Wellington Water Consultancy Panel

Connect Water

Wellington Sludge Minimisation Facility

Concept Design Report
May 2021

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Abbreviations

Abbreviation	Full name
ACB	Air Circuit Breakers
AGS	Aviation Ground Services
APE	Annual Probability of Exceedance
ATAD	Autothermal Aerobic Digestion
CH_4	Methane
BIM	Building Information Modelling
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
DAF	Dissolved Air Flotation
DB	Distribution Boards
DLD	Digestion - Lysis - Digestion
DS	Dry Solids
FMEA	Failure Mode and Effects Analysis
GBT	Gravity Belt Thickeners
GHG	Greenhouse Gas
GIS	Geographic Information System
GRP	Glass Reinforced Plastic
H_2S	Hydrogen Sulphide
H_2SO_4	Sulphuric Acid
HV	High Voltage
IL	Importance Level
IPS	Influent Pumping Station
LD	Lysis-Digestion
LINZ	Land Information New Zealand
MAD	Mesophilic Anaerobic Digestion
MSB	Main Switchboard
MCA	Multi-Criteria Assessment
MCC	Motor Control Centre
NaOCl	Sodium Hypochlorite
NaOH	Sodium Hydroxide
NZTA	New Zealand Transport Agency
OPEX	Operating Expenditure
ORP	Oxidation- Reduction Potential
PE	Polyethylene
PF	Peak Factor
PFCU	Power Factor Correction Unit
PLC	Programmable Logic Controller
PM	Project Manager
PMP	Project Management Plan

Abbreviation	Full name
PVC	Polyvinyl Chloride
RAS	Return Activated Sludge
SB	Standby
SCADA	Supervisory Control and Data Acquisition
SDP	Sludge Dewatering Plant
SLS	Serviceability Limit State
SR	Struvite Recovery
TD	Thermal Dryer
THP	Thermal Hydrolysis Process
TOTEX	Total Expenditure
UCS	Unconfined Compressive Strength
ULS	Ultimate Limit State
WAO	Wet Air Oxidation
WAS	Waste Activated Sludge
WCC	Wellington City Council
WE	Wellington Electricity
WIAL	Wellington International Airport Limited
WWL	Wellington Water Limited
WWTP	Wastewater Treatment Plant

Executive Summary

Wellington City Council (WCC) are proposing to establish a new Sludge Minimisation Facility (SMF) to substantially reduce the volume of sludge going to landfill and enable the future diversion of sludge from Southern Landfill. Under Stage 1 (Develop) of this project, site and process options need to be considered, assessed and a preferred site and process option combination is then selected.

The following four core project objectives have been established to provide direction to the selection and development of a preferred option for the SMF:

1. The volume of sludge sent to landfill is substantially reduced.
2. The resilience of sludge management in Wellington is secured.
3. The sludge management system is safe to construct, operate and maintain.
4. The whole of life cost (TOTEX) of sludge management is minimised across the wastewater network.

This report summarises the initial optioneering work undertaken to identify the preferred option and presents the concept design for the preferred SMF. The below table provides a summary of the key findings of the concept design process, and their associated section reference within this report.

Section Reference	Consideration	Key Findings
2.2	Design horizon and population basis	The proposed design horizon for the new plant is 50 years, or year 2073 assuming the plant is commissioned in 2023. Components of the new SMF will have different design lives. While the concrete structures have an expected lifespan of 50 years, the main mechanically intensive sludge processing plant is expected to have a lifespan of 20 to 25 years. Based on a detailed assessment of population growth, the population in year 2073 is 248,548. The population projections between 2023 and 2073 have been used to project sludge flows.
2.2	Sludge flows	The estimated peak week sludge flows in 2073 are 147 Tonnes Dry Solids (DS) / week. This assumes a peaking factor of 1.25 above average daily flows. The actual operating regime of the plant will be dependent on the process technology chosen.
2.2	Output sludge (biosolids) grade	The biosolids produced from the new Sludge Minimisation Facility will be subject to landfill disposal criteria (in the shorter term) and current and emerging biosolids guidelines for future re-use applications. For interim landfill disposal, a “B” stabilisation grade has been targeted.
3.5	Assessment criteria for process	The process options long list was identified and assessed against three fatal flaw criteria: » Maturity of technology

Section Reference	Consideration	Key Findings
	shortlist identification	» Dry solids content (DS%) of end product » Total plant footprint
3.6	Process options short list	Key shortlisted process options taken forward to the MCA workshop were: » Mesophilic anaerobic digestion + composting » Lysis-digestion + thermal drying » Mesophilic anaerobic digestion + thermal drying » Thermal drying only » Incineration » Auto-thermal anaerobic digestion + thermal drying » Digestion-lysis-digestion + thermal drying » Thermal drying + gasification » Wet air oxidation
3.7	Assessment criteria for preferred option identification	The below key assessment criteria and baseline weightings were collaboratively determined by key MCA participants: » Function: 21% » Mana Whenua Values: 20% » Complexity: 21% » Environmental: 17% » Cost: 21% Alternative weightings were also applied to provide a sensitivity analysis when determining the preferred option.
3.8	MCA workshop outcomes	The top three scoring options from the MCA workshop were: » DLD + TD at Moa Point » TD + Gasification at Moa Point » LD + TD at Moa Point
3.9	Post-workshop analysis	Two additional scoring reviews were undertaken, as recommended by the MCA participants: » A high-level landscape and visual assessment were undertaken, with reference to the NZ Coastal Policy Statement 13 and 15. » A high-level assessment of changes to carbon emissions for alternative electric powered thermal dryers. The additional scoring reviews made no notable changes to the top three ranking options
3.9	Highest scoring option	The initial highest scoring, preferred process option is a DLD + TD plant.
3.10	Alternative Preferred Option	One of the top-three ranking options from the MCA Workshop, LD + TD, is identified as an alternative preferred option. This option would require fewer process elements and associate infrastructure than

Section Reference	Consideration	Key Findings
		the base DLD +TD plant, which presents a capital cost reduction opportunity.
4.2	Process operating philosophy	The overall process is based on 24/7 operation, with storage tanks and equipment redundancy allowances to permit parts of the system to be taken out of service for maintenance without requiring a full system shutdown. It is expected that the DLD + TD plant will require 8/5 weekly operational site attendance, with potential weekend on-call requirements for emergency events. This, however, will be further assessed in the next stages of design.
4.2.1	Raw Sludge Storage and Conveyance	Raw sludge from Moa Point will be stored in existing tanks and pumped to thickeners in the new facility.
4.2.2	Sludge Thickening Process	Raw sludge from Moa Point will be thickened on gravity belt thickeners before blending with dewatered Karori sludge in the thickened sludge tank.
4.2.3, 4.2.6	Digestion Processes	Digester configuration is as follows. » Stage 1 influent sludge will be pre-heated using hot water from CHP system » Stage 2 influent sludge will be cooled using tepid water from Stage 1 » Digester tanks will be fixed-roof type » Biogas from both stages of digestion will be stored in membranes installed on the roofs of the Stage 1 digesters » Digesters will be mixed using unconfined gas recirculation » Biogas from both stages will be treated to remove siloxanes and hydrogen sulphide before use in the CHP system » Digested sludge will be stored in tanks for feed to downstream processes
4.2.4, 4.2.7	Dewatering Processes	Digested sludge will be dewatered using centrifuges for feed to downstream processes. Centrate from Stage 2 Dewatering will need to be ozone treated to remove light absorbing compounds before returning to the main WWTP.
4.2.5	THP	THP is required to make the remaining sludge more digestible. It is noted that both batch and continuous process configurations can be implemented in the SMF process.
4.2.8	Sludge Drying Process	Dewatered sludge from Stage 2 will be dried in indirect-heated belt dryers.

Section Reference	Consideration	Key Findings
4.4	Construction Staging Options	A two-staged approach to implementing the SMF has been assessed, to enable funding of the project to be smoothed over a longer period of time. The *D-THP-D* staging option is the recommended staging option for the project.
4.5	Key Process Design Changes for Alternative Preferred Option	The key process changes for LD + TD are: » Process plant reduced to only one digestion stage, post-THP. Sizing of digesters will be similar in size as the Stage 1 DLD + TD digesters » Larger centrifuges will be required for the Stage 1 and 2 dewatering processes » Different THP unit required. No notable difference in dimensions required.
5.1	Assessment criteria for process shortlist identification	A long list of potential site options was identified based on available spatial data and assessment against the below key criteria: » Size » Vehicle access » Noise and odour » Utilities access » Topography » Land use and designation Using these criteria, feasible sites were identified which fell generally into two groups, designated A and B, as follows: » Sites in **Group A** are all located **close to Moa Point WWTP**, and » Sites in Group B are all located close to Carey's Gully SDP
5.2	Site options short list	Two shortlisted site options (located at Moa Point and Carey's Gully) were determined through further geotechnical, planning investigations as well as engagement with WIAL and Southern Landfill operators to identify key site constraints.
5.3	Pipeline Options Analysis	Three alternative sludge transfer pipeline routes were investigated after the failure of the Mt Albert Tunnel pipelines in 2013 and 2020, with consideration to: » Pipeline route efficiency » Topography of route » Surrounding environment » Obstacles (bridges, culverts) » Utilisation of existing pipeline route Outcomes from this assessment (i.e. TOTEX costs, technical constraints identified) were inputted into the Carey's Gully site option for the MCA workshop.

Section Reference	Consideration	Key Findings
5.4	Preferred site option	Moa Point has been identified as the preferred site option for the SMF.
6.2.1	Site and Plant Layout Considerations	The Moa Point site layout has been optimised to satisfy construction and operational requirements with limited land space, as well as WIAL requirements. Site and plant layout optimisation included the following key features: » Stacked arrangement of key equipment, while remaining below 39m height limit set by WIAL » Biogas storage located on top of digester tanks » 5m space allowance for vehicle and crane access
6.2.2	Natural Gas Supply	An estimated 400kW of energy is required from natural gas to provide start-up and back-up energy supply for the TD plant. Network modelling undertaken by Powerco Ltd indicates that 25,000 kWh/d is available and sufficient to run the standalone dryer.
6.2.3	Stormwater System	It is proposed that any new stormwater systems be connected to the existing network. The Rational Method specified in the WWL Regional Standards was used to estimate the expected runoff flows and determine the concept design of the stormwater reticulation system.
6.2.4	Water Supply	It is proposed that a new potable water network be constructed to supply the various process areas to the site, from a single watermain. The watermain was sized to meet the requirements of WWL Regional Standards which stipulates the internal diameter to be at least 150mm.
6.2.5	Process Wastewater	It is proposed that this wastewater be collected at a common process drain system that would be reticulated around the ground floor of the main process building and then discharged to sewer (to be separated from stormwater).
6.2.6	Roading and Pavement Systems	Pavement systems are recommended to consist of two layers of 150mm thick NZTA M/4 AP40 and a surfacing of 50mm AC14.A, to meet the heavy vehicle requirements.
6.3	Geotechnical Considerations	Rockfall hazard from the west facing slope adjacent the AGS building is noted to be the greatest geotechnical risk to the proposed development of this site. It is proposed to stabilise the rock slope using rockfall protection measures (prevention) as opposed to limiting the travel of rockfall through use of barriers.
6.4	Structural Considerations	The main buildings and primary treatment tanks shall be considered as Importance Level 3 (IL3) structures. The design working life of both the main buildings and primary treatment tanks shall be taken as at least 50 years.
6.5	Electrical and Control	To accommodate the new upgrades, it is proposed to locate a new substation on site which will house dual HV transformers and switchgear. All

Section Reference	Consideration	Key Findings
	Systems Engineering Considerations	HV works and equipment would be provided by the local network utility provider (Wellington Electricity). The new facility's Programmable Logic Control (PLC) system will be provided to match the existing systems installed on the Moa Point WWTP and IPS sites.
6.6	Key Site Layout Changes for Alternative Preferred Option	The reduction of key process elements reduces spatial constraints and allows the possibility of retaining the existing Cyclotek building within the site envelope.
7.2	Procurement Strategy	The preferred procurement model for the SMF is an "ECI +co-delivery" model, provided that the capital cost estimates exceed \$100 million. This has been determined through assessment of options against MBIE procurement guidelines and discussions with WWL. The following key factors / considerations have been noted to be of central importance of the delivery model for this project: » The use of "pure" alliance vs competitive alliance style model » Use of four-stage approach for "pure" alliance model Applicability of established "standardised" alliance agreements and documentation, or utilisation of UK-based alliance or advanced collaboration models
7.3	Capital Cost Estimate	Level 2 capital cost estimates have been developed in accordance with the WWL Cost Estimation Manual (Rev.0 2019). Capital cost estimates for the single-stage construction of the DLD+TD and LD + TD plants are outlined below **<u>DLD + TD</u>** » Baseline estimate: \$125,068,000 » 95th percentile estimate: \$187,700,435 **<u>LD + TD</u>** » Baseline estimate: \$114,987,000 » 95th percentile estimate: \$172,748,400 Note: the above figures exclude associated WWL management fees.
7.4	Consenting Strategy	For Wellington City Council approvals, the recommended approach is to alter the existing Moa Point Drainage and Sewage Treatment Plant Designation (Designation 58). The following discretionary activities will require resource consent applications for Greater Wellington Regional Council approvals: » Discharge of contaminants to air from the operation of the SMF

Section Reference	Consideration	Key Findings
		» Discharge of stormwater from the site » Earthworks exceeding 3,000 m^2 for the construction of SMF
7.5	Stakeholder and Community Engagement Plan	A stakeholder and community engagement plan has been developed for the following key target audience: » Taranaki Whānui » Ngati Toa » WCC Waste Management Team » WCC Consents » GWRC Consents » WIAL » Cyclotek Industries » Moa Point Community Reference group » Miramar Golf Course

1 Introduction

1.1 Background Information

Most of Wellington's wastewater is treated at two wastewater treatment plants (WWTPs) – at Moa Point and Western WWTP. A by-product of these plants is sewage sludge, which is produced from primary and secondary wastewater treatment processes. This sludge is currently dewatered at the sludge dewatering plant (SDP) south of the Southern Landfill, known as Carey's Gully SDP, and then disposed of in the Southern Landfill.

