SAN JOSE DEL MONTE CITY WATER DISTRICT

WATER TREATMENT PLANT NO. 2

PLANT OPERATION MANUAL

Contents

1 List of Abbreviations

The following is a list of abbreviations used in this document:

AI	Analog Input
AO	Analog Output
AQ	Aqueduct
BV	Black & Veatch
CoCoDAFF	Counter Current Dissolved Air Flotation Filter
DAF	Dissolved Air Flotation
DI	Digital Input
DO	Digital Output
FAT	Factory Acceptance Test
FCP	Filter Control Panel
GCEC	Golden City Engineering and Construction
HMI	Human Machine Interface
I/O	Digital and Analogue Inputs and Outputs
ICA	Instrumentation, Control and Automation
LCS	Local Control Stations (Start/Stop/E-Stop Pushbuttons)
MCC	Motor Control Centre
Ml/d	Million litres per Day
NTU	Nephelometric Turbidity Unit
P&ID	Process & Instrumentation Diagram
PAC	Poly Aluminium Chloride
PFD	Process Flow Diagram
PID	Proportional, Integral, Derivative (Control Loop)
PLC	Programmable Logic Controller
Ppm	Parts per million (same as mg/l)
UPS	Uninterruptible Power Supply
VSD	Variable Speed Drive (also known as VFD)
WTP	Water Treatment Plant

2 Background Information

2.1 Introduction

San Jose del Monte City Water Treatment Plant (WTP) is located in the Bulacan province in the Philippines near Manila. The WTP is made up of the old WTP1 which has a design capacity of 20Ml/d and utilises pulsation clarifiers followed by filters and he new 30Ml/d treatment plant WTP2. The new treatment plant will primarily supply the Sto. Cristo Reservoir.

This document gives instruction on the operation of WTP2 at San Jose del Monte and it makes up the 'Section 1: Operating Instructions' component of the 'Operation and Maintenance Manual'. It is accompanied by:

- Section 2 Manufacturer's Literature (in 3 volumes)
- Section 3 Drawings (PID, Hydraulic Profile, HMI, LCS and FCP Drawings)

Proprietary components are to be operated and maintained in accordance with the Manufacturers Literature in Section 2.

Section 3 contains PID and Hydraulic Profile Drawings which are to be referred to for clarification or additional information.

2.2 Process Summary

WTP2 receives up to 53Ml/d of raw water from a pressurised aqueduct (53Ml/d intake results in 50Ml/d of treated water allowing for treatment losses through waste products and washing processes). This raw water is then pre-treated in the form of screening and grit removal before flowing into the raw water tank to assist in equalising any peaks of high turbidity and some minor settling. The flow is then divided so that up to 20Ml/d flows to WTP1 and up to 30Ml/d flows to the additional processes within WTP2.

The water leaves the raw water tank to WTP2 via a splitter box where it may be dosed with Poly Aluminium Chloride (PAC) solution prior to entry into the flocculation tanks.

After the flocculation tanks the water enters a common CoCoDAFF Inlet Channel and then to six (6) CoCoDAFF units for flotation of sludge and filtration of water. Air saturated water is provided for flotation by two pressurised air absorbers. Water is fed to the absorbers from the Clear Water Tank by one of two variable speed recycle pumps operating in a duty/standby configuration. Air is fed to the absorbers from two air receivers supplied by duty/standby air compressors. The supply of the saturated water to the CoCoDAFF units is referred to as the recycle system.

The plant may be operated in direct filtration mode at times of good raw water quality. During direct filtration mode the recycle system is shut down and the filters operate without the DAF part of the process, as standard rapid gravity filters. The backwash control sequence also reacts to remove the de-sludge step from the sequence when the CoCoDAFF units are in "Filtration Only" mode.

The filtered water discharged from the CoCoDAFF units enters the Contact Channel where it is dosed with chlorine prior to entering the two Clear Water Tanks. The chlorinated clear

water is then pumped to Sto. Reservoir via four clear water pumps.

Within the WTP2 waste stream, the screenings and grit are transferred to a common collection bin for periodic offsite disposal. Floating sludge removed from the CoCoDAFF units gravitates to one of three Sludge Lagoons. Dirty wash water from the CoCoDAFF units gravitates to one of two Sludge Separation Tanks. The sludge from the separation tanks then gravitates to the sludge lagoons and the supernatant is pumped back to the inlet chamber of WTP2.

2.3 Control System Overview

The control system for WTP2 consists of two PLC's, the master in MCC1 serving the bulk of WTP2 equipment, and slave in MCC2 serving the PAC and Chlorine dosing systems. The PLCs are linked to each other by a hardwired Allen Bradley DH+ link. Each CoCoDAFF also has a Local Filter Control Panel (FCP), which monitors and controls the operation of the unit. These FCPs are hardwired to MCC1.

There are two Human Machine Interfaces (HMIs) to provide the operator and maintenance personnel plant interfaces via mimics and alarms. One HMI is located in the new WTP control room and the other is located in the PAC dosing room on MCC2.

Manual control of the drives is via the Local Control Stations (LCS) and the HMI's.

All process values of levels, timers, flowrates, pressures etc. entered in parenthesis within this document are estimated values to be confirmed during operation.

3 Main Plant Operation

3.1 Raw Water Inlet

Raw water flows to WTP2 under pressure from the aqueduct via 600 mm diameter pipework. Control of raw water flow is via the raw water inlet flow control valve (10-AV-01). This valve can be operated manually from the HMI's or automatically. When under automatic control, the control system modulates the position of the valve to maintain a flow set-point measured by the raw water flowmeter (10-FIT-02). The flow set-point is dependant on the required flow in the existing and new plants and can be modified to be diurnal or constant. The valve position is controlled via a PID loop with the flowmeter.

The flow set-point is actually a calculated value from the following equation:-

$$Q_T = Q_{WTP1(In)} + Q_{WTP2(Out)} \times 1.06 - Q_{SR}$$

Where: Q_T = Total raw water flow required (Calculated Set-point)
$Q_{WTP1(In)}$ = Flow required to WTP1 (Operator entered Set-point)
$Q_{WTP2(Out)}$ = Flow required out of WTP2 (Operator entered Set-point)
Q_{SR} = Flow from supernatant return pumps (direct from flowmeter 60-FIT-01)

Immediately downstream of the connection point with the Aqueduct there is an online turbidity meter (10-QIT-01) that will measure the turbidity of raw water in the Aqueduct. During and after heavy rainfall events in the catchment feeding the aqueduct, it is anticipated, and has been demonstrated in the past, that the turbidity in the raw water will increase suddenly for relatively short periods of time.

As the raw water turbidity increases to between 300 and 500 NTU the flowrate set-point for WTP2 ($Q_{WTP2(Out)}$) is automatically adjusted to 20Ml/d if it is previously above this level. When the raw water turbidity is above 500NTU the flowrate set-point for WTP2 ($Q_{WTP2(Out)}$) is automatically adjusted to zero (0Ml/d) and the inlet valve is closed. When the turbidity of the raw water reduces from one state to another (i.e. from above 300 to less than 300, or from above 500 to less than 500) the turbidity must remain in the next state for a period of longer than 5 minutes prior to initiating a change to the flow set-point. This will reduce any "hunting" effects. The set-points and treatment flow rates are rationalised during commissioning and trial operations.

Adjacent to the inlet chamber is an overflow weir. If the water reaches the overflow level a level switch (10-LSH-02) will activate an overflow alarm and the inlet control valve (10-AV-01) will close. The water will flow over the weir and flow to the storm water drainage system.

3.2 Screening

The first stage of Pre-Treatment is screening. Two screens (10-SC-01 and 10-SC-02) will prevent large gross solids from entering further WTP process steps. The automatic screen cleaning mechanisms and screening conveyor (10-CN-01) are activated by the measurement of differential level across the screen or after a preset time period has expired. The operation is based on the differential level across the inlet to the outlet of the screens (10-LIT-01 and 10-LIT-02). When the preset value of level differential is reached (initially set to 150 mm) the

cleaning cycle is activated, and will operate continuously for the required run time (the run time is initially set to 5 minutes). If the differential level has not been reached within the maximum time between cleaning cycles, a certain time period (initially set to 2 hours), the screens are automatically cleaned. The cleaning cycle includes rotating the screens (10-SC-01 and 10-SC-02), opening the flushing valves (10-AV-02 and 03) and operating the screening conveyor (10-CN-01). On completion of a cleaning cycle the screens will stop, flushing valves close, and screening conveyor continue to operate for a further 60 seconds before stopping. If the differential level is still above the set-point, a cleaning cycle will commence immediately on completion.

An "Operator Request" function is available to initiate a screen cleaning cycle. To instigate an "Operator Request" scroll to the "Screening System" Mimic on the HMI and press the "Operator Request" button. After this cleaning cycle the time between cycles timer is reset.

In most instances it is expected that both screens will operate together and hence have 50% of the load each. However, each screen is sized to cater for 100% of the raw water flow to allow the plant throughput to be maintained during servicing of one screen. Manual stop logs (10-SG-01, 02, 03, & 04) are provided on each channel inlet and outlet for isolation purposes. A portable submersible pump will be required to drain the Grit Channel to allow access.

The screenings collected are discharged into a discharge chute and then to a screenings bin located at ground level adjacent to the inlet structure.

3.3 Grit Removal

A grit separation system is utilised after the screens to remove sand and grit particles from the raw water supply. The grit system is designed to operate continuously as a single unit. However redundancy of critical components is provided. This system is monitored to ensure that any alarms and/or failures are immediately reported to the HMI's.

