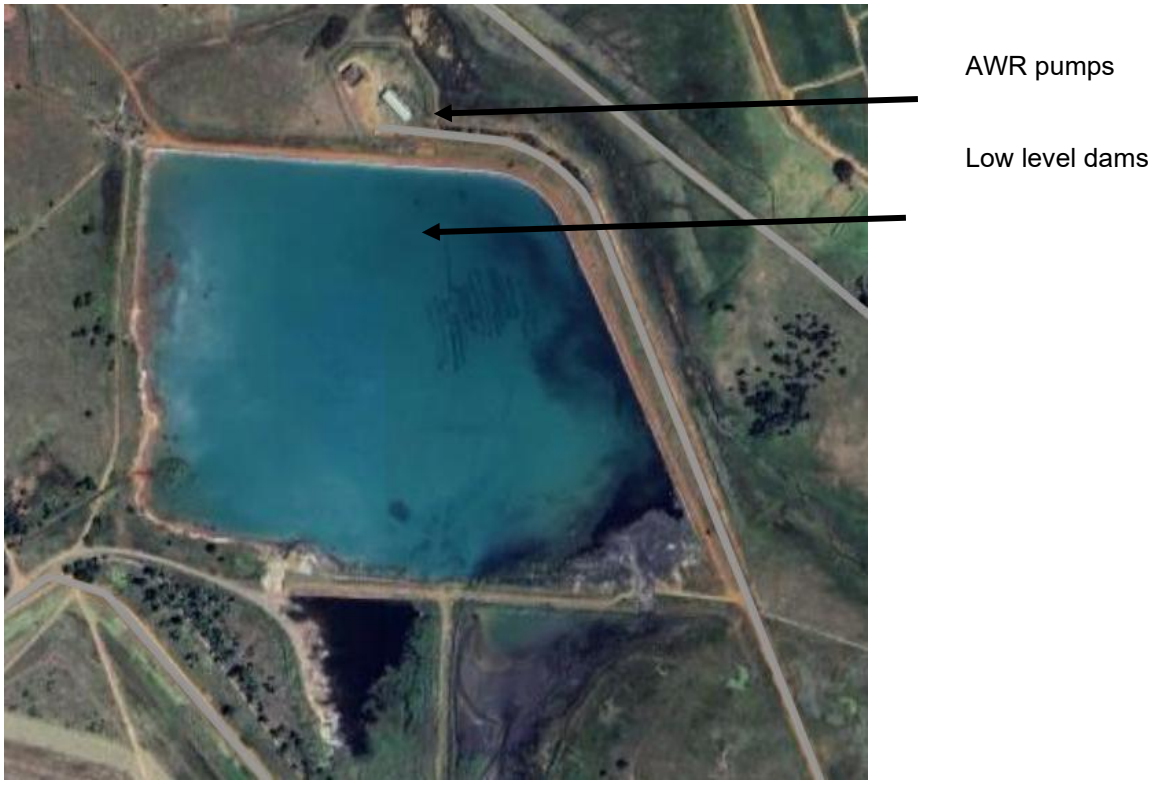

Figure 60: Google map of the Low level dams at Duvha



Figure 61: Google map of the High level dams at Duvha

c. Flue Gas desulphurisation (FGD) bleedstream (Kusile Power Station)

The source water will be taken directly from the wastewater storage tank itself or on the discharge. The permeate will be collected in a tank and will be re-used for the cleans. The rest of the permeate will be fed to the process drain recovery sump if the quality is better than raw water quality, otherwise station drains. The Employer will use the analysis of the brine (concentrate) stream to decide where it must be discharged.

- The google maps screenshot is as per Figure 63.
- The link for the tanks at the plant is as follows: https://maps.app.goo.gl/K3piiJcTKvWsAXzq7