Wellington City Council (WCC) requires a fundamental change in the management of the sludge produced from its WWTPs. The change needs to enable the management of the sludge to be 'de-coupled' from the existing disposal to the Southern Landfill and enable WCC to pursue other options for disposing of, or otherwise utilising the sludge. The Southern Landfill is located in an urban context, with a highly engaged and mobilised neighbouring community. WCC does not consider that the rate of landfilling at the site will remain viable in the longer term.

To achieve this, WCC wish to establish a new Sludge Minimisation Facility (SMF). The key drivers, objectives and outcomes for the project have been established in a project brief between WCC and Wellington Water Ltd (WWL) and are further described below. The project is to be delivered in several stages, including Develop (Stage 1), Consenting (Stage 2), Detailed Design (Stage 3), Procurement (Stage 4) and Construction (Stage 5).

The current Stage 1 (Develop) has involved the identification and evaluation of options for the sludge minimisation process, and where it is to be located. Having selected a preferred site and process through a multi-criteria assessment process, a concept design has been developed for the preferred option.

1.2 Project Objectives

Based on the strategic context provided in the project brief, the following project objectives have been established to provide direction to the selection and development of a preferred option for the site and SMF process:

Table 1-1: Project Objectives

Objective	How will we know we have achieved the objective?
The volume of sludge sent to landfill is substantially reduced, so that: » **Operational constraints on the landfill from biosolids disposal are removed (short term); and** » **WCC can meaningfully pursue its solid waste minimisation objectives / aspirations (longer term).**	» Operational constraints have been identified at the landfill, which are caused by the volume of sludge relative to solid waste available for mixing. Through consultation with the landfill operators, we will confirm that the proposed volume reduction is substantial and of the right form to take away these constraints. » The volume of sludge to landfill is minimized to the extent that it does not provide a significant constraint on the

Objective	How will we know we have achieved the objective?
	Council's proposed solid waste minimization initiatives.
The resilience of sludge management in Wellington is secured because: » **Sludge disposal is de-coupled from the landfill operation by removing the current landfill operational constraints imposed by biosolids disposal and enabling future beneficial re-use.** » **Foreseeable growth in sludge production over the next 50 years is accounted for; and** » **System reliability is acceptable to WWL based on the design, operating conditions and maintenance regime.**	» Social, environmental and cultural outcomes from future beneficial re-use are clearly defined. The technology selection can then be proven to have achieved these outcomes in previous projects. » The processing and disposal of sludge aligns to Mana Whenua values. » Sludge growth projection are confirmed, and performance tests confirm that the plant can achieve this capacity (or has space to do so). » System reliability is tested through FMEA analysis.
The sludge management system is safe to construct, operate and maintain.	» Tested through Safety in Design reviews to confirm that all parties are satisfied with the hazard controls proposed for construction and operation. » Measurement of injuries and near miss reporting through the life cycle of the project and early operations period.
The whole of life cost (TOTEX) of sludge management is minimised across the wastewater network.	» Key WWL / WCC stakeholders understand and agree that the TOTEX of the solution has been minimised based on the detailed whole of life cost analysis presented, with robust comparison against alternatives.

1.3 Scope

Under Stage 1 (Develop) of this project, sludge treatment process and site location options have been identified, a preferred option selected. A concept design for the preferred option has then been developed. This has been achieved through a six-step approach:

1. Long lists of site and process options were established, by undertaking desktop studies. For the process options, this has included a wide range of commonly available and emerging technologies across four categories. For the site options, a review of potentially feasible sites has been identified based on the construction and operating requirements of sludge processing facilities, as well as planning requirements.
2. The long lists of site options and process options has been reviewed by key project stakeholders, and criteria for the assessment of the long list has been established.
3. A "fatal flaw' assessment of the site options and process options has then been undertaken against the agreed criteria to create a short-list of potential process and potential site options. Early concept design and cost estimates have been prepared to help compare the shortlist options.

4. A multi-criteria assessment of the combined process / site options was undertaken to identify the preferred site and process option combination.
5. A concept design for the preferred option has been prepared, including the following key tasks:
6. A concept design of the process has been developed and engagement has been undertaken with international process vendors to confirm the size and configuration of the process.
7. Concept layouts have been developed which incorporate site utilities, vehicle access requirements and other key considerations that have a significant impact on the design.
8. Structural concepts have been developed for key structures to enable the preparation of Level 2 cost estimates.
9. A concept architecture for electrical and controls systems has been developed.
10. Site utilities and other key aspects of the civil design have been developed to concept level, including proposed geotechnical treatments.
11. Level 2 cost estimates (in accordance with WWL's Cost Estimation Manual) have been prepared.
12. Procurement, consenting and BIM strategies have been prepared to confirm the proposed delivery model for the project.

1.4 Purpose of This Report

The purpose of this report is to present the outcomes of the six stages noted above. This includes an overview of the site and process options that were detailed in previous reports (Stages 1 to 4 above). The concept design (Stage 5 above) for the preferred site and process option is then presented. This report also outlines a delivery strategy for execution of the project based on the preferred process and site option (Stage 6 above).

The report is structured into six key parts:

- Section 2 presents the process basis of design for the proposed plant
- Section 3 presents the process options identification framework
- Section 4 presents the concept design of the proposed plant and summarises the key processes and technologies involved
- Section 5 presents the spatial and constructability considerations, including selection of the preferred site, and the physical layout / construction of the proposed plant.
- Section 6 presents the delivery strategy for the project.

1.5 Previous Reports

This report should be read in conjunction with:

- Wellington Sludge Minimisation Facility Process Basis of Design Report (Connect Water, May 2020).
- Moa Point Sludge Pipeline Condition Assessment – Final Report (Connect Water, July 2020).
- Sludge Minimisation – MCA Workshop Minutes (July 2020).
- Sludge Minimisation – Site and Process Options Report (November 2020).
- Concept Design Report Addendum – Alternative Process Option (September 2020).

2 Process Basis of Design

2.1 Section Overview

This section presents the basis for the process design for the proposed Wellington SMF, including the design population and horizon, projected sludge flows, operating regime and use of the biosolids output.

2.1.1 Key Findings

The following table summarises the key findings of the process basis of design.

Section Reference	Consideration	Key Findings
2.2	Design horizon and population basis	The proposed design horizon for the new plant is 50 years, or year 2073 assuming the plant is commissioned in 2023. While the concrete structures have an expected lifespan of 50 years, the main mechanically intensive sludge processing plant is expected to have a lifespan of 20 to 25 years. Based on a detailed assessment of population growth, the population in year 2073 is 248,548. The population projections between 2023 and 2073 have been used to project sludge flows.
2.2	Sludge flows	The estimated peak week sludge flows in 2073 are 147 Tonnes Dry Solids (DS) / week. This assumes a peaking factor of 1.25 above average daily flows.
2.2	Output sludge (biosolids) grade	The biosolids produced from the new SMF will be subject to landfill disposal criteria (in the shorter term) and current and emerging biosolids guidelines for future re-use applications. For interim landfill disposal, a "B" stabilisation grade has been targeted as a minimum.

2.2 Process Basis of Design

A process basis of design was developed and agreed with WWL in May 2020, and is presented in Appendix A. The following table summarises the key sludge inlet and outlet parameters for the proposed SMF. These parameters have been determined to achieve the project objectives outlined in Table 1-1.

Table 2-1: Summary of Key Process Design Parameters Determined from the Basis of Design.

Design Basis Parameter	Summary
Design Horizon:	The design horizon of the plant, in terms of plant capacity, is proposed to be 50 years. Therefore, assuming that the plant is commissioned in 2023, the design horizon is year 2073.

Design Basis Parameter	Summary
	Components of the new SMF will have different design lives. The typical design life of a mechanically intensive sludge processing plant is 20 to 25 years. Therefore, a design horizon of 50 years represents two to two-and-a-half "life cycles" of the main process train of the new facility.
Design population:	Wellington City Council have published 30-year population projections from years 2013 – 2043[1], which have been used as a baseline population projection for the proposed SMF. These projections have then been tested by considering low, high and very high projections around the baseline. It is proposed that the SMF be sized to cater for a "high population growth" scenario, representing 20% growth above the baseline growth rate from WCC figures. This allows for some head room above baseline population growth and is thought to align with urban growth limitations in the Wellington City catchments. If population growth were to follow the "very high" scenario (which would create significant urban growth challenges), the capacity of the plant would be reduced to 33 years. However, this is still beyond the first lifecycle of a process/mechanical plant and would allow the capacity of the plant to be adjusted during a major upgrade in 20-25 years' time. Under the high scenario, the estimated population of the catchments serviced by Moa Point and Karori WWTPs is 248,548 persons. In the absence of specific trade waste growth predictions, it has been assumed that the trade waste contribution per head of population will stay the same as the population increases.
Sludge Flows:	An analysis of historical sludge flows over the last five years has been undertaken and then applied directly to the population projections. The historical sludge flow analysis has identified that sludge flows are reducing, and it is uncertain whether these trends will continue. Therefore, to accommodate future sludge flow increases caused by changes in the WWTP operation, 2015 sludge flows have been used, which are higher than the most recent available dataset for 2019. Applying the "high" population projection, and assuming no significant change in the industrial / domestic mix of waste in the WWTP influent or significant changes to the WWWTP configurations, the estimated peak week sludge production in year 2073 is 147 Tonnes Dry Solids (DS) / week, or 17,544 m^3/week (as 0.8% DS raw sludge). A peaking factor of 1.25 between average and peak weekly flows has been applied, based on analysis of rolling average weekly historical flows. A weekly sludge production figure has been used to accommodate daily variations in sludge production, which are expected to be accommodated by buffer storage.
Operating regime:	The above sludge flows assume continuous (24/7) operation of the SMF without maintenance shutdowns. The actual operating regime of the plant will be dependent on the technology and should be considered when evaluating process options. The projected sludge flows above do not account for additional capacity required for maintenance and operational

[1] *Source: https://forecast.idnz.co.nz/wellington/population-households-dwellings?WebID=10*

Design Basis Parameter	Summary
	interruptions and will be taken into account when sizing specific process options. The expected level of weekly operational site attendance is 8/5, with additional on-call attendance during the weekend.
Biosolids End Use Criteria:	The biosolids produced from the new SMF will be subject to landfill disposal criteria (in the shorter term) and current and emerging biosolids guidelines for future re-use applications. For landfill disposal, the key criteria are that the biosolids are a minimum of 20% DS and are of a volume that enables the biosolids to be disposed of at 1-part biosolids to 4 parts other solid waste. This is currently achieved (albeit barely and with considerable constraints), and the new SMF is expected to substantially improve this. In addition, odour management is a key driver for landfill disposal, so stabilising volatile organics which would otherwise generate odour is a key criterion for the new facility. In New Zealand, biosolids are graded for both “Stabilisation” (A or B) and “Contamination” (a or b) levels. The combination of these two grades (Aa, Ab, and so on) dictate what type of reuse pathways may be viable, subject to consenting. In order to allow future de-coupling of Wellington’s sludge from discharge to Southern Landfill, a pragmatic approach would be to treat the sludge to at least a B stabilisation grade[2]. This would represent a reduction in water content and odour-causing compounds, making it more acceptable to the landfill in the short-term, and produce a biosolid which a land discharge consent could be obtained for in the future. It may be more cost effective to treat to a class A stabilisation grade, once handling and transportation costs are taken into account, but this will need to be determined as part of the options development and assessment process. There is very little information available on the contaminant concentrations in the Wellington sludges and so the likely contaminant grade of any biosolid produced cannot be assessed at this time. Sludge characterisation sampling is currently being undertaken by Veolia which will allow determination of the sludge’s suitability for land application in particular. It is unlikely that the sludge will meet the current ‘a’ contaminant grade as municipal sludges are typically too high in copper and zinc to meet those concentration limits. It is worth noting that the current guidelines are under revision, with the future guidelines being more permissive with respect to heavy metal concentrations. However, the timeframe for adopting the new guidelines is uncertain. As such the current guidelines are considered to be the most relevant.