In the aerated grit chamber, grit is removed by causing the raw water to flow in a spiral pattern. Air is introduced to the grit chamber via duty/standby blowers (10-B-01 and 10-B-02) and air diffusers along one side causing a perpendicular spiral velocity pattern to flow through the tank. The blowers can operate continuously, intermittently or be turned off or they can be linked to operate based on the incoming water's turbidity. All this can be operated from the HMI's.

The grit removal function consists of a travelling bridge (10-TB-01) and duty/standby air lift pump units (10-P-01 and 10-P-02). The travelling bridge and associated air lift pumps are activated by a timer. When the turbidity is less than 5 NTU the travelling bridge is activated after a preset default time (initially set to four hours). One travelling bridge cycle consists of the travelling bridge being activated and leaving its "home" location and proceeding along the track with an air lift pump operating. When the travelling bridge hits one of the end proximity switches, the bridge reverses direction. When it returns to its home location and activates one of the proximity switches the bridge and air lift pumps stop. The PLC is responsible to activate the pulse to start the travelling bridge sequence based on the turbidity of the raw water in the aqueduct. All other control functions of the bridge are performed locally by a local control panel.

The grit classifier (10-GS-01) consisting of an inclined steel screw conveyor contained in a

stainless steel trough, will operate whenever the air lift pumps are operating. When the air lift pumps stop, the grit classifier will continue to operate for a preset time period (initially set to 30 seconds). The classifier transfers the grit to a Grit Bin (10-BIN-02).

As the turbidity of the raw water in the aqueduct increases the time between travelling bridge sequences is reduced. The maximum turbidity setting is 500 NTU, the default time between sequences is set at 240 minutes, and minimum time between cycles is set at 15 minutes.

The time between grit cycles with the turbidity is calculated using the following formula:

Time Between Cycles = [(x - 15) / (500 - y)](500 - z) + 15

Where: x = the maximum time between cycles (default of 240 mins)
y = the minimum NTU required to change the time between cycles (default 30)
z = the current NTU of the raw water.

3.4 Flow Separation

After grit removal, the pre-treated water flows into the raw water tank (10-TK-05), where water quality is equalized before flowing to either WTP1 or WTP2. The flow split is achieved by a flocculation splitter box (10-TK-06), which delivers flow to WTP2 over the weir and to WTP1 through a high level pipe connection within the raw water tank. The flowrate to WTP1 is controlled via a PID loop with the position of the control valve (10-AV-04) modulated to achieve the desired flowrate measured from the flowmeter (10-FIT-03).

When the water overflows a fixed weir and into the flocculation splitter box (10-TK-06), PAC is dosed as a flocculant. The flocculant is mixed by the turbulence of the water flow over the weir caused by the change in level from the weir to the floor of the splitter box.

The dosed water then flows into one of two flocculation tanks.

3.5 Flocculation

PAC solution is used as a flocculant aid for both WTP1 and WTP2. Further details of chemical dosing are given in Section 4 of this document.

For WTP2, the PAC dosing will only be initiated when high turbidity in the aqueduct raw water is detected through the online turbidity meter (10-QIT-01). The turbidity trigger point for PAC dosing is 4 NTU for a period of 60 seconds. This may be adjusted later based on operational experience.

After dosing with PAC, the dosed pre-treated water flows through the baffled tanks, where flocculation takes place.

Manual stop logs (10-SG-05, 06, 07, & 08) are provided on each flocculation tank inlet and outlet for isolation purposes as may be required.

3.6 CoCoDAFF Operation

Flocculated water flows under gravity from the CoCoDAFF Inlet Channel to one of six CoCoDAFF units. A level probe (10-LSH-03) in the inlet channel is used to detect an

impending overflow. The signal from this probe is used by the control system to automatically close the plant inlet control valve (10-AV-01) and prevent overflow. Any minor overflow, which may occur from the CoCoDAFF inlet channel, flows over the weir at the end of the channel and then by gravity into the storm water drainage system. If the level in the CoCoDAFF unit is above a predefined High High level (measured by the level transmitter and initially set for 3.3m), the relevant CoCoDAFF Inlet Control Valve (20-AV-01, 11, 21, 31, 41, or 51) will need to be closed. This is done automatically.

Each CoCoDAFF unit comprises a dissolved air flotation unit with counter current flow, combined with a rapid gravity filter, before discharging through the filtered water outlet pipe to the Contact Channel.

The level in each CoCoDAFF unit is controlled by the outlet flow control valves (20-AV-08, 18, 28, 38, 48, 58). When in automatic mode, these valves are modulated by the control system to maintain the level set-point in the relevant CoCoDAFF unit at a preset level (2.97m above the filter media), as measured by the Level (pressure) transducer (20-LIT-01). The control of the level in each unit using its flow control valve is via PID loops.

Each CoCoDAFF unit requires periodic cleaning both to remove the floating sludge and to clean the filter media. The required cleaning processes are described in Section 3.8.

In normal operation all six CoCoDAFF units are in service. However, the plant can be operated at a reduced throughput with fewer units in service as long as the flow to each unit does not exceed the design flow – 5.25 Ml/d (218.8 m3/h) during normal operation and 6.3 M/ld (262.5 m3/h) for short term use whilst another unit is being backwashed. Also note that the plant is able to be operated in "Filtration Only" mode when the turbidity in the raw water tank (10-QIT-01) is less than (5 NTU). In this mode the filtration function of the CoCoDAFF is enabled and the flotation function, the recycle system, is disabled.

3.6.1 Flotation

Within each CoCoDAFF unit the flocculated water is distributed evenly near the top water level by a system of submerged laterals and distribution cones, and flows downwards through the unit against a counter-current flow of rising micro-bubbles.

Recycle water (clear water saturated with air under pressure) is distributed uniformly over the CoCoDAFF area, by an array of nozzles located below the inlet cones and above the filter media. The pressure drop across the nozzles causes the air to come out of solution in the form of fine micro-bubbles, forming a dense air blanket. The functionality of the recycle system is further described in Section 3.7.

The flow of flocculated water is counter-current to the rising air blanket, promoting increased bubble-particle interaction. The micro-bubbles attach themselves to the floc particles and float to the surface to form a layer of sludge, which is supported by interstitial air and the layer of fine bubbles immediately below.

The sludge blanket is periodically removed hydraulically over a de-sludge weir. Sludge removal is aided by pumping a small quantity of flushing water to a trough positioned on the opposite wall to the de-sludge weir. This water overflows a "ski-jump" weir, designed to impart horizontal momentum to the sludge blanket and push it towards the de-sludge weir. Water is also applied to the walls during the de-sludge operation, to prevent sludge adhering to the walls of the de-sludging unit. The sludge gravitates to the Sludge Lagoons. A further description of the washing system is described in Section 3.8.

3.6.2 Filtration

Clarified water, having passed through the rising micro-bubble blanket, gets filtered by flowing through a sand media filter bed.

Filter run times are expected to be in excess of 24 hours, with longer run times possible during periods of low solids loading.

Loss of head is measured across the filter bed via differential pressure transmitters (20-PDIT-01 to 06). A high headloss (initially set to 2m or higher) for a sustained period of 30 seconds places the unit into the backwash queue.

The filtered water is sampled and turbidity is monitored at each unit outlet via turbidity meters (20-QIT-03, 04 & 05). A high turbidity signal (initially set to 1.5 NTU or higher) for a sustained period of 30 seconds, will place the unit into the backwash queue.

A combined air scour and backwash regime is used and filter washes are initiated automatically either on elapsed time, turbidity or headloss. Dirty washwater gravitates to the sludge separation tank. Refer to Section 3.8 for a detailed description of the washing functionality.

3.6.3 Mode of Operation

There are two modes of operation for the CoCoDAFF Plant – "Filtration Only" and "CoCoDAFF" modes. During "Filtration Only" mode the Recycle System, flotation function, is isolated and only the filtration component of the CoCoDAFF operates. During "CoCoDAFF" mode both flotation and filtration functions operate. This will enable the plant to operate efficiently and reduce the operating costs.

The system initiates Filtration Only mode during periods of good raw water quality (initially set to NTU less than 4). In Filtration Only mode the PAC dosing and recycle systems are isolated and the unit operates as a filter without flotation. It should be noted that the Recycle System is only required when the inlet turbidity is greater than 4 NTU (to be confirmed during commissioning). For the Recycle System to automatically be activated, the turbidity in the Raw Water Tank needs to be greater than 4 NTU for more than two (2) continuous minutes. Likewise for going from "CoCoDAFF" mode to "Filtration Only" mode, the Turbidity in the raw water tank needs to be less than 4 NTU for more than five (5) continuous minutes.

All CoCoDAFF units are de-sludged before changing the plant operation to "Filtration Only" mode. The air compressors are kept online to provide air for valve actuation. When the system changes to "Filtration Only" mode the de-sludges are performed and then the air saturated water inlet valves (20-AV-02, 12, 22, 32, 42, and 52) absorber outlet valves (40-AV-03 and 40-AV-04) are closed and the recycle pumps 40-PV-01 & 02 are stopped.

Switching from "Filtration Only" mode to "CoCoDAFF" mode involves restarting the Recycle System, namely the recycle pumps (40-P-01 & 02) and air absorbers (40-PV-01 & 02).

No De-sludges take place when the units are in "Filtration Only" mode. The wash sequence in "Filtration Only" mode is similar to the wash sequence in "CoCoDAFF" mode except the de-sludge step is omitted from the backwash sequence. All other timers and sequences are the same.