Figure 62: Photo of the wastewater storage tank and pumps

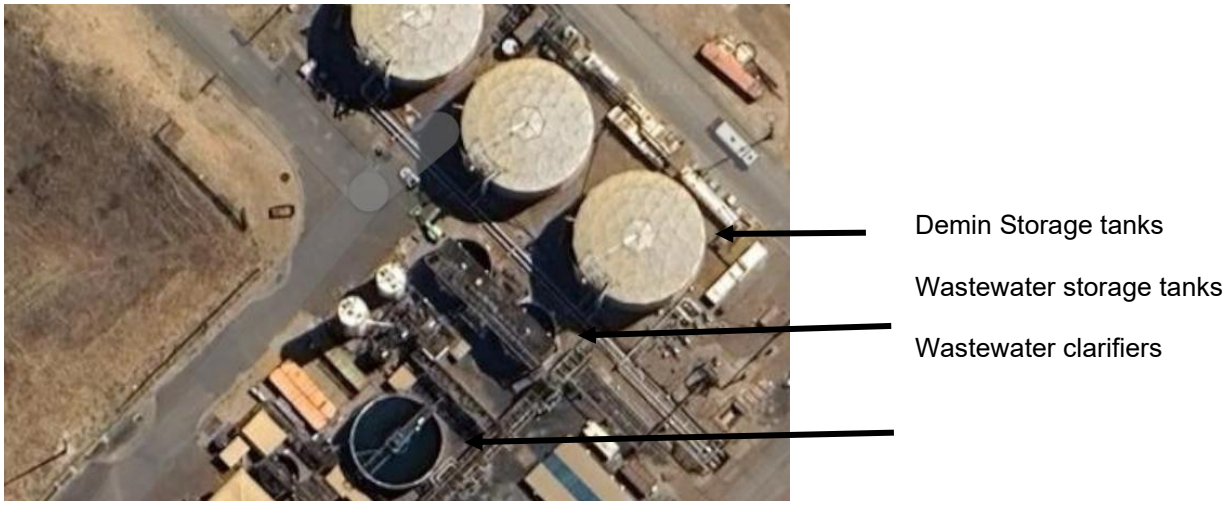

Figure 63: Google maps image of the area

d. Effluent from the neutralisation sump (ENS) (Tutuka Power Station)

The source water to the plant will be taken from the effluent neutralisation sump. The permeate will be collected in a tank and will be re-used for the cleans. The rest of the permeate will be fed back to the cooling water return launders. The Employer will use the analysis of the brine (concentrate) stream to decide where it must be discharged.

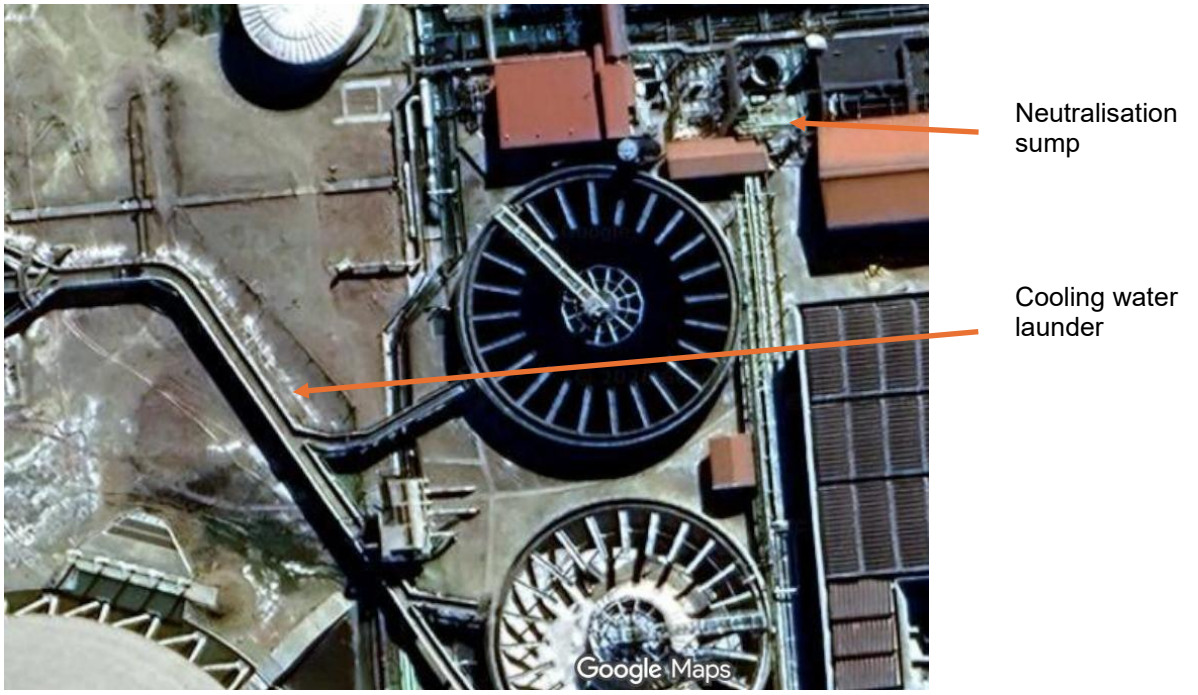

Figure 64: Google map of the Effluent neutralisation sump and cooling water launder at Tutuka



Figure 65: Picture of the effluent pump house at Tutuka

- A google maps screenshot of the area is as per Figure 64.
- The link for the google maps location for the effluent neutralisation sump is as follows: https://www.google.com/maps/place/26%C2%B046'36.3%22S+29%C2%B020'54.5%22E/@-26.7767554,29.3459091,653m/data=!3m1!1e3!4m4!3m3!8m2!3d-26.7767554!4d29.348484?hl=en&entry=ttu&g_ep=EgoyMDI2MDUyMC4wIKXMDSoASAFQAw%3D%3D.

e. Concentrated cooling water (Tutuka Power Station)

The source water to the plant can be taken from the Cooling water launders. The permeate will be collected in a tank and will be re-used for the cleans. The rest of the permeate will be fed back to the cooling water return launders after the take-off point. The Employer will use the analysis of the brine (concentrate) stream to decide where it must be discharged.