[2] *Guidelines for the Safe Application of Biosolids to Land in New Zealand. (August 2003).* New Zealand Water & Waste Wastes Association (NZWWA)

3 Process Options Identification and Selection

3.1 Section Overview

This section presents the process by which the preferred process option was identified and selected, through a long listing, short listing and multi-criteria assessment.

3.1.1 Key Findings

The following table summarises the key findings of the process options identification and evaluation.

Section Reference	Consideration	Key Findings
3.5	Assessment criteria for process shortlist identification	The process options long list was identified and assessed against three scoring parameters: » Maturity of technology » Dry solids content (DS%) of end product » Total plant footprint
3.6	Process options short list	Key shortlisted process options taken forward to the MCA workshop were: » Mesophilic anaerobic digestion + composting » Lysis-digestion + thermal drying » Mesophilic anaerobic digestion + thermal drying » Thermal drying only » Incineration » Auto-thermal anaerobic digestion + thermal drying » Digestion-lysis-digestion + thermal drying » Thermal drying + Gasification » Wet Air Oxidation
3.7	Assessment criteria for preferred option identification	The below key assessment criteria and baseline weightings were collaboratively determined by key MCA participants: » Function: 21% » Mana Whenua Values: 20% » Complexity: 21% » Environmental: 17% » Cost: 21% Alternative weightings were also applied to provide a sensitivity analysis when determining the preferred option.
3.8	MCA workshop outcomes	The top three scoring options from the MCA workshop were:

Section Reference	Consideration	Key Findings
		» DLD + TD at Moa Point » TD + Gasification at Moa Point » LD + TD at Moa Point
3.9	Post-workshop analysis	Two additional scoring reviews were undertaken, as recommended by the MCA participants: » A high-level landscape and visual assessment were undertaken, with reference to the NZ Coastal Policy Statement 13 and 15. » A high-level assessment of changes to carbon emissions for alternative electric powered thermal dryers. The additional scoring reviews made no notable changes to the top three ranking options
3.9	Highest scoring option	The initial highest scoring, preferred process option is a DLD + TD plant.
3.10	Alternative Preferred Option	One of the top-three ranking options from the MCA Workshop, LD + TD, is identified as an alternative preferred option. This option would require fewer process elements and associate infrastructure than the base DLD +TD plant, which presents a capital cost reduction opportunity.

3.2 Overview of Approach to Process Options Assessment and Selection

A three staged approach was used to identify and select a preferred option for the Wellington SMF. This included:

1. An initial long list of options was developed based on an initial desktop study which considered a wide range of commonly available and emerging technologies across four sludge management technologies categories, as outlined in Section 3.3.
2. A fatal flaw (traffic light) analysis was undertaken to identify non-favourable long list options and identify a short list. This included both technical considerations and consultation with iwi to understand cultural concerns with sludge management that might influence process selection.
3. Following development of initial concepts for the short-listed options, a multi-criteria assessment of the short-listed options was undertaken to establish a preferred process option. This included a sensitivity analysis to confirm the multi-criteria assessment outcome.

3.3 Sludge Management Pathways

Sludge treatment processes usually involve a combination of individual process units, which when combined, are used to achieve one or more outcomes. The individual process units can be classified as follows:

» **Concentration Processes** – Reducing sludge volume, generally by removing water from the sludge

» **Stabilisation Processes** – Stopping or stabilising biological activity, which can reduce odour emissions from further handling / disposal.

- **Hydrolysis Processes** – Treatment to support the enhanced recovery of energy or nutrients, or aid sludge reduction.
- **Conversion Processes** – Conversion of the sludge into other forms for beneficial re-use.

Figure 3-1 provides an overview of the range of process units for sludge treatment, which have been organised into potential pathways depending on the desired end product or the characteristics of the sludge produced in a certain WWTP.

Refer to Appendix B for an overview of the technologies that are classified under each of the processes above.

3.4 Sludge Types

As noted above, there are a range of technologies available to process the sludge, which require different sludge product inputs, and produce different sludge product outputs. The general classifications of different types of sludges that occur at different stages in sludge processing include:

- **Raw sludge** – this is the sludge produced in liquid form from the WWTP process. For the Wellington City WWTPs, this includes primary sludge (from the primary clarifiers) and secondary sludge (from the MBBR process). Its typical consistency is a non-viscous liquid in the range of 0.5 – 2% dry solids.
- **Thickened sludge** – thickening processes are typically used to remove some of the freely available water from the raw sludge, to produce a concentrated (thickened) liquid sludge, typically of 2 – 6% dry solids consistency.
- **Dewatered sludge** – dewatering processes are typically used to remove as much freely available water as possible from either raw or thickened sludge to produce a moist solid "weak soil like" product, typically ranging in concentration from 18 – 28% dry solids. The dryness of the sludge is dependent on the make-up of the raw sludge (the types of processes employed in the WWTP) and the type of dewatering process used, including the amount and type of chemicals (such as polymer) added to achieve dewatering.
- **"Converted" sludge** – this relates to the range of end products from conversion of sludge through processes such as drying, pyrolysis, gasification and the like. Each of these processes produces (generally) a dryer and/or inert product.

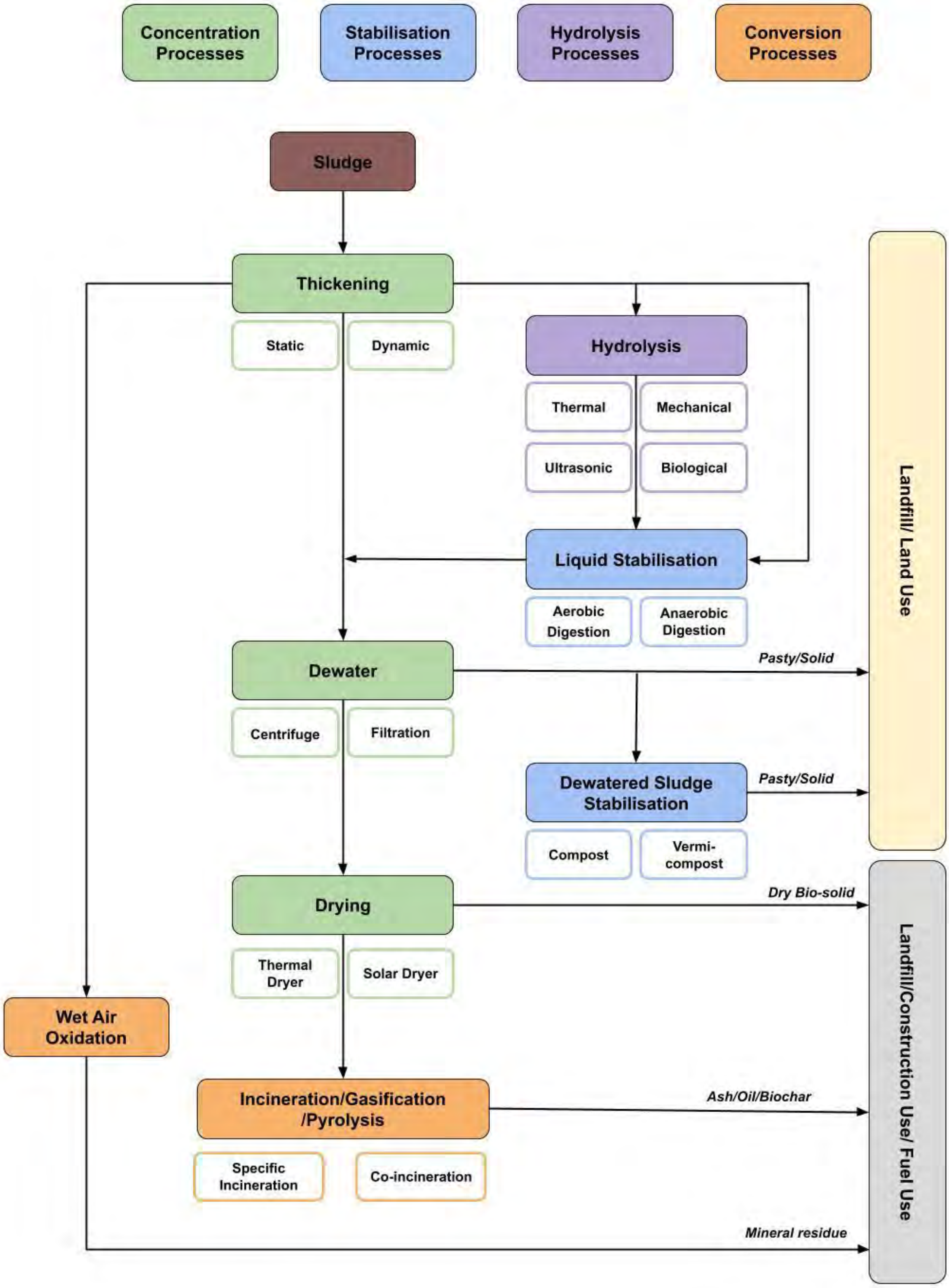

Figure 3-1: Sludge Management Pathways

3.5 Approach to Identifying a Shortlist of Process Options

Sludge processes are normally made up of a combination of the concentration, stabilisation, hydrolysis and/or conversion technologies to form a process train. Using the range of technologies described in Attachment A, an initial long list of 25 process potential options suitable for the raw sludge produced from Moa Point WWTP (and dewatered sludge from Karori WWTP) were developed. The longlist options were then scored against the fatal flaw assessment criteria and scoring parameters, outlined in Table 3-1 below.

These criteria were developed collaboratively by representatives of the Connect Water and WWL Project team as they were considered to be relevant to the core objectives of the project – i.e. options that do not meet these criteria would not meet the core objectives of the project, because:

» If the technology is not mature / well established, it would not provide for a resilient sludge management solution for Wellington. This includes technologies only available from a single global supplier that has not established in New Zealand.
» The Sludge Minimisation Project aims to reduce sludge significantly to what is currently the case. The dry solids content of the end sludge product is an important consideration, as a high dry solids content represents a significant reduction in volume of sludge. In addition, the sludge exhibits viscoplastic behaviour at a dry solids content between 40% and 60%, meaning it will be hard to mix into other waste.
» Only processes that are able to fit within available site footprints should be considered. The estimated maximum land available is 15,000 m^2.

Table 3-1: Summary of Technical Fatal Flaw Criteria for Process Options.

Criteria	Scoring Parameters		
Grading	**Meets well**	**Meets marginally**	**Does not meet**
Maturity of Technology	Current application in NZ	Applied in more than 2 sites globally	Applied in 1 site/Novel
Dry solid content of End Product	> 60%	~ 60%	< 60%
Total plant footprint	< 15,000 m^2	~ 15,000 m^2	> 15,000 m^2

3.6 Short List of Process Options for Multi-criteria Assessment

The below table summarises the long list of 26 process options which were considered and the results from the fatal flaw traffic light analysis[3].