3.6.4 Default Starting Condition

When a CoCoDAFF unit first comes on line, whether they are in "Filtration Only" or "CoCoDAFF" modes, the following actions will occur:

1. All valves for the relevant CoCoDAFF unit will remain closed.
2. The Inlet Control Valve (20-AV-01) will open to allow flocculated water to fill-up the CoCoDAFF unit.
3. If in "CoCoDAFF" mode and when the water level reaches 2.9m, the Recycle Flow Inlet Control Valve (20-AV-02) is opened. Note that if the CoCoDAFF is in "Filtration Only" mode, the Recycle Flow Inlet valve remains closed.
4. The Filtered Water Control Valve (20-AV-08) is returned to its normal control mode: controlling the level within the CoCoDAFF to a constant level set-point (2.97m).

3.7 CoCoDAFF Recycle System

WTP2 has an air saturation recycle plant, referred to as the Recycle System, which is used to generate a supply of air saturated water for the flotation component of the CoCoDAFF units. Water for the recycle system is pumped from the clear water tanks, via the Recycle Pumps (40-P-01 and 02) into two air absorber vessels (40-PV-01 and 02) where air is absorbed under pressure. The air saturated water then flows under pressure from the absorber vessel to the CoCoDAFF units. Note that the Recycle System is only required when the plant is in "CoCoDAFF" mode and not required if the plant is in "Filtration Only" mode.

Water is pumped to the air absorber vessel using duty/standby recycle pumps (40-P-01 and 02). The recycle pumps are both variable speed units, with the speed of the pumps controlled to achieve a pressure set point (8 Bar). The pressure is measured by a pressure transmitter (40-PIT-01) on the discharge line of the recycle pumps. The pressure is controlled using a PID loop to control the speed of the pump, so that if the pressure rises the pump speed is reduced and as the line pressure falls, the pump speed is increased. Under automatic control, the required flow will generally be a function of the number of CoCoDAFF units in operation and the total plant flow. As such, the pump speed will usually only need adjustment when CoCoDAFF units are brought into, or taken out of service.

A flowmeter (40-FIT-01) on the discharge of the recycle pumps allows monitoring of the flow water flow to the air absorbers. The flowmeter is also used as a safety device for the pumps so that if after 30 seconds from the pump starting there is not flow signal from the flowmeter, the pump is stopped and a "no flow" alarm raised and the "CoCoDAFF" component isolated so that it operates in "Filtration Only" mode.

The recycle water is pumped into two air absorbers (40-PV-01 & 02) both operating when the recycle system is active. It is not expected to have either of these units unavailable, however if one absorber is out of service, the maximum plant throughput will have to be reduced when the recycle system is active. This is done automatically – details are given in Table 7.1 of this report. The air absorbers are a vertical, packed-bed type. In each unit the water is saturated with air under pressure.

There are two air compressors operating on a duty/standby basis to supply air into two air receivers. Pressure switches control the air compressor to maintain the required system pressure of between 8 and 9 bar. The two air receivers are arranged in parallel and supply both the air absorption units and the instrument air and ensures on power failure there is sufficient air to close the CoCoDAFF outlet valves. Further information on the compressed air system is described in Section 3.10.

The air/water interface is maintained in each air absorber by the inlet control valves (40-AV-01 & 02), which admits air from the air receivers. Each absorber has a set of four (4) level switches –

1. Level 1 – Low Low
2. Level 2 – Low
3. Level 3 – High
4. Level 4 – High High

Control of the Air Absorbers and associated control valves are as follows:

- If the level is at or above the High level probe (40-LIS-01 Level 3) then the air inlet valve is opened. The valve will remain open even when the level is driven below the high level probe by the introduction of air into the absorber.

- If the level is at or below the Low level probe (40-LIS-01 Level 2) then the air inlet valve is closed. The valve will remain closed even when the level rises above the low level probe by the absorption of air.

- The absorber vessel Low Low level probe (40-LIS-01 Level 1) is used to detect if the air/water interface has been driven too low and there is a danger that air may be driven out of the absorber vessel outlet. If this condition is detected, then the absorber outlet valve (40-AV-03 and 04) will close and raises an alarm. The effects of plant failure are covered in detail elsewhere in this document.

- The air absorber vessel outlet valve is also designed to close automatically on power failure to prevent compressed air being driven out of the absorber outlet into the CoCoDAFF units. The air absorber outlet valve will also close on air failure.

- The High High level probe (40-LIS-01 Level 4) in each air absorber is used to detect failure of the air absorber system and raises an alarm. Further details are given in the system failure section of this document.

A pressure relief valve is positioned on top of each absorber vessel.

3.8 CoCoDAFF Washing System

There are two (2) washing processes required for the CoCoDAFF:

- CoCoDAFF De-sludge – for removing the Float/Sludge formed from flotation.
- CoCoDAFF Backwash – for cleaning the filter media.

During a CoCoDAFF De-sludge, one of two De-sludge Pumps (30-P-03 and 04) transfers water from the clear water tanks to the de-sludge pipework on the relevant CoCoDAFF unit. The pumps are operated in a duty/standby configuration to ensure the standby pump will automatically start after the failure of a running pump and equal running time and sharing of the load.

Air for the air scour stage of the CoCoDAFF Backwash is provided by one of two blowers (30-B-01 and 02). The blowers have a common blow off valve (30-AV-04). At any time one air scour blower will operate, the other one being available as a standby. The blowers are operated in a duty/standby configuration to ensure the standby blower will automatically start after the failure of a running blower and equal running time and sharing of the load.

The CoCoDAFF air scour blow off valve (30-AV-04) is used to start the blowers at 50% flow to avoid disruption to the filter media packing layer as well as allowing any water in the air

manifold to be ejected. The valve is open when the blowers are stopped. On start-up the valve remains open for a period of 30 seconds to allow the air scour blower to be at full speed and the relevant air scour inlet valve to be fully opened (30-AV-06, 16, 26, 36, 46, and 56). The blow-off valve is then closed, and remains closed until the blower has stopped, where upon it is re-opened.

Water for the washing stage of a CoCoDAFF Backwash is provided by one of two Backwash Pumps (30-P-01 and 02). These pumps transfer water from the clear water tanks to the washwater pipework on the relevant CoCoDAFF unit, and through the filter media. The pumps are operated in a duty/standby configuration to ensure the standby pump will automatically start after the failure of a running pump and equal running time.

Control of backwash water flow is via the backwash flow control valve (30-AV-01). When under automatic control, the control system modulates the position of this valve to maintain the desired flow (598 m3/h), measured by the backwash flowmeter (30-FIT-01), equal to a flow set-point. This control function is via a PID loop. When the control system starts the backwash pump, the backwash flow control valve is opened. The flowmeter is also used as a safety device for the pumps so that if after 30 seconds from the pump starting there is not flow signal from the flowmeter, the pump is stopped and a "no flow" alarm raised and backwash sequence fails.

When under automatic control, the de-sludge pumps, backwash pumps, air scour blowers and associated equipment start and stop automatically as required.

3.8.1 CoCoDAFF De-Sludging

Each CoCoDAFF unit must be periodically de-sludged to remove the accumulation of floated sludge. The process sequence required to de-sludge a CoCoDAFF can either be carried out manually, or can be controlled automatically. Note that de-sludging is only required to operate if the CoCoDAFF is operating in "CoCoDAFF" mode.

The de-sludging process involves flushing the layer of sludge from the surface of the CoCoDAFF unit using a supply of clear water from the clear water tanks (30-TK-01 and 02) and pumping this via the de-sludge pump (30-P-03 and 04) to the CoCoDAFF sludge wash pipework. The sludge is flushed into the CoCoDAFF sludge drain pipe and then flows by gravity to one of three sludge lagoons. To prevent sludge adhering to the filter walls, they are sprayed throughout the de-sludging process by water from the service water system.

The time between de-sludge sequences is dictated by the turbidity of water in the raw water tank. Initially the values given in Table 3.1 will be used for the wash timer settings.

Table 3.1 – Default CoCoDAFF De-sludge Washing Intervals

Turbidity (NTU)	Time between Washes
4 to 10	10 hours
11 to 20	7 hours
21 to 40	3 hours
41 to 80	2 hours
81 +	1 hour

The CoCoDAFF de-sludge sequence is as follows (the numbering used in the sequence assumes that CoCoDAFF Unit 1 is being washed – use the equivalent valves for washing the other units as shown in Table 3.2):

1. The Filtered Water Control Valve (20-AV-08) is controlled to maintain a constant

outflow from the CoCoDAFF unit by maintaining its last position.
2. The Descum Spray Solenoid Valve (20-AV-09) is opened.
3. The Sludge Control Valve (20-AV-03) is opened.
4. The Scum Wash Water Control Valve (20-AV-07) is opened.
5. The duty De-sludge Pump (30-P-03 or 04) is started to provide a flow of flushing water.
6. After the required flushing time (initially set to 220 seconds) the pump is stopped.
7. The Scum Wash Water Control Valve (20-AV-07) is closed.
8. The Sludge Control Valve (20-AV-03) is closed.
9. The Descum Spray Solenoid Valve (20-AV-09) is closed.
10. The Filtered Water Control Valve (20-AV-08) is returned to its normal control mode: controlling the level within the CoCoDAFF to a constant set-point (2.97m).

Please refer to Table 3.2 for the equivalent equipment for each CoCoDAFF (CCD).