- The google maps screenshot is as per Figure 64.
- The link for the google maps location for the effluent neutralisation sump is as follows: https://www.google.com/maps/place/26%C2%B046'34.7%22S+29%C2%B020'52.6%22E/@-26.7769387,29.3453682,653m/data=!3m1!1e3!4m4!3m3!8m2!3d-26.7763066!4d29.3479539?hl=en&entry=ttu&g_ep=EgoyMDI2MDUyMC4wIKXMDSoASAFQAw%3D%3D

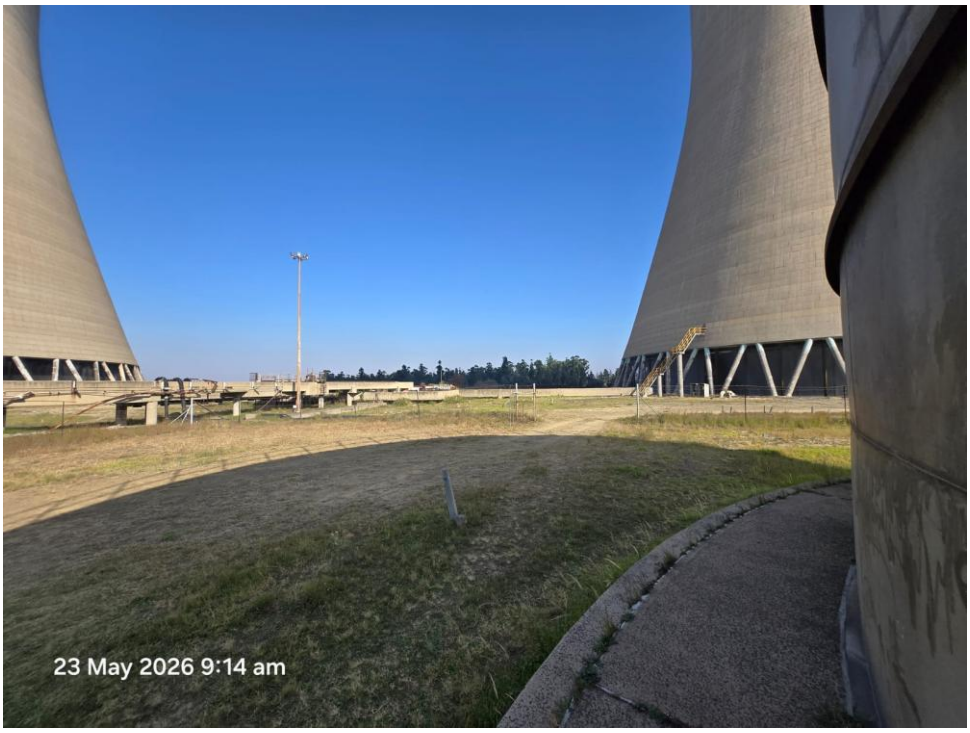

Figure 66: Picture of the CW launders and ponds at Tutuka

3 MODES OF OPERATION

The testing rig must be fully automated with an integrated logger to log the physical parameters. However, the rest of the operating and sampling will be done by the *contractor*.

4 LABORATORY TESTING

The *Contractor* must perform daily analysis for the monitoring of the plant and on a monthly basis the samples must be taken to a SANAS ISO 17025 accredited laboratory for analysis. The requirement is daily analysis of at least the feed, concentrate and permeate throughout the entire period of testing. The daily sample should be a composite sample from the operations during the day. Refer to the table below for the minimum required parameters.

Analysis required			
pH	TOC	Beryllium	Strontium

Conductivity	FOG	Boron	Zinc
“P” alkalinity	Chloride	Cadmium	Calcium
“M” alkalinity	Fluoride	Cobalt	Magnesium
Turbidity	Nitrates	Chromium	Sodium
Total hardness	Nitrates	Copper	Potassium
Calcium hardness	Sulphates	Iron	Nickel
Magnesium hardness	Silica	Phosphate	Lead
TDS	Aluminium	Manganese	Barium
TSS	COD	Ammonium	

The wastewater which contains oil (tutuka water from the wastewater dam) will require Fats, oils and grease (FOG) analysis to be done.

It should be noted that the stream from the FGD bleedstream is concentrated and will need special treatment during sampling and analysis. The contractor must sample and analyse as per the requirements in EPRI technical report 1013347: FGD Chemistry and Analytical Methods Handbook Volume 1 and 2 - Chemical and Physical Test Methods (Revision 2).

5 DURATION OF THE TEST

An estimated schedule for the duration of the tests is as per the Table below.

No.	Activity	Duration	Person Responsible
1.	Contract award		Eskom
2.	Lab scale tests	4-6 weeks	Contractor
3.	Pilot testing Oil and grit water	4 months	Contractor
4.	Pilot testing ENS water	3 months	Contractor
5.	Pilot testing FGD bleedstream water	3 months	Contractor
6.	Pilot testing AWR water	3 months	Contractor
7.	Pilot testing of CW	3 months	Contractor
8.	Review of results and compilation of the report	1 month	Contractor
9.	Review the report and accept	1 month	Eskom