Table 3-2: Summary of Process Options Longlist

Technology	Evaluation Criteria		
	Maturity of Technology	Dry Solids content of End Product	Total plant footprint
Option 1 - Base case			
Option 2- Electrostatic Belt Filter Press			
Option 3 – Heated Filter Press			
Option 4 – Solar Drying*			
Option 5 – Aerobic digestion + Solar drying			
Option 6 – MAD + solar drying			
Option 7 – ATAD + TD			
Option 8- MAD + composting			
Option 9- MAD + vermicomposting			
Option 10 – LD + TD*			
Option 11- MAD + THP + TD (or Digestion-Lysis + TD)			
Option 12- DLD + TD			
Option 13- Mechanical Hydrolysis + MAD + TD			
Option 14 - Ultrasonic Hydrolysis + MAD + TD			
Option 15 - Biological Hydrolysis + MAD + TD			
Option 16 - MAD + Struvite recovery (SR)			
Option 17 - MAD + TD			
Option 18 - TD			
Option 19 - TD + Gasification			
Option 20 - TD + Pyrolysis			
Option 21 - MAD + TD + Pyrolysis			
Option 22 - Hydrothermal liquefaction + oil upgrading			
Option 23 - Wet Air Oxidation (WAO)			
Option 24 - THP + MAD + WAO			
Option 25 - Incineration (TD optional)			

**The traffic light analysis of this option has been amended following a peer review undertaken by GHD in February 2021.*

Based on the evaluation presented above, the following options were determined to fit the criteria very well and were therefore taken forward for further consideration:

- MAD + Composting
- MAD + TD
- TD only
- Incineration

[3] *Wellington Sludge Minimisatio Facility – Site and Process Options Report*. (November 2020). Connect Water (CH2M Beca Limited).

Several other options had a 'marginal' score for one criterion, due to not being implemented in NZ, although used extensively worldwide. These options were still deemed viable at this stage of the project, especially because there are often heat integration advantages to be had which have not been considered in this analysis. These options included:

- ATAD + TD
- DLD + TD
- LD + TD
- TD + Gasification
- Wet Air Oxidation

Further details on each of these options are provided in Appendix C.

These shortlisted options were taken forward for further feasibility assessment in conjunction with the selected shortlisted site options, prior to the multi-criteria assessment. When process and site options were combined, the combinations were excluded, leaving the options listed in Table 3-3 below.

- MAD + Composting at the Moa Point site – this option was excluded due to the limited available land area at the Moa Point site, relative to the footprint requirement for composting.
- Thermal Hydrolysis + MAD + TD at Carey's Gully – this option was only considered further for the Moa Point WWTP site, where primary and secondary sludge would be treated differently prior to being mixed.

Table 3-3: Summary of Shortlisted Process Options Taken Forward for Multi-criteria Assessment.

Moa Point Site	Carey's Gully Site
TD only	TD only
MAD + TD	MAD + TD
LD + TD	DLD + TD
DLD + TD	MAD + Composting
TD + Gasification	TD + Gasification
Incineration	Incineration
WAO	WAO
ATAD + TD	ATAD + TD

3.7 Selection of Preferred Process Option

A Multi-Criteria Assessment (MCA) workshop was held in July 2020 with key stakeholders to identify a preferred option from the short-listed site and process options outlined in Section 3.6. The workshop included discussion on the below key agenda items:

- Presentation of project background and work undertaken to date.
- Presentation of the site and process options short list to be assessed during workshop.

- Discussion and confirmation of the MCA baseline and alternative weightings (sensitivity analysis).
- Evaluation of site and process options against the MCA criteria and sub-criteria.
- Identification of top-ranking option.
- Discussion on post-workshop actions.

To view the full list of MCA participants and discussion notes, please refer to the Sludge Minimisation – MCA Workshop Minutes in Appendix D.

3.7.1 Assessment Criteria Development

The basis of the MCA (i.e. MCA criteria and interpretation) was collaboratively developed by the Connect Water, Veolia, WWL and iwi stakeholders, based on the key projective objectives outlined in the project brief.

The associated weightings of the criterion and sub-criterion were determined based on feedback received from key stakeholders involved in the MCA workshop. An email survey regarding the MCA criteria was circulated by Connect Water in June 2020. Each MCA participant was requested to rank each key sub-criterion (1 = least / less important, 5 = most / very important), and provide any additional feedback on the interpretation of each sub-criterion.

The below points outline the key feedback received from the MCA participants:

- There was an opportunity to bundle up some of the criteria (i.e. *performance* and *solution resilience*) to concisely capture the essence of how we should make a decision on the preferred process / site option.
- Mana Whenua Values were bundled up into a single criterion to capture the essence of values / principles.

It is noted that there was a high level of consistency in how important the criteria were to each workshop participant, with only a couple of significantly different views.

Table 3-4 provides a summary of the agreed assessment criteria and baseline weightings that were adopted.

Table 3 4: Summary of Revised assessment criteria and baseline weighting presented during MCA workshop.

Criteria	Sub-criteria	Baseline Weighting (based on feedback from all stakeholders)	
Function	Sludge Minimisation	12%	21%
	Biosolids Re-use	9%	
Mana whenua values	Mana whenua values / principles	20%	20%
Complexity	Operational & Technological Complexity	21%	21%
Environmental	Carbon Emissions	5%	17%
	Ecological effects	5%	
	Community impacts	3%	
	Consenting and planning	4%	
Cost	Whole of life cost	11%	21%
	Staging to meet budget	10%	

3.7.1.1 Sensitivity Analysis – Alternative Criteria Weightings

To test the MCA process, alternative weightings were applied and incorporated into the final rankings of the short-listed options, to provide a sensitivity analysis of how the outcomes of the assessment might change if criteria weightings are changed. These set of alternative weightings were based on key differences gathered from the MCA criteria survey feedback, where key individuals noted specific criterion that are the most and least critically important from their point of view (or, in the case of weightings 2-4, which they thought would be useful to test the MCA results). The presented alternative weightings are as follows:

- Alternative Weighting 1 - for sensitivity analysis, weighted towards core project objectives and comments from individual participants.
- Alternative Weighting 2 - for sensitivity analysis, 100% towards core project objectives.
- Alternative Weighting 3 - for sensitivity analysis, Environmental and Mana Whenua Values at 100%.
- Alternative Weighting 4 - for sensitivity analysis, Environmental and Mana Whenua Values at 60%.

Table 3-4: Alternative Weightings presented during MCA workshop

Criteria	Sub-criteria	Alternative Weighting 1		Alternative Weighting 2		Alternative Weighting 3		Alternative Weighting 4	
Function	**Sludge Minimisation**	25%	**35%**	23%	**33%**	0%	**0%**	15%	**20%**
	Biosolids Re-use	10%		10%		0%		5%	

Criteria	Sub-criteria	Alternative Weighting 1		Alternative Weighting 2		Alternative Weighting 3		Alternative Weighting 4	
Mana whenua values	**Mana whenua values / principles**	20%	**20%**	0%	**0%**	50%	**50%**	25%	**25%**
Complexity	**Operational & Technological Complexity**	5%	**5%**	33%	**33%**		**0%**	10%	**10%**
Environmental	**Carbon Emissions**	15%	**20%**	0%	**0%**	25%	**50%**	20%	**35%**
	Ecological effects	2%		0%		8%		5%	
	Community impacts	2%		0%		8%		5%	
	Consenting and planning	2%		0%		8%		5%	
Cost	**Whole of life cost**	15%	**20%**	23%	**33%**	0%	**0%**	5%	**10%**
	Staging to meet budget	5%		10%		0%		5%	

3.7.2 Assessment Criteria Interpretation and Basis of Scoring

Prior to the MCA workshop, the core project team (Connect Water, WWL, Veolia and Latitude) facilitated a workshop to confirm the definition and scoring basis of each assessment criterion. Each technical expert was then assigned to a specific sub-criterion to initially score (1 = lowest / least favourable to 10 = highest / most favourable) and present during the MCA workshop. The below subsections provide a summary of the associated definitions and basis of scoring for each key sub-criterion.

A summary of initial scores presented during the workshop is outlined in Table 3-5 further below.

3.7.2.1 Sludge Minimisation Sub-criterion

Defined as: The degree to which the solution reduces the mass of sludge going to landfill.

Basis of scoring: Calculation of reduction in mass of sludge compared to base case (dewatering) out of each type of plant (to indicate degree to which sludge mass going to landfill is minimized). This scoring is irrespective of the site options.

Options with the most stabilized and greatest volume reduction are scored the highest, whereas options with no volume reduction in comparison to the base case scenario are scored the lowest. Because the initial technical fatal flaw analysis has already filtered the process options which do not substantially reduce the volume of the sludge, all options (with the exception of MAD + Composting) have obtained a score greater than 5.

Although the MAD process reduces the volume and stabilizes the sludge, additional bulking compounds are added during the composting process to the sludge product which substantially increases the volume of sludge. Hence, the MAD + Composting option obtains a zero score.

3.7.2.2 Biosolids Re-use Sub-criterion

Defined as: The degree to which the solution enables a pathway to future beneficial re-use which allows biosolids to be diverted from the landfill.

Basis of scoring:

It is important to note that biosolids re-use in New Zealand is not common. The more successful examples of biosolids re-use are related to agricultural land application. This, however, is not applicable for cities such as Wellington, with very minimal agricultural market.

» ‘Reuse potential’ has been ranked based on residual volatile solids (VS) in the biosolids. Process options which result in the lowest VS% are scored the highest, whereas options which result in the highest VS% are scored the lowest.

» This is a proxy for how well the biosolids might perform against the biosolids guidelines stabilisation gradings.

» More stabilised sludge with lower VS% product will enable future beneficial re-use for sludge in the long-term once the market has been established.

3.7.2.3 Mana Whenua Values Sub-criterion

Defined and scored based as:

The degree to which the solution meets mana whenua values / principles relevant to this project, including:

» Use of processes that align to traditional Maori values and methods of human waste management, and the principles of rahui in disposing of human waste.

» Ability to harness and use the resources for the sludge to give them another life.

» Having a positive impact on the environment and our communities through the action we take (kaitiakitanga).

» Use of processes that align to traditional Maori values and methods of human waste management, and the principles of rahui in disposing of human waste.

» Potential impacts on areas of settlement (marae, papakainga), use (food gathering areas), wāhi tapu, statutory acknowledgements and sites of significance.

It is noted that the Mana Whenua Values sub-criterion is correlated to the environmental impacts sub-criterion, as this assessment considers the effects on the health and well-being of our surrounding environment. Process options, such as incineration, which have a great potential to emit harmful by-products to the atmosphere are scored the lowest.

Conversely, process options which produce the least discharge to the environment and mimic the traditional methods of human waste management are scored the highest. An example of this are the digestion processes which mimic the natural decomposition of waste.

The Owhiro Bay area is noted to be of high significance and is highly utilised by the surrounding community. The Owhiro stream is part of the network of mahinga kai sites. In contrast, the surrounding Moa Point area has already been established as a site for wastewater treatment process. It is therefore unfavourable to establish the SMF in Carey's Gully. Because of this, the scores for the Carey's Gulley site option were reduced by 3 points, in comparison to their Moa Point counterpart.

3.7.2.4 Operational Complexity Criteria Sub-criterion

Defined as: The degree of complexity of the solution, including operability, engineering complexity, and technological risk.

Basis of scoring:

- » Familiarity of technology in New Zealand.
- » Overall complexity of process (i.e. adding more process units makes it more complex).
- » Complexity of design.
- » Complexity of operation.

Process options which are well established in the market and have low hazardous components, such as ATAD + TD, score the highest. Conversely, process options such as Wet Air Oxidation, which has not been established as a sludge minimizing technology in NZ and has significant complexities in design, are scored the lowest.

The scoring for the process options are irrespective of the site. It is noted that while the pipelines to Carey's Gully add complexity, the Moa Point site (which is more visible and higher risk for odour complaints) makes plant operation more complex.

3.7.2.5 Carbon Emissions Sub-criterion

Defined and scored based on: Estimated operational GHG emissions (by calculation) for processing and disposal of the sludge for each option

An operational carbon model, utilising the Ministry of Environment (MfE) Carbon Emissions Estimation Guide, has been developed for each process option. The option which obtained the lowest GHG emissions (i.e. Wet Air Oxidation) scored a 10. A one-point difference was established for the remainder options based on level of GHG emissions, e.g. Incineration has the second lowest GHG emissions and therefore scores a 9.

Operational GHG emission accounts for the following activities: disposal of biosolid, electricity use, fossil fuel use, combustion of biogas and transportation emissions.

3.7.2.6 Ecological Effects Sub-criterion

Defined as: The degree of impact on the environment in terms of residual ecological effects (with controls in place), such as discharges to air, water and land

Basis of scoring: It is noted that discharges to water will be directed to the existing Moa Point WWTP, and for the purposes of the project, the direct application to land will be solely to the landfill. Thus, the focus of this sub-criterion is the discharges to air.

Wet air oxidation scores the highest as this process emits CO_2, H_2O and N_2 byproducts, which are already major constituents of our atmosphere.