Table 3.2 – Equivalent CoCoDAFF Equipment

Item	CCD 1	CCD 2	CCD 3	CCD 4	CCD 5	CCD 6
Inlet Control Valve	20-AV-01	20-AV-11	20-AV-21	20-AV-31	20-AV-41	20-AV-51
Recycle Flow Inlet Control Valve	20-AV-02	20-AV-12	20-AV-22	20-AV-32	20-AV-42	20-AV-52
Sludge Control Valve	20-AV-03	20-AV-13	20-AV-23	20-AV-33	20-AV-43	20-AV-53
Backwash Water Inlet Control Valve	20-AV-04	20-AV-14	20-AV-24	20-AV-34	20-AV-44	20-AV-54
Dirty Washwater Control Valve	20-AV-05	20-AV-17	20-AV-27	20-AV-37	20-AV-47	20-AV-57
Backwash Air Control Valve	20-AV-06	20-AV-16	20-AV-26	20-AV-36	20-AV-46	20-AV-56
Scum Wash Water Control Valve	20-AV-07	20-AV-17	20-AV-27	20-AV-37	20-AV-47	20-AV-57
Filtered Water Control Valve	20-AV-08	20-AV-18	20-AV-28	20-AV-38	20-AV-48	20-AV-58
Descum Spray Solenoid Valve	20-AV-09	20-AV-19	20-AV-29	20-AV-39	20-AV-49	20-AV-59
Level Transmitter	20-LIT-01	20-LIT-02	20-LIT-03	20-LIT-04	20-LIT-05	20-LIT-06
Low Level Switch	20-LSL-01	20-LSL-02	20-LSL-03	20-LSL-04	20-LSL-05	20-LSL-06

3.8.2 CoCoDAFF Filter Washing

Each CoCoDAFF unit must be periodically washed to remove the accumulation of dirt in the filter bed. The filter washing sequence includes a normal de-sludge, if the CoCoDAFF is in "CoCoDAFF" mode. The filter is then drained down to a level just above the filter bed, where it is then subject to air scour, a combined air scour and backwash, and finally a backwash without air. After refilling with water the CoCoDAFF unit is available for service.

The time between backwash sequences is dictated by the turbidity of water in the raw water tank. Initially the values given in Table 3.3 will be used for the backwash timer settings:

Table 3.3 – Default CoCoDAFF Backwashing Intervals

Turbidity (NTU)	Time between Washes
0 to 10	42 hours
11 to 20	35 hours
21 to 40	26 hours
41 to 80	18 hours
81 +	12 hours

The CoCoDAFF wash sequence has the following stages (the numbering used in the sequence assumes that CoCoDAFF Unit 1 is being washed – use the appropriate valves for washing the other units as shown in Table 3.2):

Stage 1 – De-sludge (ONLY if in "CoCoDAFF" mode)

1. A de-sludge sequence as described in Section 3.8.1 but finishing with the Filtered Water Control Valve (20-AV-08) fixed in its last position to maintain a constant flow out of the CoCoDAFF when the de-sludge has completed.

Stage 2 - Drain Down (Start here if in "Filtration Only" mode)

1. The Inlet Control Valve (20-AV-01) and the Recycle Flow Inlet Control Valve (20-AV-02) are both closed together.
2. The water in the CoCoDAFF unit drains down until the Low Level Switch (20-LSL-01) is activated (initially set to 100 mm above the filter media).
3. The CoCoDAFF Filtered Water Control Valve (20-AV-08) is closed on Low level activation.
4. If after a predefined time period (30 minutes) the low level switch has not been activated, the Filtered Water Control Valve (20-AV-08) is closed and the Dirty Washwater Control Valve (20-AV-05) opens to dump any volume above the washout weir.

Stage 3 – Air Scour

1. The Air Scour Vent Control Valve (30-AV-04) is confirmed to be open.
2. The Backwash Air Control Valve (20-AV-06) is opened.
3. The duty Air Scour Blower (30-B-01 or 02) is started.
4. When the Backwash Air Control Valve (20-AV-06) is open and after a delay of 20 seconds, the air scour valve (30-AV-04) is closed.

Stage 4 - Combined Air Scour/Backwash

1. After the required air scour time (initially set to 60 seconds) the Backwash Water Inlet Control Valve (20-AV-04) and the Dirty Washwater Control Valve (20-AV-05) are opened together.
2. The duty Backwash Pump (30-P-01 or 30-P-02) is started to provide backwash water.
3. After the required combined air scour/backwash time (initially set to 430 seconds – 2.0 work volumes) the CoCoDAFF Air Scour Blower (30-B-01 or 30-B-02) is stopped and the Air Scour Vent Control Valve is opened (30-AV-04).
4. After a preset dwell time (initially set to 10 seconds) the Backwash Air Control Valve (20-AV-06) is closed.

Stage 5 – Backwash

1. After the required period of backwashing to waste (initially set to 540 seconds from pump start – 2.5 work volumes) the Dirty Washwater Control Valve (20-AV-05) is closed.
2. The water level in the CoCoDAFF rises to the low refill level (initially set to 2.9m) via

the Level Transmitter (20-LIT-01).
3. The Backwash Pump (30-P-01 or 30-P-02) is stopped.
4. The Backwash Water Inlet Control Valve (20-AV-04) is closed.

Stage 6 - Refill

1. The Inlet Control Valve (20-AV-01) and the Recycle Flow Inlet Control Valve (20-AV-02) are opened together. Note that if the CoCoDAFF is in "Filtration Only" mode, the air saturation water inlet valve remains closed.

Stage 7 - Return to Service

1. The Filtered Water Control Valve (20-AV-08) is returned to its normal control mode: controlling the level within the CoCoDAFF to a constant level set-point (2.97m).

3.8.3 Cleaning Initiation

When under automatic control, the CoCoDAFF units are monitored to determine if a cleaning sequence is required. The various types of cleaning sequences can be initiated by several methods. Note that the de-sludge cleaning process will only be activated when in "CoCoDAFF" mode.

Automatic CoCoDAFF de-sludges can be initiated by:

1. An operator request for the CoCoDAFF unit to be de-sludged.
2. The period since the CoCoDAFF unit was last de-sludged being greater than the maximum permitted time. Note that the maximum time between de-sludges will vary with the turbidity level in the raw water tank (10-QIT-02) – refer to Table 3.1.
3. Failure of the recycle system.
4. Initiated automatically as part of the wash sequence if in "CoCoDAFF" mode.

Automatic CoCoDAFF filter washes can be initiated by:

1. An operator request for the CoCoDAFF unit to be washed.
2. The CoCoDAFF unit outlet turbidity (20-QIT-03) being greater than a maximum permitted value (1.5 NTU).
3. The headloss across the CoCoDAFF unit filter bed (20-PDIT-01) being greater than a maximum permitted value (2m).
4. The period since the CoCoDAFF unit was last washed being greater than a maximum permitted time (see table 3.3).

Since the CoCoDAFF units share common backwash pumps, only one CoCoDAFF unit can be cleaned at one time. When under automatic control this is achieved by forming a queue of all units requiring to be cleaned. The control system will then automatically clean the unit at the head of the queue as soon as the preceding cleaning sequence is complete.

The queue of CoCoDAFF filters to be washed is formed in a priority order. The priorities of the different clean requests are shown in Table 3.4, with highest priority first and lowest priority last.

Table 3.4 – CoCoDAFF De-sludging Priority Order

Priority	Request
1	CoCoDAFF de-sludge on absorber fail request.
2	CoCoDAFF operator de-sludge request.
3	CoCoDAFF wash request - de-sludge stage.
4	CoCoDAFF time de-sludge request.

Table 3.5 – CoCoDAFF Filter Washing Priority Order

Priority	Request
1	CoCoDAFF operator wash request.
2	CoCoDAFF turbidity wash request.
3	CoCoDAFF headloss wash request.
4	CoCoDAFF time wash request.

If a particular unit has more than one reason to clean, for the purpose of forming the queue, the highest priority reason is used. This means that a unit will not have more than one entry in each queue.

When a unit requests a wash then it is entered in the queue immediately after the last entry in the queue with an equal or greater request priority. If there are no other requests in the queue then the unit is entered at the head of the queue.

If the wash request from a unit is removed before the unit is automatically washed then the entry for the unit is removed from the queue.

If the priority of the wash request for a unit which is in the queue changes and the priority of the new request is higher than that of the current request, then the unit is removed from its old position in the queue and re-inserted at the correct position in the queue for the new request priority.

Note that a de-sludging sequence can be performed during a washing sequence as long as the de-sludging component of the washing sequence has completed.