Anaerobic digestion processes score the second highest as these processes produce biogas, which requires to be treated (de-sulpherised) prior to being utilized as a fuel source. ATAD process is powered using natural gas.

Processes such as incineration, gasification and thermal drying score the lowest as these produce flue gas as a byproduct, which is harmful to the atmosphere. Small amounts of NO_x are still released in the atmosphere, even after flue gas treatment. Additionally, the TD only option produces a dried sludge product which will continue to digest as it settles in landfill and emit substantial amounts of methane into the air.

The scoring of these process options is irrespective of the site.

3.7.2.7 Community Impacts Sub-criterion

Defined as: The degree of impact on landholders, construction impacts, traffic and access impacts, recreational impacts, and public health risk (if any)

Basis of scoring:

» Lower scores given to Moa Point options in comparison to Carey's Gulley (i.e. 5 vs 7) due to proximity of residential neighbours to site
» Composting marked particularly low (i.e. 4) due to previous challenges and the negative perception that this has created

The scoring of these options was irrespective of the process option, with the exception of the composting option.

3.7.2.8 Consenting and Planning Sub-criterion

Defined as: Consentability of the solution, degree of difficulty in obtaining property, and potential contaminated land management.

Basis of scoring:

» For Moa Point, the degree and location of changes to the designation.
» For Carey's Gully, the noted cultural concerns of the Owhiro Bay area.
» For specific processes:
» case history (e.g. incineration and composting),
» the type of activities and likely impacts.

The difference in scoring within the Moa Point options is predominantly a factor of the footprint of the plant. Processes such as the DLD + TD option require a larger footprint and therefore require more significant changes to the designation boundary. Conversely, the TD only option requires minimal changes to the existing Moa Point / WIAL designation boundary.

For the Carey's Gully option, it is assumed that the existing Southern Landfill Designation (Designation 61: Carey's Gully) which includes a 'proposed sludge processing plant' can be utilised for the whole site. Thus, there are no scoring variations for the Carey's Gully process options, with the exception of the composting and incineration processes.

For both site options, specific are marked particularly low due to historical cases, such as the Tahuna Incinerator and the Living Earth Composting facility. The negative perceptions created around incineration and composting processes result in a higher degree of difficulty with obtaining a consent.

3.7.2.9 Staging to Meet Budget Sub-criterion

Defined as: The ability of each option to be staged, so that design and construction of the first stage(s) can be completed within the currently available budget, and any subsequent stages can be undertaken later when budget becomes available.

Basis of scoring:

» The likelihood that a Stage 1 can be built within the currently available budget, based on the concept capital cost estimates undertaken to date
» Highly likely options given a score of 10

3.7.2.10 Whole of life Cost Sub-criterion

Defined as: Relative total capital and operating cost for the project

Basis of scoring:

» Concept level estimate of capital and operating costs (50-year design horizon), using previous project estimates. This was established by taking the minimum (highest scoring = 10) and maximum cost option (lowest scoring = 0) and proportionally deriving the scores for the remainder options.
» Carey's Gully options include for pipelines replacement in 30-year horizon for mid-cost option (noting that all options were very close), and pipeline operation and maintenance

Table 3-5: Initial scoring of options shortlist pre-MCA workshop

Site	Option	Function		Mana whenua values	Complexity	Environmental				Cost		Total	
		Sludge Minimisation 12%	Biosolids Re-use 9%	Mana whenua values / principles 20%	Operational & Technological Complexity 21%	Carbon Emissions 5%	Ecological effects 5%	Community impacts 3%	Consenting and planning 4%	Whole of life cost 11%	Staging to meet budget 10%	Weighted Score	Ranking
Moa Point Site	TD	3	3	5	8	3	6	5	7	8.12	10	6.08	9
	MAD + TD	7	6	9	7	5	8	5	6	3.65	10	7.06	3
	LD + TD	7	6	8	6	6	8	5	6	7.06	10	7.08	2
	DLD + TD	8	8	9	6	7	8	5	5	4.69	10	7.33	1
	TD + Gasification	9	8	5	5	8	7	5	5	9.34	10	6.95	4
	Incineration	10	10	2	7	9	7	5	2	6.87	1	5.85	10
	Wet Air Oxidation	9	9	3	4	10	10	5	5	2.05	1	4.97	15
	ATAD + TD	7	4	9	9	4	8	5	6	0.00	10	6.84	5
Carey's Gully Site	TD	3	3	2	8	3	6	7	5	7.70	10	5.42	13
	MAD + TD	7	6	6	7	6	8	7	5	4.14	10	6.59	6
	DLD + TD	8	6	6	6	5	8	7	5	5.16	10	5.36	14
	MAD + Composting	0	6	9	8	7	9	4	1	2.44	5	5.74	11
	TD + Gasification	9	8	2	5	8	7	7	5	10.00	10	6.50	7
	Incineration	10	10	0	7	9	7	7	1	7.79	1	5.58	12
	Wet Air Oxidation	9	9	0	4	10	10	7	5	2.50	1	4.50	16
	ATAD + TD	7	4	6	9	4	8	7	5	0.47	10	6.32	8

3.8 MCA Workshop Outcomes

3.8.1 Key Feedback from MCA Participants

The initial scoring presented during the MCA workshop was amended based on the below feedback received from the MCA workshop participants:

- The score of the TD option for both sites should be increased from **3** to **6,** under the *Sludge Minimisation* sub-criterion. This is agreed by all participants, as the option still achieves the required 60% volume reduction of sludge, albeit less efficient than the other process options.
- The score of the Incineration option for both sites should be decreased from **10** to **8**, under the *Biosolids re-use* sub-criterion. Although it achieves a volatile solids content of 0% (degradable content), there is no current re-use opportunity for the end product. It, however, provides the most stabilised sludge output product which will enable sufficient re-use, once the market for this has been established.
- The initial scoring of all Carey's Gully process options should be **increased by 1 point** under the Mana Whenua Values sub-criterion, i.e. establish 2-point difference between equivalent Moa Point and Carey's Gully options. It is noted that the Moa Point area has already been established as a site for WWTP processes, whereas the Owhiro Bay area is highly utilised by the community. Additionally, establishing the facility at Moa Point avoids the need for the sludge transfer pipeline from Moa Point to Carey's Gully, thus avoiding the risk of pipeline failure and discharge to waterways, which is culturally abhorrent. It is, however, important to note that the Moa Point facility is located along the coastline. Trucking of dewatered sludge from Western WWTP to Moa Point would occur along the coastline, which is also not ideal from a cultural perspective. Because of this, the scoring difference between the two options has decreased.
- The score of the TD option for both sites should be increased from **6** to **8,** under the *Ecological Effects* sub-criterion. This is agreed by all participants as GHG emissions have already been incorporated within the *Carbon Emissions* sub-criterion.

Furthermore, the following additional sensitivity analyses were recommended:

- **Scoring Review 1:** Revised scoring for the *Consenting and Planning* criterion, to assess landscape and visual impacts in accordance with Part II of the RMA for each shortlisted option.
- **Scoring Review 2:** Revised scoring for the *Carbon Emissions* criterion, to provide an assessment of alternative power source for running the process equipment. This assessment will specifically look into electric heat generation for the thermal dryers.

Outcomes from the additional analyses of the above three scenarios are outlined in Section 3.9. These aim to close out the nuances between the top ranked options during the workshop as outlined in Table 3-6 and Table 3-7, and confirm the preferred option to take forward through Concept Design.

3.8.2 MCA Workshop Results (Baseline Weighting)

The MCA workshop results, as outlined in Table 3-7 and 3-8, indicate that the preferred option for the SMF is a DLD + TD facility to be located at the Moa Point site. As noted above, additional analyses have been undertaken to further confirm the best practicable option to take forward for further design development.

Table 3-6: Summary of MCA Workshop scoring for shortlisted options

		Function		Mana whenua values	Complexity	Environmental				Cost		Total	
		Sludge Minimisation 12%	Biosolids Re-use 9%	Mana whenua values / principles 20%	Operational & Technological Complexity 21%	Carbon Emissions 5%	Ecological effects 5%	Community impacts 3%	Consenting and planning 4%	Whole of life cost 11%	Staging to meet budget 10%	Weighted Score	Ranking
Moa Point Site	TD	6 (3)	3	5	8	3	8 (6)	5	7	8.12	10	6.52	9
	MAD + TD	7	6	9	7	5	8	5	6	3.65	10	7.06	3
	LD + TD	7	6	8	6	6	8	5	6	7.06	10	7.08	2
	DLD + TD	8	8	9	6	7	8	5	5	4.69	10	7.33	1
	TD + Gasification	9	8	5	5	8	7	5	5	9.34	10	6.95	4
	Incineration	10	8 (10)	2	7	9	7	5	2	6.87	1	5.66	13
	Wet Air Oxidation	9	9	3	4	10	10	5	5	2.05	1	4.97	15
	ATAD + TD	7	4	9	9	4	8	5	6	0.00	10	6.84	5
Carey's Gully Site	TD	6 (3)	3	3 (2)	8	3	8 (6)	7	5	7.70	10	6.06	11
	MAD + TD	7	6	7 (6)	7	6	8	7	5	4.14	10	6.79	6
	DLD + TD	8	6	7 (6)	6	5	8	7	5	5.16	10	6.76	7
	MAD + Composting	0	6	9 (9)	8	7	9	4	1	2.44	5	5.74	12
	TD + Gasification	9	8	3 (2)	5	8	7	7	5	10.00	10	6.70	8
	Incineration	10	8 (10)	0 (0)	7	9	7	7	1	7.79	1	5.39	14
	Wet Air Oxidation	9	9	1 (0)	4	10	10	7	5	2.50	1	4.70	16
	ATAD + TD	7	4	7 (6)	9	4	8	7	5	0.47	10	6.52	10

KEY: Updated scoring during MCA workshop

Note: Original scoring pre-MCA workshop have been included in parenthesis.

Table 3-7: Ranking of options during MCA workshop

		Weighted Score						No. of top 3 ranking	Median Ranking	Ranking based on total score
		Baseline	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Total Score			
Moa Point Site	TD	6.60 (9)	5.73 (13)	7.26 (4)	5.08 (12)	5.71 (14)	30.39 (11)	0	12	10
	MAD + TD	6.94 (3)	6.56 (7)	6.42 (11)	7.08 (3)	6.78 (3)	33.78 (6)	3	3	4
	LD + TD	7.14 (2)	7.05 (4)	6.88 (7)	7.19 (4)	7.02 (2)	35.28 (3)	2	4	3
	DLD + TD	7.39 (1)	7.48 (2)	6.76 (8)	7.89 (1)	7.57 (1)	37.10 (1)	4	1	1
	TD + Gasification	7.09 (4)	7.74 (1)	7.75 (2)	6.19 (9)	7.08 (4)	35.86 (2)	2	4	2
	Incineration	5.81 (13)	6.77 (5)	7.17 (5)	4.72 (14)	6.18 (11)	30.66 (10)	0	11	11
	Wet Air Oxidation	4.88 (15)	6.10 (10)	4.91 (15)	5.47 (10)	5.99 (10)	27.35 (14)	0	10	14
	ATAD + TD	6.71 (5)	5.77 (12)	6.03 (13)	6.83 (4)	6.50 (6)	31.84 (8)	0	6	8
Carey's Gully Site	TD	6.20 (11)	5.29 (15)	7.16 (6)	4.19 (15)	5.25 (16)	28.10 (13)	0	15	15
	MAD + TD	6.93 (6)	6.51 (9)	6.53 (10)	6.94 (6)	6.87 (5)	33.79 (5)	0	6	6
	DLD + TD	6.70 (7)	6.51 (6)	6.67 (9)	6.19 (7)	6.52 (7)	32.60 (7)	0	7	7
	MAD + Composting	5.59 (12)	4.40 (16)	4.34 (16)	6.92 (2)	5.62 (12)	26.87 (15)	1	12	13
	TD + Gasification	6.84 (8)	7.47 (3)	7.90 (1)	5.36 (11)	6.72 (8)	34.29 (4)	2	8	5
	Incineration	5.64 (14)	6.57 (8)	7.38 (3)	4.00 (16)	5.89 (15)	29.48 (12)	1	14	12
	Wet Air Oxidation	4.83 (16)	5.90 (11)	5.02 (14)	5.11 (13)	5.89 (13)	26.75 (16)	0	13	16
	ATAD + TD	6.65 (10)	5.56 (14)	6.14 (12)	6.44 (8)	6.39 (9)	31.19 (9)	0	10	9

Note: ranking of options has been included in parenthesis

3.9 Post- Workshop Outcomes

3.9.1 Additional Scoring Review 1: Landscape and Visual Assessment (LVA)

This sensitivity analysis provides an amendment to the scoring of the *Consenting and Planning* sub-criterion. A workshop was held with Connect Water landscape architects to undertake a high-level land and visual assessment (LVA) of each of the shortlisted options. The two main additional assessment parameters (or basis of scoring) are outlined below.