3.8.4 Automatic Cleaning Interlocks

Interlocks are provided when the CoCoDAFF units are under automatic control as follows:

a) A CoCoDAFF filter washing sequence will not be started if:

1. Another CoCoDAFF unit is being washed.
2. One sludge separation tank (60-TK-01 or 02) is not in "Filling" mode.
3. Insufficient water in the clear water tanks (30-TK-01 or 02).
4. Both CoCoDAFF air scour blowers (30-B-01 and 02) are not available.
5. Both backwash pumps (30-P-01 and 02) are not available.
6. Another CoCoDAFF unit is de-sludging.
7. If any control valve required for the filter wash sequence is not in the correct position.

b) A CoCoDAFF de-sludging sequence will not be started if:

1. The Plant is in "Filtration Only" mode.
2. Another CoCoDAFF unit is being de-sludged.
3. Insufficient water in the clear water tanks (30-TK-01 or 02).
4. Both de-sludge pumps (30-P-03 and 04) are not available.
5. If any control valve required for the de-sludge sequence is not in the correct position.

c) A CoCoDAFF filter washing sequence is aborted and a backwash sequence failure alarm raised if during washing:

1. The level in both sludge separation tanks (60-TK-01 and 02) is too high.
2. The level in the clear water tanks (30-TK-01 or 02) is too low.
3. Any valve required during the backwash sequence, other than the CoCoDAFF spray

water inlet valve or the CoCoDAFF air saturated water inlet valve, fails to operate correctly within a preset time.
4. The backwash pumps fail to deliver the correct flow when required.
5. Both air scour blowers (30-B-01 and 02) fail.
6. Both backwash pumps (30-P-01 and 02) fail.
7. A refill operation takes too long.
8. Power failure.

d) A CoCoDAFF de-sludging sequence is aborted if during de-sludging:

1. The level in the clear water tanks (30-TK-01 or 02) becomes too low.
2. Both de-sludge pumps (30-P-03 and 04) fail.
3. The CoCoDAFF outlet valve or sludge outlet valve fails to operate correctly within a preset time. If the flush inlet valve fails an alarm is raised.

3.8.5 CoCoDAFF Cleaning Sequence Failure

If an automatic backwash fails, the control valves of the failed unit are closed and the unit taken "Out of Service". Automatic de-sludging and backwashing of the remaining units in service will continue. The isolated unit will return to service when the fault has been rectified and the controls reset manually by the operator on the HMI. The plant flow is reduced if necessary based on the number of CoCoDAFF units in service.

3.9 Clear Water Supply

Filtered water from the CoCoDAFF units flows into the Contact Channel (30-TK-03), over a weir and into one of two Clear Water Tanks (30-TK-01 and 02). As the water flows over the weir it is dosed with Chlorine for final disinfection. Further details of the Chlorine dosing system are given in Section 4.

3.9.1 Clear Water Tank

The Clear Water Tank is divided into two compartments which can be manually isolated via two inlet valves (30-V-27 and 28) and the two outlet valves (30-V-29 and 30). Both compartments have ultrasonic level transmitters (30-LIT-01 and 02) and low level switches (30-LSL-01 and 02) to monitor the water level in the tanks. The low level switches are used as a safety device for the pumps. As well as feeding the clear water pumps, the tank supplies clear water to the backwash, recycle, de-sludge, motive water and service water pumps.

The level in the clear water tank is the average level between the "In Service" clear water tanks. So if they are both "In Service" and one of the level transmitters shows 2m and the other shows 2.1m the average is 2.05m. When a tank needs to be cleaned or a level transmitter or switch is not functioning, the relevant tank should be placed "Out of Service" to ensure that only the level of the "In Service" tank is considered. When a tank is place "Out of Service" the level switch for that tank becomes inactive.

Analysers are set up to monitor pH (30-QIT-03), turbidity (30-QIT-01) and residual chlorine (30-QIT-02). These analysers are connected to allow sampling and monitoring of the inlet and outlet of the Clear Water Tank. Two solenoid valves (30-AV-02 & 03) are used to alternate the samples from either the inlet or the common outlet to each tank. The PLC will record the measured values for each Clear water tank 30 seconds after the relevant solenoid valve opens/closes until alternating to the other connection point. The alternation sequence will initially be set to 5 minutes. Once the changeover from Inlet to Outlet has occurred, the PLC will maintain the last measurements taken from the Inlet for pH, Cl2 and NTU until the next alternation sequence.

3.9.2 Clear Water Pump System

The clear water pumps (50-P-01 to 04) in WTP2 pump treated water to the Sto. Cristo Reservoir. The pumping system has been designed to operate with up to 3 duty units and 1 standby unit to produce the required 30Ml/d maximum output. If the daily production needs to be reduced the operators can reduce the plant flow set-point on the HMI to an appropriate level. Note that the pumps are fixed speed units and therefore the plant output will vary only based on the number of pumps operating and the length of operating time. When the pumps are required for to be used they should be started in a staggered fashion so that the next pump will not start until the earlier one has reached full load.

The four pumps are designated:

1. Duty 1 Pump
2. Duty 2 Pump
3. Duty 3 Pump
4. Standby Pump

Every 24 hour period the duty designation is changed to ensure that all available pumps get equal operating time. The pumps will start operating in the order of duty designation. If a pump fails, the nearest duty designated pump not operating below the failed pump should start.

The pumps will operate to achieve the required set-point volume:

$Q_{WTP2(Out)}$ = Flow required out of WTP2 (Operator entered Set-point)

At a pre-determined set time on a daily basis (initially set at 0800 hours) the operator will enter the set-point volume of water to be produced for the next 24 hour period. The following table lists the number pumps required to achieve target volumes.

Table 3.6 – Target Volume Pumping Table

Target volume	Number of Pumps
Less than or equal to 10 MLD	1 Duty
More that 10, less than 20 MLD	2 Duty
More than 20, less than 30 MLD	3 Duty

For target volumes in-between the given table, the control system will run a pump at a fraction of time over the 24 hour period. To run at the target volumes, at least one clear water tank must be in service and minimum water levels must be exceeded.

The pumps are operated within level (30-LIT-01 and 02) and discharge pressure limits (50-PIT-01). A treated water flow meter (50-FIT-01) will monitor the flow that is discharged from the plant and also be used as a "No flow" alarm and pump interlock in the event of pump failure. If after 30 seconds from the first pump starting there is not flow signal from the flowmeter the pump is stopped and a "no flow" alarm raised.

The starting sequence of the clear water pumps is as follows:

1. If the level in the clear water tank(s) is above the minimum water level start the Duty Pump.
2. After 30 seconds, start the next Duty Pump until the number of pumps required to achieve the daily set-point volume has been reached.

Clear Water Pump System interlocks

1. If the level in the clear water tank reaches the predefined Low level and stays at or below this level for 20 seconds stop the last duty pump (i.e. if the flow set-point is between 20-30 stop the duty 3 pump, if the flow set-point is 20 or less stop the duty 2 pump).
2. If the level in the clear water tank reaches the predefined Low Low level and stays at or below this level for 20 seconds, or one of the low-low level switches is activated, stop all remaining operating duty pumps in a staggered manor so that only one pump stops at a time.
3. If the level in the clear water tank reaches the predefined High High level and stays at or above this level for 20 seconds and the maximum number of duty pumps are already running the inlet flow to WTP2 is to be reduced. During this event individual CoCoDAFF unit will be sequentially placed into out of service by having it's inlet valve and filtered water control valve closed to maintain a full level in the operating CoCoDAFF unit. CoCoDAFF units to be out of service mode will be based on the priority and on the queue developed for filter washing The inlet flow condition will be trimmed to remain in this state until the level in the clear water tank reduces to the High level.
4. If the pressure in the clear water pump delivery main, measured by 30-PIT-01, is at or above the High setting for more than 10 continuous seconds stop the last duty pump (i.e. if the flow set-point is between 20-30 stop the duty 3 pump, if the flow set-point is 20 or less stop the duty 2 pump). If after 60 seconds the pressure is above the High pressure setting, stop the next duty pump and repeat this process until there are no pumps operating.
5. If the pressure in the clear water pump delivery main, measured by 30-PIT-01, is at or above the High High setting for more than 5 consecutive seconds stop all operating pumps in a staggered manner.

3.10 Compressor Plant

The new WTP is provided with a proprietary packaged compressed air system which is used to provide compressed air for the pneumatic control valves and CoCoDAFF recycle system. This system comprises of duty/standby air compressors (40-B-01 and 02) and air receivers (40-PV-03 and 04) and provides filtered and dried compressed air at between 8 and 9 bar.

The starting and stopping of the air compressors is by the air compressor control operating on a duty/standby system and starting the duty compressor when the pressure is 8 bar and stopping the compressor when the pressure is 9 bar. The PLC will alternate the duty air compressor every 24 hours to share the load.

3.11 Service Water System

Service water for the works is supplied from a service water system located in the clear water pumping station. The service water system pumps clear water from the clear water tanks via one of two service water pumps (50-P-05 and 06). The pressure in the service water system is between 4 and 7 Bar and is maintained by the action of the pumps and a pressure vessel

and associated pressure switches and control system.

When the service water system is operating automatically from the control system it is started and stopped automatically as required by the action of the pressure switches. Also, when under automatic control the standby pump will start automatically after failure of the duty pump.

The service water system is stopped when there is insufficient water in the clear water tanks (30-TK-01 or 02) via activation of the low level switches of an "In Service" tank.

3.12 Drainage System

WTP2 is provided with two sump drainage pumps, one in the clear water pumping station (50-P-07) and the other in the sludge separation pumping station (60-P-03). The purpose of the sumps and associated pumps is to ensure that any water that collects in the pump houses due to maintenance and other operating activities is pumped to drainage. The pumps are automatically started and stopped based on activation of the in-built level switch. The drainage water is pumped to the nearest stormwater drainage point.

4 Chemical Plant Operation

4.1 PAC Dosing Plant

Liquid Poly Aluminium Chloride (PAC) is dosed to aid flocculation prior to the CoCoDAFF units.

4.1.1 PAC Storage

The PAC liquid is stored in plastic storage tanks in WTP1. The storage tanks are connected to two day tanks which are used to supply the PAC solution to the dosing pumps by gravity. The new dosing pumps are connected to the existing day tanks.

Normally, only one tank will supply PAC at a time and the outlet valves of the other tanks are closed. The tanks are changed over and filled manually when the duty tank level becomes low.