3.9.1.1 Preservation of Natural Character

To assess the impact that the options might have on the preservation of natural character in the locations they are proposed, our LVA team has reviewed the shortlisted options assessed how they might be impacted by legislative and policy requirements.

For Moa Point options, we have referred to the NZ Coastal Policy Statement 13 and 15 (NZCPS), which state:

- 13.1a - avoid adverse effects of activities on natural character in areas of the coastal environment with outstanding natural character; and
- 13.1b - avoid significant adverse effects and avoid, remedy or mitigate other adverse effects of activities on natural character in all other areas of the coastal environment.
- 15.a - avoid adverse effects of activities on outstanding natural features and outstanding natural landscapes in the coastal environment; and
- 15.b - avoid significant adverse effects and avoid, remedy, or mitigate other adverse effects of activities on other natural features and natural landscapes in the coastal environment.

Moa Point options which require modifications to the escarpment were revised and ranked lower against this assessment parameter under the *Consenting and Planning* sub-criterion. These modifications include minor slope excavation and stabilisation to allow room for plant equipment.

For Carey's Gully options, we have referred to the *Outer Green Belt Management Plan 2019,* which identifies Natural Character as *"an area of high natural value (regenerated forest), habitat, openness, predominantly natural land cover, lack of buildings and development".*

All options for Carey's Gully site were considered similar enough to be categorized into one overall assessment due to the following landscape conditions:

- proposed sludge plant is located in a highly modified industrial waste site.
- proposed sludge plant is not visible from the access road into the site.
- proposed sludge plant is not visible from any public road or surrounding residential community.

Hence, the varying arrangements for the options do not make a significant difference to the overall assessment. No change was considered necessary to any of the ecological effects scores, after this review of the landscape and natural character aspects.

3.9.1.2 Visual Impact

For both site options, this assessment parameter refers to the level of visual change and the site's ability to mitigate these visual impacts (due to height, mass, location of plant equipment). This was established by having the Connect Water engineering team present each option to the Connect Water LVA Team so that the LVA Team could make an assessment.

3.9.1.3 LVA Results

Table 3-8 and 3-10 provide an outline of the revised scoring and ranking of options based on the incorporation of LVA results under the *Consenting and Planning* sub-criterion. Based on this scoring, the top-ranking preferred options remains to be a DLD + TD facility to be located at Moa Point.

Table 3-8: Revised scoring post-LVA assessment of shortlisted options

		Function		Mana whenua values	Complexity	Environmental				Cost		Total	
		Sludge Minimisation 12%	Biosolids Re-use 9%	Mana whenua values / principles 20%	Operational & Technological Complexity 21%	Carbon Emissions 5%	Ecological effects 5%	Community impacts 3%	Consenting and planning 4%	Whole of life cost 11%	Staging to meet budget 10%	Weighted Score	Ranking
Moa Point Site	TD	6	3	5	8	3	8	5	9 (7)	8.12	10	6.60	10
	MAD + TD	7	6	9	7	5	8	5	3 (6)	3.65	10	6.94	4
	LD + TD	7	6	8	6	6	8	5	7 (6)	7.06	10	7.14	2
	DLD + TD	8	8	9	6	7	8	5	7 (5)	4.69	10	7.39	1
	TD + Gasification	9	8	5	5	8	7	5	8 (5)	9.34	10	7.09	3
	Incineration	10	8	2	7	9	7	5	6 (2)	6.87	1	5.81	13
	Wet Air Oxidation	9	9	3	4	10	10	5	3 (5)	2.05	1	4.88	15
	ATAD + TD	7	4	9	9	4	8	5	3 (6)	0.00	10	6.71	8
Carey's Gully Site	TD	6	3	3	8	3	8	7	8 (5)	7.70	10	6.20	11
	MAD + TD	7	6	7	7	6	8	7	8 (5)	4.14	10	6.93	5
	DLD + TD	8	6	7	6	5	8	7	8 (5)	5.16	10	6.90	6
	MAD + Composting	0	6	9	8	7	9	4	7 (1)	2.44	5	5.99	12
	TD + Gasification	9	8	3	5	8	7	7	8 (5)	10.00	10	6.84	7
	Incineration	10	8	0	7	9	7	7	7 (1)	7.79	1	5.64	14
	Wet Air Oxidation	9	9	1	4	10	10	7	8 (5)	2.50	1	4.83	16
	ATAD + TD	7	4	7	9	4	8	7	8 (5)	0.47	10	6.65	9

KEY: Updated scoring based on LVA

Note: MCA workshop scoring has been included in parenthesis.

Table 3-9: Revised ranking of options based on Land and Visual Assessment

		Weighted Score						No. of top 3 ranking	Median Ranking	Ranking based on total score
		Baseline	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Total Score			
Moa Point Site	TD	6.60 (10)	5.73 (13)	7.26 (4)	5.08 (13)	5.71 (15)	30.39 (11)	0	13	11
	MAD + TD	6.94 (4)	6.56 (8)	6.42 (11)	7.08 (4)	6.78 (5)	33.78 (6)	0	5	6
	LD + TD	7.14 (2)	7.05 (4)	6.88 (7)	7.19 (3)	7.02 (3)	35.28 (3)	3	3	3
	DLD + TD	7.39 (1)	7.48 (2)	6.76 (8)	7.89 (2)	7.57 (1)	37.10 (1)	4	2	1
	TD + Gasification	7.09 (3)	7.74 (1)	7.75 (2)	6.19 (9)	7.08 (2)	35.86 (2)	4	2	2
	Incineration	5.81 (13)	6.77 (5)	7.17 (5)	4.72 (14)	6.18 (10)	30.66 (10)	0	10	10
	Wet Air Oxidation	4.88 (15)	6.10 (10)	4.91 (15)	5.47 (10)	5.99 (12)	27.35 (15)	0	12	15
	ATAD + TD	6.71 (8)	5.77 (12)	6.03 (13)	6.83 (6)	6.50 (8)	31.84 (8)	0	8	8
Carey's Gully Site	TD	6.20 (11)	5.29 (15)	7.16 (6)	4.19 (15)	5.25 (16)	28.10 (14)	0	15	14
	MAD + TD	6.93 (5)	6.51(9)	6.53 (10)	6.94 (5)	6.87 (4)	33.79 (5)	0	5	5
	DLD + TD	6.90 (6)	6.71 (6)	6.67 (9)	6.69 (7)	6.77 (6)	33.75 (7)	0	6	7
	MAD + Composting	5.99 (12)	4.80 (16)	4.34 (16)	7.92 (1)	6.12 (11)	29.17 (13)	1	12	13
	TD + Gasification	6.84 (7)	7.47 (3)	7.90 (1)	5.36 (11)	6.72 (7)	34.29 (4)	2	7	4
	Incineration	5.64 (14)	6.57 (7)	7.38 (3)	4.00 (16)	5.89 (14)	29.48 (12)	1	14	12
	Wet Air Oxidation	4.83 (16)	5.90(11)	5.02(14)	5.11 (12)	5.89 (13)	26.75 (16)	0	13	16
	ATAD + TD	6.65 (9)	5.56 (14)	6.14 (12)	6.44 (8)	6.39 (9)	31.19 (9)	0	9	9

Note: Ranking of options has been included in parenthesis

3.9.2 Additional Scoring Review 2: Alternative Power Supply Assessment

An additional assessment on operational GHG emissions has been undertaken for the option of supplying electrical heat generation for the thermal dryers, as opposed to those powered by natural gas. The approximate GHG emissions were obtained based on the annual electrical demand simulated from the simulation outputs of the Veolia OCEAN software package. This was incorporated into the ATAD + TD and TD only options, which utilise natural gas for heating.

3.9.2.1 Alternative Power Supply Results

Based on the revised scoring outlined in Table 3-10, this alternative electric heat source for the drying unit results in an improved emissions rating against equivalent options which utilize natural gas. However, their rankings do not improve against process options, such as DLD + TD or TD + Gasification, which produce biogas and syngas as a power source for the thermal drying facility.

The DLD + Thermal Drying option at Moa Point remains as the top-ranked option of this additional sensitivity analysis.

Table 3-10: Revised scoring post-alternative power supply assessment of shortlisted options

		Function		Mana whenua values	Complexity	Environmental				Cost		Total	
		Sludge Minimisation 12%	Biosolids Re-use 9%	Mana whenua values / principles 20%	Operational & Technological Complexity 21%	Carbon Emissions 5%	Ecological effects 5%	Community impacts 3%	Consenting and planning 4%	Whole of life cost 11%	Staging to meet budget 10%	Weighted Score	Ranking
Moa Point Site	TD	6	3	5	8	1 (3)	8	5	7	8.12	10	6.42	10
	MAD + TD	7	6	9	7	5 (5)	8	5	6	3.65	10	7.06	3
	LD + TD	7	6	8	6	6 (6)	8	5	6	7.06	10	7.08	2
	DLD + TD	8	8	9	6	7 (7)	8	5	5	4.69	10	7.33	1
	TD + Gasification	9	8	5	5	8 (8)	7	5	5	9.34	10	6.95	4
	Incineration	10	8	2	7	9 (9)	7	5	2	6.87	1	5.66	12
	Wet Air Oxidation	9	9	3	4	10 (10)	10	5	5	2.05	1	4.97	15
	ATAD + TD	7	4	9	9	2 (4)	8	5	6	0.00	10	6.74	6
Carey's Gully Site	TD	6	3	3	8	1 (3)	8	7	5	7.70	10	5.96	11
	MAD + TD	7	6	7	7	6 (6)	8	7	5	4.14	10	6.79	5
	DLD + TD	8	6	6	6	7 (5)	8	7	5	5.16	10	6.66	8
	MAD + Composting	0	6	7	8	5 (7)	9	4	1	2.44	5	5.25	14
	TD + Gasification	9	8	3	5	8 (8)	7	7	5	10.00	10	6.70	7
	Incineration	10	8	0	7	9 (9)	7	7	1	7.79	1	5.39	13
	Wet Air Oxidation	9	9	1	4	10 (10)	10	7	5	2.50	1	4.70	16
	ATAD + TD	7	4	7	9	4 (4)	8	7	5	0.47	10	6.52	9

KEY: Updated scoring based GHG emissions calculations on electrical TD option

Note: MCA workshop scoring has been included in parenthesis.

Table 3-11: Revised ranking of options based on alternative power supply assessment

		Weighted Score						No. of top 3 ranking	Median Ranking	Ranking based on total score
		Baseline	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Total Score			
Moa Point Site	TD	6.42 (10)	5.40 (14)	7.26 (4)	4.42 (14)	5.21 (14)	28.71 (11)	0	14	11
	MAD + TD	7.06 (3)	6.61 (7)	6.42 (11)	7.33 (2)	6.93 (3)	34.36 (4)	3	3	4
	LD + TD	7.08 (2)	7.03 (4)	6.88 (7)	7.08 (3)	6.95 (2)	35.03 (3)	3	3	3
	DLD + TD	7.33 (1)	7.45 (2)	6.76 (8)	7.75 (1)	7.48 (1)	36.78 (1)	4	1	1
	TD + Gasification	6.95 (4)	7.69 (1)	7.75 (2)	5.92 (8)	6.92 (4)	35.22 (2)	2	4	2
	Incineration	5.66 (12)	6.71 (6)	7.17 (5)	4.42 (13)	5.99 (11)	29.95 (10)	0	11	10
	Wet Air Oxidation	4.97 (15)	6.14 (10)	4.91 (15)	5.67 (10)	6.10 (10)	27.80 (13)	0	10	13
	ATAD + TD	6.74 (6)	5.52 (12)	6.03 (13)	6.58 (5)	6.25 (8)	31.12 (8)	0	8	8
Carey's Gully Site	TD	5.96 (11)	4.94 (15)	7.16 (6)	3.42 (16)	4.69 (16)	26.17 (14)	0	15	14
	MAD + TD	6.79 (5)	6.45 (9)	6.53 (10)	6.67 (4)	6.71 (6)	33.15 (7)	0	6	7
	DLD + TD	6.66 (8)	6.76 (5)	6.67 (9)	6.42 (6)	6.76 (5)	33.26 (6)	0	6	6
	MAD + Composting	5.25(14)	4.00 (16)	4.34 (16)	5.92 (9)	4.92 (15)	24.42 (16)	0	15	16
	TD + Gasification	6.70 (7)	7.42 (3)	7.90 (1)	5.08 (11)	6.55 (7)	33.65 (5)	2	7	5
	Incineration	5.39 (13)	6.47 (8)	7.38 (3)	3.50 (15)	5.59 (13)	28.33 (12)	1	13	12
	Wet Air Oxidation	4.70 (16)	5.84 (11)	5.02 (14)	4.83 (12)	5.73 (12)	26.11 (15)	0	12	15
	ATAD + TD	6.52 (9)	5.50 (13)	6.14 (12)	6.17 (7)	6.22 (9)	30.55 (9)	0	9	9

Note: Ranking of options has been included in parenthesis

3.9.3 Final Ranking of Options

As outlined in Table 3-7, 3-10 and 3-12, the overall preferred option for the proposed SMF was determined by assessing the outcomes of the MCA workshop, scoring review 1 and 2 against the below three parameters:

- Number of “top-three scoring” occurrences of each shortlisted option against each alternative weighting scenario
- Median ranking of each shortlisted option, based on individual rankings for each alternative weighting scenario
- Ranking based on the total weighted score of each shortlisted option

Based on the results summary outlined in Table 3-7, 3-10 and 3-12, the Moa Point DLD + TD option scores the highest for the baseline weighting applied during the MCA and the additional scoring reviews. This option appears consistently in the top three ranked options for the alternative weighting scenarios, with the exception of Alternative weighting 2, which solely focuses on the four core project objectives. This specific weighting scenario is not considered an ideal basis of ranking as no consideration has been given towards mana whenua values and environmental impacts.

The Moa Point TD + Gasification option obtains the top-ranking for alternative weighting 1 during the MCA workshop and additional scoring reviews. A reason for this is the added weighting towards the *Function* and the substantial decrease of the *Complexity* criterion weighting. While the process option performs at a greater level than that of DLD + TD, it is noted that this type of sludge processing technology has not been established in New Zealand and requires skilled operators to use the specialised equipment. This needs to be carefully considered when selecting the preferred option.

Similarly, the Carey’s Gully TD + Gasification obtains the top-ranking for alternative weighting 2 across the MCA workshop and additional scoring reviews. As noted above, this specific weighting scenario may not be an ideal basis of ranking as no consideration has been given towards mana whenua values and environmental impacts.

Table 3-12: Summary of ‘top three’ options based on total weighted scores for MCA and additional scoring reviews

Ranking	MCA workshop	Scoring Review 1	Scoring Review 2
1st place	Moa Point DLD + TD	Moa Point DLD + TD	Moa Point DLD + TD
2nd place	Moa Point TD + Gasification	Moa Point TD + Gasification	Moa Point TD + Gasification
3rd place	Moa Point LD + TD	Moa Point LD + TD	Moa Point LD + TD

When assessing the total weighted scores of all the site and process options, the Moa Point DLD + TD option appears consistently the highest. The Moa Point TD + Gasification and Moa Point Point LD + TD fall into second and third place consistently, with less than one-point difference in total weighted scoring between the two options.

It is noted that technologies involving digestion and thermal hydrolysis (i.e. DLD + TD and LD +TD) options are well-proven globally. Detailed design has been completed for the Rosedale WWTP site for a sludge management system involving digestion and thermal hydrolysis processes. Though gasification processes have been utilised for sludge management internationally, there are some noted concerns with the lack of expertise within NZ and the associated complexities for the continuous operation and maintenance of a gasification plant.

3.10 Highest Scoring Option

Based on the outcomes of the MCA workshop and additional scoring reviews, the concluded highest scoring option to take forward to concept design is a digestion-lysis-digestion + thermal drying plant to be located at Moa Point, adjacent to the existing influent pump station and WWTP. The design development for this option is presented in Section 4.

3.10.1 Alternative Preferred Option for Concept Design: LD + TD

A technical specialist at the MCA workshop noted that selection of a lysis-digestion (LD) plant versus a digestion-lysis-digestion (DLD) plant is typically based on scale. Plants for smaller populations favour LD. However, the size of the plant required for Wellington is close to the crossover point at where DLD becomes financially viable, and therefore either process option would be feasible. It is noted that the LD + TD facility located at Moa Point WWTP was within the top three options identified by the MCA process.

An LD + TD facility plant would require fewer process elements and associate infrastructure than the base DLD +TD plant, which presents a capital cost reduction opportunity, while still achieving the project objectives of sludge minimisation, stabilisation, odour and carbon reduction. Following further analysis and discussion with Wellington Water, and in response to this opportunity, this concept design report also includes an overview of the alternative preferred LD + TD option. Subsequent sections of this concept design report provide a brief overview of how the alternative LD + TD option differs from the base DLD + TD option, in terms of process design, site layout and a Level 2 capital cost estimate.

4 Process Design Development

4.1 Section Overview

This section presents the concept development of the proposed SMF DLD + TD process including:

- The development of the preferred process option, including technology options for each process unit making up the overall sludge minimisation process.
- An overview of key ancillary processes that support.
- Opportunities to stage the process.
- An overview of key changes in process elements for the alternative preferred LD + TD option

4.1.1 Key Findings

The following table summarises the key findings of the process design.

Section Reference	Consideration	Key Findings
4.2	Operating Philosophy	The overall process is based on 24/7 operation, with storage tanks and equipment redundancy allowances to permit parts of the system to be taken out of service for maintenance without requiring a full system shutdown. It is expected that the DLD + TD plant will require 8/5 weekly operational site attendance, with potential weekend on-call requirements for emergency events. This, however, will be further assessed in the next stages of design.
4.2.1	Raw Sludge Storage and Conveyance	Raw sludge from Moa Point will be stored in existing tanks and pumped to thickeners in the new facility.
4.2.2	Sludge Thickening Process	Raw sludge from Moa Point will be thickened on gravity belt thickeners before blending with dewatered Karori sludge in the thickened sludge tank.
4.2.3, 4.2.6	Digestion Processes	Digester configuration is as follows. » Stage 1 influent sludge will be pre-heated using hot water from CHP system » Stage 2 influent sludge will be cooled using tepid water from Stage 1 » Digester tanks will be fixed-roof type » Biogas from both stages of digestion will be stored in membranes installed on the roofs of the Stage 1 digesters » Digesters will be mixed using unconfined gas recirculation

Section Reference	Consideration	Key Findings
		» Biogas from both stages will be treated to remove siloxanes and hydrogen sulphide before use in the CHP system » Digested sludge will be stored in tanks for feed to downstream processes
4.2.4, 4.2.7	Dewatering Processes	Digested sludge will be dewatered using centrifuges for feed to downstream processes. Centrate from Stage 2 Dewatering will need to be ozone treated to remove light absorbing compounds before returning to the main WWTP.
4.2.5	THP	THP is required to make the remaining sludge more digestible. It is noted that both batch and continuous process configurations can be implemented in the SMF process.
4.2.8	Sludge Drying Process	Dewatered sludge from Stage 2 will be dried in indirect-heated belt dryers.
4.4	Construction Staging Options	A two-staged approach to implementing the SMF has been assessed, to alleviate the upfront funding required for the construction of the SMF. The *D-THP-D* staging option is the recommended staging option for the project.
4.5	Key Process Design Changes for Alternative Preferred Option	The key process changes for LD + TD are: » Process plant reduced to only one digestion stage, post-THP. Sizing of digesters will be similar in size as the Stage 1 DLD + TD digesters » Larger centrifuges will be required for the Stage 1 and 2 dewatering processes » Different THP unit required. No notable difference in dimensions required.

4.2 Overview of Main Process

Figure 4-1 provides an overview of the DLD + TD process developed for the new SMF, located at the Moa Point Site. This process involves a two-stage anaerobic digestion process, with thermal hydrolysis in between the two stages and a thermal drying process after the second digestion process. The biogas that is generated from the anaerobic digestions can be beneficially used to generate electricity to power the processes, as well as to generate heat for energising the thermal hydrolysis and thermal drying processes.

Process inputs and outputs are summarised in Table 4-1. Full process flow diagrams and mass balance are included in Appendix E. Values from the heat and mass balances are indicative and are subject to further refinement depending on vendor supplier specifications.

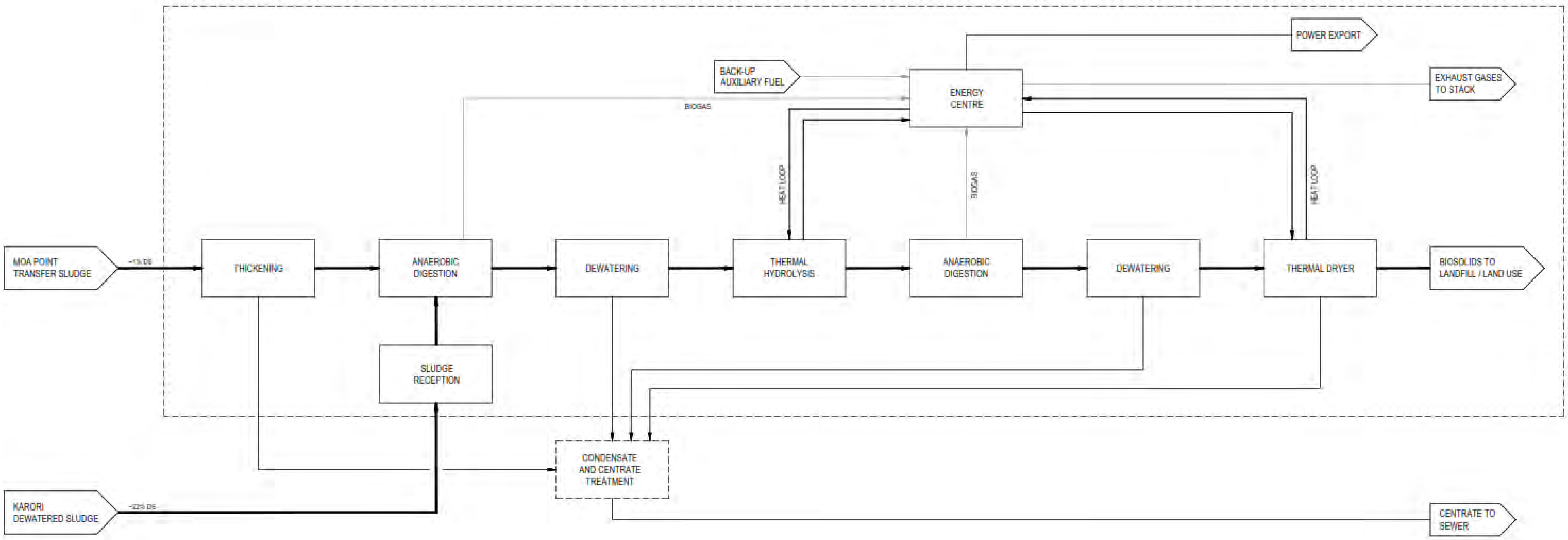

Figure 4-1: Block Flow Diagram (BFD) of Main Process

Table 4-1: Key Process Inputs and Outputs

Parameter	Unit	Value	Comment
Total Daily Sludge inflow	tDS/day tonnes/day	21 377	From Design Basis From mass balance
Inlet Sludge concentration	%DS	0.8% Moa Point 22% Karori	From Moa Point and Southern Landfill operations team. Assumed value to be revised once sludge characterisation data available.
Inlet Sludge Volatile Suspended Solids fraction	%VS		Assumed value to be revised once sludge characterisation data available.
Daily Sludge outflow	tDS/day tonnes/day	7.0 7.8	From mass balance
Final Sludge concentration	%DS	90%	Design target
Final Sludge Volatile Solids Fraction	%VS		From mass balance
Biogas Produced	m^3/day	11,327	From mass balance
Centrate returned to main process	m^3/day	2,704	From mass balance
Electricity generation potential	kW_e	1,100	From energy balance – assumes no losses
Heat generation potential	kW_h	1,900	From energy balance – assumes no losses

The overall system has been sized based on 24/7 operation, with storage tanks and equipment redundancy allowances to permit parts of the system (either process trains or individual pieces of equipment) to be taken out of service for maintenance without requiring a full system shutdown. The main objective of operating the system will be to maintain stable feed lines to both stages of digestion for consistent biogas production, and to the sludge dryer for energy-efficient operation.

It is expected that the DLD + TD plant will require 8/5 weekly operational site attendance, with potential weekend on-call requirements for emergency events. This, however, will be further assessed in the next stages of design.