4.1.2 PAC Dosing

PAC is dosed into the inlet of the splitter box (10-TK-06) by one, two, or three variable speed and variable stroke dosing pumps (70-P-01, 02 and 03) depending on the required flowrate required. These pumps operate on a Duty 1/Duty 2/Standby basis.

The duty dosing pump(s) are started and stopped automatically as required based on the raw water flow (10-FIT-02) and the turbidity in the raw water tank (10-QIT-02). When the dosing pump is operating under automatic control the speed is varied in proportion to the plant flow (10-FIT-02) and the stroke in relation to raw water tank turbidity (10-QIT-02). The Duty 2 pump will automatically start when the output of the Duty 1 pump is no longer able to satisfy the raw water flow. The Duty 3 pump will automatically start when the output of the Duty 1 and Duty 2 pumps are no longer able to satisfy the raw water flow. To prevent hunting the addition and reduction of Duty pumps will require the flowrate to be above or below the change points for more than 60 seconds. The theoretical change points are 46 l/hr and 92 l/hr.

The PAC dosing pumps will also act as standby units so that if one pump fails, the next available duty pump operates in its place. For example, if one pump is required to operate Duty 1 pump will automatically operate. If Duty 1 pump fails, Duty 2 pump will automatically start. Likewise if two pumps are required, both Duty 1 and Duty 2 pumps will operate. If one of these pumps fails, the Duty 3 pump will automatically start.

The PAC dosing system is provided with a flow switch (70-FSL-01) and flow indicator (70-FI-01) on the common outlet pipe. The flow switch is used by the control system to raise an alarm if the flow is not detected while the pumps are running.

Each pump is fitted with suction flushing water facilities, discharge relief valve, loading valve, and pulsation damper.

PAC is transferred by the dosing pump to the dosing point through a single dosing line, and is dosed over the weir in the flocculation splitter box to assist with mixing.

The dosing concentration required is adjusted by using the dosing chart and rates used in Table 4.1.

Table 4.1 PAC Dosing Rate Table

Turbidity (NTU)	Equation	Dosage (ppm)
4 to 10	2(NTU)	8 to 20 ppm
11 to 30	0.75(NTU - 10) + 20	20.75 to 35 ppm
31 to 100	0.5(NTU - 30) + 35	35.5 to 70 ppm
101 +	0.35(NTU - 100) + 70	70.35 + ppm

Each PAC dosing pump has a maximum capacity of 46 L/h. The maximum dosing rate using three pumps at 100% flow is 138 L/hr. There is no flowmeter as part of this system so the flowrates are calculated based on calibration of pump speed and stroke versus output.

It should be noted that the PAC dosing pumps and equipment is suitable to be used for Alum if for any reason the dosing medium is changed. The installed equipment has been sized for PAC dosing and not Alum and may require additional unit(s).

As a guideline the following PAC Dosing Matrix shown in Table 4.2 is anticipated. These values will be updated during commissioning.

Table 4.2 – PAC Dosing Matrix

Stroke / Speed	10	20	30	40	50	60	70	80	90	100
10	4.6	6.6	8.7	10.7	12.8	14.8	16.9	18.9	21.0	23.0
20	6.6	9.2	11.2	13.3	15.3	17.4	19.4	21.5	23.5	25.6
30	8.7	11.2	13.8	15.8	17.9	19.9	22.0	24.0	26.1	28.1
40	10.7	13.3	15.8	18.4	20.4	22.5	24.5	26.6	28.6	30.7
50	12.8	15.3	17.9	20.4	23.0	25.0	27.1	29.1	31.2	33.2
60	14.8	17.4	19.9	22.5	25.0	27.6	29.6	31.7	33.7	35.8
70	16.9	19.4	22.0	24.5	27.1	29.6	32.2	34.2	36.3	38.3
80	18.9	21.5	24.0	26.6	29.1	31.7	34.2	36.8	38.8	40.9
90	21.0	23.5	26.1	28.6	31.2	33.7	36.3	38.8	41.4	43.4
100	23.0	25.6	28.1	30.7	33.2	35.8	38.3	40.9	43.4	46.0

From the concentration (ppm) required from table 4.1 and the plant flowrate, the actual dosing rate can be calculated using the following formula:

PAC flowrate required (L/hr) = ppm (concentration) x $Q_{WTP2(In)}$ / 1200

Where: Q_T = Total raw water flow required (Calculated Set-point)
$Q_{WTP2(In)}$ = Flow in to WTP2 (Calculated Set-point)
$Q_{WTP1(In)}$ = Flow required to WTP1 (Operator entered Set-point)

$$Q_{WTP2(In)} = Q_T - Q_{WTP1(In)}$$

4.2 Chlorine Plant

Chlorine dosing is provided to WTP2 by a chlorine gas system and two separate dosing systems: one to provide the pre-chlorine dose upstream of the raw water tank, and the second to provide the post chlorine dose immediately downstream of the contact channel. The gas supply system for WTP2 will incorporate using the existing chlorine gas cylinders and facilities in WTP1 and installing additional chlorinators and associated equipment in the existing chlorinator room. Additional pipework will link the chlorinators and carry the chlorine

gas to WTP2 where it is mixed with motive water prior to be dosed.

4.2.1 Chlorine Gas System

Chlorine gas under vacuum is provided to the two dosing systems by the existing chlorine cylinders located in the chlorine drum room.

Before chlorine gas is supplied to the dosing equipment the pressure in the gas line is reduced to below atmospheric using a vacuum regulator.

The flow of chlorine gas is regulated by the chlorinators located in the existing chlorine building. There are two automatic chlorinators primarily dedicated for post chlorination and one manual chlorinator dedicated for pre-chlorine.

The regulated supply of gas is then fed to WTP2 where two ejectors mix the pre and post chlorine gas with motive water. This chlorinated water is then used for the two dosing points.

Motive water for each dosing system is provided by duty/standby motive water pumps (80-P-01 & 02). These pumps automatically change over on pump failure. The motive water pumps are located in the clear water pump house and use water from the clear water tanks.

4.2.2 Post Chlorine Dosing System

The flow of Chlorine gas is regulated by one of two automatic chlorinators located in the existing chlorine building. There is one duty and one standby automatic chlorinator. Change over between the two chlorinators is carried out manually.

The chlorine residual is measured by a chlorine analyzer (30-QIT-02) at the clear water tank outlet. The post chlorine dose applied is controlled to be proportional to the clear water outlet flow (50-FIT-01) and also to maintain a preset chlorine residual in the clear water tanks (initially set to 2 ppm). This control is done via a slow acting PID loop controlling the dose rate from the automatic chlorinators. All control is performed by the automatic chlorinators, with the PLC's providing the necessary monitoring and signals as required.

4.2.3 Pre-Chlorine Dosing System

The flow of pre-chlorine gas is regulated by one duty manually adjustable chlorinator. If required the standby automatic chlorinator for the post chlorine system can be used with a manual change over between the two chlorinators.

The pre-chlorine dose is applied across the raw water splitter tank weir as required. The system is an on/off type control with dosing rates changed by manually adjusting the chlorinator. It is envisaged that the pre-chlorine will be used as a shock chlorine dose to reduce any build up of algae in the raw water and flocculation tanks.

To activate the pre-chlorine system the solenoid valve (80-AV-01) is opened to allow flow to the pre-chlorine ejector and the manual chlorinator is activated to supply chlorine as per its manually set dosing rate. The activation of the pre-chlorine dose is done by pressing the "Pre-Chlorine" button on the "Chlorine System" mimic on the HMI.

5 Waste Plant Operation

5.1 Waste Water Plant

Dirty backwash water from the CoCoDAFF units gravitates to one of two sludge separation tanks (60-TK-01 and 60-TK-02). The tanks are filled sequentially through two inlet control valves (60-AV-01 and 02). After a tank has been filled, it undergoes a settling, desludging and supernatant pumping phase. There are three modes of operation for the sludge separation tanks:

1. Filling Mode
2. Emptying Mode
3. Available

Supernatant from the sludge separation tanks is pumped to the inlet chamber of WTP2 by duty/standby supernatant pumps (60-P-01 & 02). The flowrate of the pumps is recorded by flowmeter (60-FIT-01). This flow is known as Q_{SR} (flow from supernatant pumps) and the measured flow is used in calculations for the total plant flows and other set-point calculations. The flowmeter is also used as a safety device for the pumps so that if after 30 seconds from the pump starting there is not flow signal from the flowmeter, the pump is stopped and a "no flow" alarm raised.

The level in each tank is measured by ultrasonic level transmitters (60-LIT-01 and 02). This level reading is compared against the following set-points by the control system:

1. Level 1 – Low Low (4m from the top of the structure)
2. Level 2 – Low (2.1m from the top of the structure)
3. Level 3 – High (1.725m from the top of the structure)
4. Level 4 – High High (0.5m from the top of the tank)

The High High level corresponds to the maximum fill level, and at this level the inlet control valve is closed and the relevant tank goes into "Emptying" mode. If the other Tank is "Available" at this time it then changes to "Filling" mode.

The High level is used to trigger the tank into "Emptying" mode. If the level in the tank is above the High level set-point, the current CoCoDAFF backwash will continue to completion after which the tank is placed into "Emptying" mode completed or failed.

During "Emptying" mode, the Low level is used by the control system to stop removing the sludge from the tank if it is still within the preset de-sludge time period (initially set to 18 minutes).

The Low Low level is used by the control system to stop the pumping of supernatant from the tank.

Assuming sludge separation tank 1 (60-TK-01) is in "Filling" mode, the sequence of operation is as follows:

1. The inlet control valve for tank 1 (60-AV-01) is opened and inlet control valve for tank 2 (60-AV-02) is closed. This starts the "Filling" mode for Tank 1.
2. Tank 1 receives waste water from the CoCoDAFF units as required.
3. The level in tank 1 reaches the High High level, or the level in tank 1 is above the

High level and CoCoDAFF backwash has completed AND tank 2 is available to be filled. This completes the Filling Mode for Tank 1.

4. Tank 1 inlet valve (60-AV-01) is closed. This starts the "Emptying" mode for Tank 1.
5. Tank 2 inlet valve (60-AV-02) is opened if it has completed its "Emptying" cycle.
6. Tank 1 awaits for the required settling time (initially set to 60 minutes).
7. The sludge lagoon inlet control valve (60-AV-05) is opened.
8. Tank 1 outlet valve (60-AV-03) is opened and desludging occurs.
9. Wait until the de-sludge preset time (initially set to 18 minutes) has elapsed or the level in the tank falls to below the Low level.
10. The sludge lagoon inlet control valve (60-AV-05) is closed.
11. The duty supernatant pump (60-P-01 or 60-P-02) is started.
12. Wait until the level in tank 1 falls to the Low Low level, or the Low Level Switch (60-LSL-01) is activated.
13. The operating supernatant pump is stopped.
14. Tank 1 outlet valve (60-AV-03) is closed.
15. Wait until tank 2 has completed its "Filling" cycle and its inlet valve (60-AV-02) closed.
16. Tank 1 inlet valve (60-AV-01) is opened. This starts the "Filling" mode for Tank 1.

The sequence for CoCoDAFF sludge separation tank 2 (60-TK-02) is identical to tank 1 however with 1 and 2 plant items transposed.

5.2 Sludge Plant

5.2.1 CoCoDAFF De-sludging

Sludge from the CoCoDAFF units de-sludging system gravitates to one of the sludge lagoons where it accumulates and dries. There are no specific controls for this system other than the ones described in CoCoDAFF de-sludging in Section 3.8.1.

5.2.2 Sludge Lagoons

Three sludge lagoons receive sludge from the CoCoDAFF de-sludging process and the sludge separation tanks. The automatic controls for the CoCoDAFF de-sludging process and the sludge separation tanks are discussed in earlier sections of this document. There are no automatic controls for the sludge lagoons. The lagoon inlet valves are operated and controlled manually by the operators. It is important to ensure that one sludge lagoon inlet valve from the CoCoDAFF and one from the sludge separation tank should always be open. There should always only be one sludge lagoon being filled at one time.

The design of the lagoons allows for settlement of the sludge with any additional supernatant water able to flow to drain. The quality of the supernatant should determine when the lagoons are required to be rotated. When a lagoon is full of sludge and a rotation of lagoons is required, the inlet valves to the new lagoon should be opened prior to closing the old lagoons inlet valves.

6 Control System

6.1 MCCs

There are two MCC's, MCC1 and MCC2, that are required for the operation of WTP2. MCC1 is located in the electrical room of WTP2 and MCC2 is located in the PAC dosing room of WTP1. The MCC's contain starters, PLC's, power supply for drives and instruments, UPS's and control terminations for all the equipment associated with the new plant.

Note that the air compressors, service water, and grit removal travelling bridge systems will have there own starter and control systems.

6.2 PLC

Each MCC has its own Programmable Logic Controller (PLC). The PLC in MCC1 is the master PLC whilst the one in MCC2 is the slave. The WTP2 PLC is located within MCC1 and monitors and controls all the WTP2 functions including the PAC dosing and Chlorine areas.

Human Machine Interfaces (HMI's) are provided in the Control Room and on the front panel of MCC2. The HMI's will show the operator the status of WTP via mimic displays. The HMI will also show any current alarms and operators with sufficient privileges are permitted to change certain operating set-points as required.

Drawings of the HMI's are included in Section 3 of this Manual.

6.3 UPS System

A UPS system is provided at the two MCC's. Each UPS will power the control systems for 15 minutes to allow safe plant shutdown on power failure.

6.4 Filter Control Panels

Each CoCoDAFF unit has a control panel adjacent to it in the CoCoDAFF building. These are designated Filter Control Panels (FCP). The FCPs display the current status of the individual CoCoDAFF units through the use of meters and indication lamps. They also are capable of manual control of washing sequence, and will send requests to the PLC for backwashes and/or de-sludges.

Drawings of the FCP's are included in Section 3 of this Manual.

There are five states of CoCoDAFF operation shown on the FCP:

1. Inhibited
2. "Filtration Only" Mode
3. "CoCoDAFF" Mode
4. Backwashing
5. De-sludging

All control valves associated with the CoCoDAFF unit have an associated indicator lamp on the FCP to advise the operator of the current configuration of open and closed valves. Also the relevant plant such as the backwash pumps, de-sludge pumps and air scour blowers have their individual status shown.

On each FCP there is a two way switch to alter between INHIBITED and AUTO modes. These control modes have the following functions:

Inhibited - In this condition the PLC has no control over the filters. When switched to inhibited, all control valves for that CoCoDAFF unit will close.

Auto - In normal operation the CoCoDAFF de-sludge operation and Filter backwashes are controlled automatically via the queue system described earlier in this document. A manual de-sludge can be initiated whilst in the Auto mode, if the plant is not in "Filtration Only" mode, by pressing the "Operator De-sludge" button. A manual filter wash cycle can be initiated whilst in the Auto mode by pressing the "Operator Filter Wash" button. The PLC will then automatically cycle through the relevant de-sludge or wash sequences. Note that even though an operator sequence has been initiated, the sequence must wait in line based on the queue priority tables and any de-sludges or washes currently in progress will run through their complete cycle. Also available is a step advance facility. Pressing the "Proceed" push button starts the next step in the wash sequence if the wash was instigated by an operator request. This is particularly useful during a demonstration or for any testing of fault correction activities.

6.5 Drive Control

All drives are controlled from the MCC. Each drive has the option of being in "Auto", "Manual" and "Off" modes through the use of a selector switch. When the drive is in "Auto" mode the PLC automatically starts and stops the drives, adjusts the speed and initiates automatic changeovers. In "Auto" mode, the push buttons on the LCS and MCC do not function. The only button that functions when the drive is in "Auto" mode is the emergency stop button on the LCS.

In "Manual" mode the drive may be stopped and started either "Locally" by the LCS or "Remotely" at the MCC. For variable speed drives, speed adjustments may also be made at the MCC.

When the drive is in the "Off" mode it is deemed to be unavailable and can not be started by the push buttons or by the PLC.

6.6 Plant Start-up

This section deals with start-up after a total plant shutdown. It is assumed that the following conditions exist:

1. General Plant and equipment are available.
2. The PLC is available.

The start-up sequence for the plant is automatic operation via the PLC as follows:

1. Open the inlet control valve (10-AV-01) to achieve the required flow set-point (Q_T).
2. PAC Dosing, if required, commences when the water level in the Raw Water tank reaches the low level switch (10-LSL-01) indicating that there is flow over the weir to the flocculation splitter box.
3. The CoCoDAFF units go through there individual start-ups as per Section 3.6.4. Depending on the turbidity of water in the raw water tank the CoCoDAFF units are either started in "Filtration only" mode or "CoCoDAFF" mode.
4. The Clear Water pumps start as soon as at least two CoCoDAFF units are available.

Throughout this process, water quality monitoring takes place to ensure water quality from each CoCoDAFF unit is within limits.

If the CoCoDAFF units have been out of service for a predefined period, each unit is automatically washed prior to entry into service. A timer in the PLC determines whether a unit has been out of service in excess of this predetermined period (initially set to 48 hours). This function may be overridden at the HMI if required.

6.7 Plant Shutdown

Shutdown of the plant can be initiated from the HMI and will automatically occur upon no power availability at the site. Individual CoCoDAFF units may be taken out of service by the operator at either the HMI or the FCP as required. The flow into the plant must then be stopped to prevent an overflow from occurring.

When a CoCoDAFF unit is taken out of service, it will automatically be backwashed. (The backwash sequence includes the necessary de-sludge if in CoCoDAFF mode). The CoCoDAFF unit is entered into the backwash queue with a manual request priority. When the unit has completed the backwash, it will then go out of service. This function may be overridden at the HMI with necessary authorisation.

6.8 Power Failure

If the power supply to WTP2 fails, all the drives will stop. The instrument air supply from the air receivers is sufficient to drive all the pneumatic actuated valves on the plant to the Fail Safe position as required. All electric solenoid valves will close on loss of power. Further details on plant shutdown are described in Section 7.2.1.

6.9 PLC Failure

On power failure to the PLC all outputs are de-energised such that all drives selected to automatic PLC control will stop. Any drives running in manual or under local package plant control will continue to operate normally.

All valves selected to automatic PLC control will close except for the air vent valve (30-AV-04), which will fail open on loss of output signal from the PLC. All electric solenoid valves will close on loss of output signal from the PLC.

7 Systems Failure

7.1 Automatic Plant Shutdown

When WTP2 is operating under full automatic control, the flow is automatically reduced, or stopped, if a number of failure conditions occur. After some of these failure conditions has occurred, and then cleared, the works will automatically restart, while after others an operator reset is required. The failure conditions, failure actions, restart conditions and restart actions are summarised in Table 7.1.

For reference, use the following legend for the different parameters used in Table 7.1.

Q_T = Total raw water flow required (Calculated Set-point)
$Q_{WTP1(In)}$ = Flow required to WTP1 (Operator entered Set-point)
$Q_{WTP2(Out)}$ = Flow required out of WTP2 (Operator entered Set-point)
Q_{SR} = Flow from supernatant return pumps (direct from flowmeter 60-FIT-01)
$Q_{WTP2(In)}$ = Flow in to WTP2 (Calculated Set-point)

Table 7.1 – Automatic Plant Shutdown Conditions

FAILURE CONDITION	FAILURE ACTIONS	RESTART CONDITION	RESTART ACTION
Only 4 CoCoDAFF units are available. (See Note 6).	If the WTP2 Output flow set-point ($Q_{WTP2(Out)}$) is greater than 20 Ml/d, change it to be equal to 20 Ml/d. (See Note 2).	More than 4 CoCoDAFF units are available. (See Note 6).	The WTP2 Output flow set-point ($Q_{WTP2(Out)}$) will return to the value it was prior to the change being made.
Only 3 CoCoDAFF units are available. (See Note 6).	If the WTP2 Output flow set-point ($Q_{WTP2(Out)}$) is greater than 15 Ml/d, change it to be equal to 15 Ml/d. (See Note 2).	More than 3 CoCoDAFF units are available. (See Note 6).	The WTP2 Output flow set-point ($Q_{WTP2(Out)}$) will return to the value it was prior to the change being made. The set-point is limited to the number of units available.
Only 2 CoCoDAFF units are available. (See Note 6).	If the WTP2 Output flow set-point ($Q_{WTP2(Out)}$) is greater than 10 Ml/d, change it to be equal to 10 Ml/d. (See Note 2).	More than 2 CoCoDAFF units are available. (See Note 6).	The WTP2 Output flow set-point ($Q_{WTP2(Out)}$) will return to the value it was prior to the change being made. The set-point is limited to the number of units available.
Only one CoCoDAFF unit is available. (See Note 6).	Change the total flow set-point so that $Q_T = Q_{WTP1(In)}$. Flow will therefore only go to WTP1. (See Note 1).	2 or more CoCoDAFF units are available. (See Note 6).	The total flow set-point (Q_T) will return to the value it was prior to the change being made. The set-point is limited by $Q_{WTP2(Out)}$ and the number of units available.
Air absorber outlet valves (40-AV-03 and 40-AV-04) closed and CoCoDAFF units are in "CoCoDAFF" Mode.	Change the total flow set-point so that $Q_T = Q_{WTP1(In)}$. Flow will therefore only go to WTP1. Stop the recycle pump (40-P-01 and 40-P-02). Force an "absorber fail de-sludge request" to the de-sludge queue for all CoCoDAFF units. (See Note 3).	Air absorber outlet valve (40-AV-03 or 40-AV-04) not closed. (See Note 5).	The total flow set-point (Q_T) will return to the value it was prior to the change being made. The set-point is limited by $Q_{WTP2(Out)}$ and the number of units available. Start the duty recycle pump (40-P-01 or 40-P-02).

FAILURE CONDITION	FAILURE ACTIONS	RESTART CONDITION	RESTART ACTION
Inlet Chamber high level switch activated (10-LSH-02).	Close raw water inlet valve (10-AV-01).	Inlet Chamber high level switch deactivated (10-LSH-02) for more than a preset time (initially 5 mins).	Allow the raw water inlet valve (10-AV-01) to open to its normal control position based on the Total Flow Set-point Q_T.
CoCoDAFF common inlet channel high level switch activated (10-LSH-03).	Change the total flow set-point so that $Q_T = Q_{WTP1(In)}$. Flow will therefore only go to WTP1. (See Note 1).	CoCoDAFF common inlet channel high level switch deactivated (10-LSH-03) for more than a preset time. (initially 5 mins).	Allow the raw water inlet valve (10-AV-01) to open to its normal control position based on the Total Flow Set-point Q_T.
Clear water tanks level (30-LIT-01 or 02) above the High High level set-point for more than a preset time (10 secs).	Change the total flow set-point so that $Q_T = Q_{WTP1(In)}$. Flow will therefore only go to WTP1. (See Note 1).	Clear water tank level (30-LIT-01 and 30-LIT-02) below the high level set-point for more than a preset time. (initially 5 mins).	Allow the raw water inlet valve (10-AV-01) to open to its normal control position based on the Total Flow Set-point Q_T.
Power fails.	Close all control valves except the air vent valve (30-AV-04) on the air scour main which will remain open. (See Note 4).	Power restored or generator is started.	If power is restored allow the raw water inlet valve (10-AV-01) to open to its normal control position based on the Total Flow Set-point Q_T. If the generator is started the plant starts in 50% Flow mode (see below).
Generator supplies the power to WTP2.	If the WTP2 Output flow set-point ($Q_{WTP2(Out)}$) is greater than 20 Ml/d, change it to be equal to 20 Ml/d. The Clearwater pumps are also modified so that there are only two (2) duty pumps (a maximum of 2 pumps can operate).	Power supply is changed so it is supplied from Meralco.	Allow the raw water inlet valve (10-AV-01) to open to its normal control position based on the Total Flow Set-point Q_T and remove the restrictions from the clear water pumps.

Note 1: This action will stop the flow of water to WTP2. The outlet valves on the CoCoDAFF units will close as the levels in the units fall below the level control set-points. If the CoCoDAFF units are operating in "CoCoDAFF" mode, the recycle system will still be running, the level in the CoCoDAFF units will then rise causing the outlet valves to re-open. Thus the level in each CoCoDAFF unit is maintained near the level control set-point. If the CoCoDAFF units are operating in "Filtration Only" mode, the outlet valves will close as the level falls. Since CoCoDAFF cleaning is not inhibited, any cleaning sequence that is in progress will continue. Also, further cleaning sequences will start as required as long as there is sufficient clear water available. All chemical dosing is proportional to plant flow, and so will stop with the plant flow to WTP2. The waste water and sludge plant will continue to operate as normal.

Note 2: This action simply reduces the plant flow to its maximum setting for the number of

CoCoDAFF units available. As such the plant will continue to operate normally at this reduced flow. If the rate needs to be reduced, further CoCoDAFF units will need to be placed offline.

Note 3: This action has a similar affect to that described in Note 1. However, since the recycle pumps are stopped the CoCoDAFF outlet valves will remain closed. Also, the CoCoDAFF units will all be de-sludged in sequence because there is no supply of air saturated water.

Note 4: Under power failure the plant will operate as described elsewhere in this document. However, if the generator fails to start on power failure, the raw water inlet valve, will close to prevent the works from overflowing.

Note 5: As detailed elsewhere in this document, the air absorber outlet valves close when the water level in the air absorber falls below the Low Low level probe. Also, when the outlet valve is closed the control system prevents the recycle pumps from running. Therefore, if the water level is below the Low Low level probe in the absorber then the operator must run a recycle pump manually from the pump starter in order to raise the level. The pump can then be put back into automatic mode.

Note 6: "Available" means that the unit is under automatic control, that the unit has not failed and that the unit is not washing.

7.2 Power failure

WTP2 is equipped with a standby generator (by others), which will need to be started and switched over manually after a mains power failure. On restoration of mains power the operator must manually switch the works back to the mains supply.

To prevent the works flooding during the changeover conditions, all control valves will return to the closed position except for the air vent control valve (30-AV-04) which will open and the sludge separation tank valves remain in their current position. This will result in any de-sludging operation that is in progress continuing under gravity. Note that after the de-sludging interval the sludge outlet valves will close.

If there is power supply available to WTP2, however WTP1 does not have power supply, the Operator will need to manually change the "Flow required to WTP1" Set-point ($Q_{WTP1(In)}$) to zero.

7.2.1 Effects of Power Failure

Power failure will cause the following effects on the equipment in WTP2:

1. All control valves will close except for the air vent control valve (30-AV-04) which will open and the sludge separation tanks control valves which will continue to control as required.
2. All drives will stop. This will result in the backwash pumps, the air scour blowers, the recycle pumps, clear water pumps, all chemical dosing, the supernatant pumps stopping.
3. All instrument and control circuits will continue to operate for 15 minutes via the UPS.

7.2.2 Effects of Re-establishment of Power

On power becoming re-established the following will happen:

1. After a preset delay (initially set to 30 seconds) for the control system, instruments and plant to recover from the power failure the control system will start to take control action.
2. All drive starters will have their trip circuits reset. This will clear any hardwire trips which are not valid.
3. All plant shutdown interlocks are disabled for a preset time (initially set to 5 minutes).
4. The Flow required to WTP1 ($Q_{WTP1(In)}$) and Flow required out of WTP2 ($Q_{WTP2(Out)}$) (Operator entered Set-points) will revert to the last flow set-point. These are used to calculate the total flow set-point so that QT and then control the WTP inlet control valve.
5. All modes of operation and drives will operate automatically in the same state as prior to the power failure.
6. If a CoCoDAFF unit is not in its default starting condition (level above 2.9m measured by 20-LIT-01 to 06), it will be flagged as out of service?
7. The PLC system will check if other system are available such as
    a. Inlet screens;
    b. Grit Removal;
    c. Post chlorinators;
    d. PAC dosing;
    e. Sludge Separation Tanks;
    f. CoCoDAFF ancillaries;
    g. Clear Water Tank;
    h. Clear Water Pumps;
8. Plant Start-up as described elsewhere will be initiated

Appendix A

Control System Schematic