As an initial attempt at balancing cost, space, and operational requirements, the following general redundancy and storage principles have been applied:

- Major process items, including thickeners, centrifuges, dryers, digesters and cogeneration engines: Two units sized for duty/assist operation (i.e. two units in parallel each sized for 50% of the 2073 peak week capacity).
- Storage tanks are allowed between key process areas and are sized for a residence time that is dependent on the degree of process flexibility immediately downstream.
- Minor process items, including pumps, blowers and heat exchangers: Three units, sized for duty/duty/standby operation (typically one per major process item and one spare).

Table 4-2 outlines the sludge pumps required for the inter-stage pumping within the facility, including the assumed design flow and percentage of dry solids in the material that the pumps will convey. The following types of pumps are typically required:

1. Centrifugal pump which generally pump dilute solids streams of up to 4% DS
2. Dosing pump, which is a small, positive displacement pump designed to pump a measured flow rate of chemical, typically in this case polymer to assist with thickening and dewatering
3. Screener cutter pumps which have a macerating as well as grit capture functionality
4. Progressive cavity (PC) pumps which generally pump sludges of up to 12% DS (depending on the stator geometry and pump stage pressure)
5. Dry sludge (cake) progressive cavity pumps which generally pump dry sludges of up to 40% DS. Dry sludge pumps require an inlet chamber or hopper with a large inlet opening with conveyor to feed the sludge to the rotor.

Table 4-2: Intermediate Sludge Pumps

Pump	Pump Type	No. of pumps	Design Flow (m^3/h)	%DS
GBT dosing pump	Dosing pump	3	0.9	0.2%
Raw sludge pump (Karori)	Dry sludge PC	1	1	22%
Digester feed pump stage 1	Screener / cutter	3	8	5.7%
Digester recirculation pump stage 1	Dry sludge PC	2	24	2.6%
Centrifuge feed pump stage 1	Progressive cavity	3	15	2.6%
Centrifuge dosing pump stage 1	Dosing pump	3	1.6	0.2%
THP feed pump	Dry sludge PC	3	1.5	23%
Digester recirculation pump stage 2	Progressive cavity	2	6	8.3%
Centrifuge feed pump stage 2	Progressive cavity	2	12.1	8.3%
Centrifuge dosing pump stage 2	Dosing pump	2	5.0	0.2%
Dewatered sludge pump	Dry sludge PC	3	3.7	32%
TD feed pump	Dry sludge PC	2	0.6	32%
Off – spec pump		3	32	0 – water
Hot water pump to digester stage 1	Centrifugal	2	13	0 – water
Hot water pump to CHP stream	Centrifugal	2	0.4	0 – water
Hot water pump to cleaning heat exchanger	Centrifugal	2	48	0 – water
Steam feed pump	Centrifugal	2	0.4	0 – water
Tepid water pump	Centrifugal	2	16	0 – water

An overview of each key section of the process is provided below.

4.2.1 Raw Sludge Storage and Conveyance

4.2.1.1 Existing Storage System

The existing WWTP raw sludge storage system consists of three sludge storage tanks (each 9.7m x 12m x 6.9m maximum height) located on the ground floor of the pre-treatment building. The floor of the sludge tank slopes towards the outlets. A service gallery runs adjacent to the tanks and allows for piping and pipe connections to the sludge tanks. Six primary sludge pumps sit within the service gallery and discharge to a single primary sludge manifold. The manifold has inlet pipe branches to each storage tank which cross the service gallery near the ceiling and enter the tanks at a high level.

There is a waste activated sludge (WAS) diversion from the return activated sludge (RAS) pumped line. The 300mm diameter WAS manifold has pipe branches to each storage tank which come up through the floor of the service gallery and enter the tanks at a low level. A manual valve at the inlet to each tank provides WAS flow control.

A high-level pipe connects from sludge tank No. 1 to sludge tank No. 2 and from No. 2 to No. 3 to convey the tank overflow. Each tank has an actuated valve outlet connection to a single manifold which conveys sludge to the three raw sludge pumps. Additionally, each tank has an air vent pipe which is conveyed to the existing Moa Point odour control system.

The existing sludge pumps are high pressure piston pumps with a high static and dynamic head due to the significant length and elevation of the discharge pipe. The pumps convey sludge to the Carey’s Gully SDP.

4.2.1.2 New Storage system

The raw sludge storage and conveyance system will be re-configured to pump primary and WAS sludge as separated streams to the gravity belt thickeners on the second floor of the new main sludge process building. The following works are proposed to treat the WAS and primary solids as separate solids streams.

Sludge tank No.1 will be the WAS tank, sludge tank No.2 will be the spare tank and sludge tank No.3 will be the primary sludge tank. The overflow pipework in between tanks will be kept in service.

The following changes connections will be made:

- Valve on the primary sludge connection to new WAS tank will be normally closed.
- Valve on the WAS connection to the new primary tank will be normally closed.
- A blind flange will be installed on the outlet from the WAS tank into the existing outlet pipe.

The primary and WAS inlets to the spare tank will remain. The outlet from the spare tank will be valved to allow connection to the outlet primary and the WAS sludge lines.

The existing outlet pipe from the tanks will be kept for primary sludge only and a new outlet pipe will be installed adjacent to the existing to convey WAS sludge.

The pumps will be replaced with progressive cavity pumps that are able to convey the 0.8% DS to 2% DS WAS and primary sludge. A strategy will need to be developed to stage the replacement of pumps so we can maintain the pumping to Careys Gully.

The pumps will convey WAS and primary sludge as separate streams and the spare pump will be a standby that could convey either sludge stream. The new raw sludge pumps will run approximately 10 – 18 hours a day to convey the total design sludge load through the thickeners. The pumps will be a common pump selection to allow for changeover between duty and standby pumps. Table 4-3 below details the raw sludge pump parameters.

Table 4-3: Raw Sludge Pump Parameters

Pump	Pump Type	No. Of Pumps	Design Flow (m^3/h)	%DS
Raw sludge pump (primary)	Progressive cavity	1	20.1	1.4%
Raw sludge pump (WAS)	Progressive cavity	1	86.5	0.7%
Raw sludge pump (spare)	Progressive cavity	1	86.5	0.7 – 1.4%

The outlet pipes from the pumps will be modified to separate the sludge streams and convey to the different gravity belt thickeners. Piping and changeover valving will be installed before the gravity belt thickeners to accommodate for the WAS and primary sludge flows to be split where required. Drawings indicating the required changes to the existing sludge conveyance infrastructure (pumps and pipework) at Moa point WWTP are provided in Appendix E.

Further assessment of sludge conveyance will be undertaken in the next phase of design. Design reviews will involve the existing WWTP operations team to ensure a logical construction sequencing leading to the commissioning of the new SMF and decommissioning of the existing Carey's Gully SDP.

4.2.2 Sludge Thickening

The success of the digestion operation heavily relies on the upstream pre-conditioning stages, particularly the sludge thickening process. Implementing a sludge thickening process has several key benefits:

- It substantially reduces the required capacity of the digesters, and increases the residence time within the available digester capacity, and
- it reduces the heat demand (i.e. less liquid to be heated).

There are various thickening methods available, the most common of which are gravity (picket fence) thickeners, dissolved air floatation (DAF), gravity belt thickeners (GBT) and rotary drum thickeners. Mechanical processes (GBT, DAF and rotary drum) are preferred over gravity thickening as they allow both high dryness while providing a short residence time, which prevents septic fermentation of the sludge.

DAF generally thickens sludge around 3% DS, which is at the lower end of the available mechanical technologies. Because of site space constraints, and therefore the need to reduce digester capacity as much as possible, DAF has not been considered further, leaving gravity belt and rotary drum thickening as the preferred thickening options. A comparison of the process and operating capabilities of these two thickening technologies is presented in Table 4-4 and Table 4-5.

Table 4-4: Summary of Key Advantages and Disadvantages of Thickening Technologies.

Technology	Advantages	Disadvantages
GBT	» Larger loading volume » Low energy consumption » Flocculation chamber not required	» Considerable footprint » Low volume reduction » Odour risk (if not enclosed)
Rotary Drum	» Low energy consumption » Enclosed system	» Higher capital cost » Risk of shearing floc

Table 4-5: Evaluation Summary of Thickener Options.

Criteria	Gravity Belt Thickener	Rotary Drum Thickener
Space Requirement	-*	0*
Long-Term Equipment Reliability	+	-
Polymer Addition Requirement	0	0
Backwash Downtime	+	+
Maintenance Requirement	+	+
Odour Control	+	+

**The analysis of this option has been amended following a peer review undertaken by GHD in February 2021.*

Ratings:

+: ***Positive comparative characteristic***

-: Negative comparative characteristic

0: Neutral comparative characteristic

Based on the above tables, GBTs are favoured as they provide are expected to provide better outcomes for this project and have therefore been taken forward in the concept design development. Further detail on the proposed GBT technology is provided below.

Figure 4-2 provides a schematic of a typical GBT configuration. Thickening of the sludge is achieved by first injecting polymer online or in a dynamic mixer to flocculate the sludge. The sludge is deposited on a rotating belt, which performs sludge drainage by gravity. The belt moves at 2 to 15 m/min over a certain distance determined by the inlet flow and dewatering requirements. A pressurized nozzle water injection system continuously cleans the belt as it passes along the bottom. At the new facility, three (two duty, 1 standby) GBTs will be required. The GBTs will be placed on a mezzanine floor, which is elevated above the thickened sludge tanks. This will enable the thickened sludge to be transferred efficiently by gravity to a dedicated tank for each GBT, and free draining of filtrate to a process waste system that ultimately discharges process wastewater to the existing Influent Pump Station (IPS).

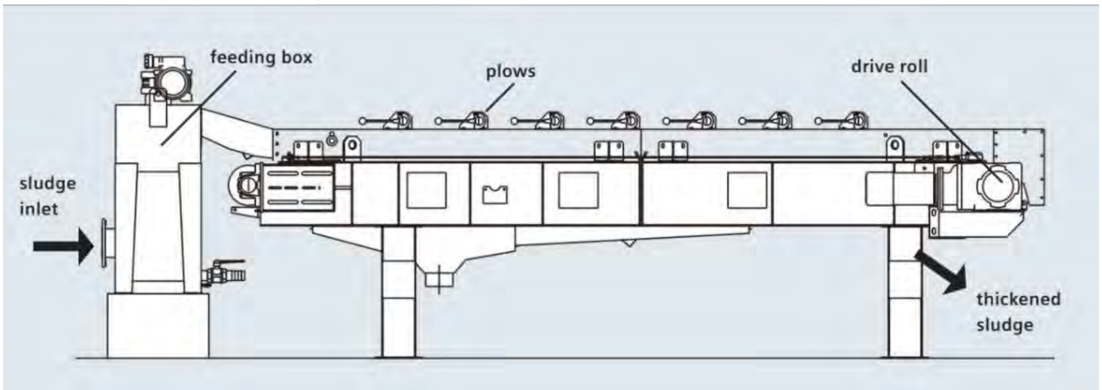

Figure 4-2: Schematic of a Gravity Belt Thickener (GBT).

The thickened sludge tanks contain mixers. These tanks will incorporate the dewatered sludge from Karori WWTP with the thickened Moa Point sludge to form a mixed sludge of approximately 6 %DS. The residence time of the tanks is intentionally kept short to prevent septic fermentation. Following this, the mixed sludge is drawn via three (two duty, one standby) screening cutter pumps to the Stage 1 Digestion Process. Table 4-6 outlines the key design parameters for the thickening and storage process.

Table 4-6: Key Parameters of the Sludge Thickening and Storage Process..

Stream Parameter	Inlet	Outlet	Comments
Sludge flow	106.6 t/h	15.5 t/h	From mass balance
Sludge displacement type	Pump	gravity	
Sludge %DS	~1%	5.5%	From mass balance
Centrate flow	-	91.1 t/h	From mass balance
Temperature	15 ºC	15 ºC	
Polymer dosing	0.9 t/h	-	From mass balance
Equipment Parameter			Comments
GBT			
GBTs space allocation	429 m^3		3 units: 2 duty, 1 standby
GBT Location	Mezzanine floor of main process building		At least 4 m elevation from 1st floor
Thickened Sludge Storage Tank			
Dimensions per unit	20m^3		2x parallel tanks at 50% capacity
Sludge residence time	2 hrs		
Tank Location	1st floor of main process building		

4.2.3 Stage 1 Digestion Process

Stabilisation technologies, such as anaerobic digestion, involve the use of microorganisms to digest sludge. Figure 4-3 provides an overview of the anerobic digestion process.

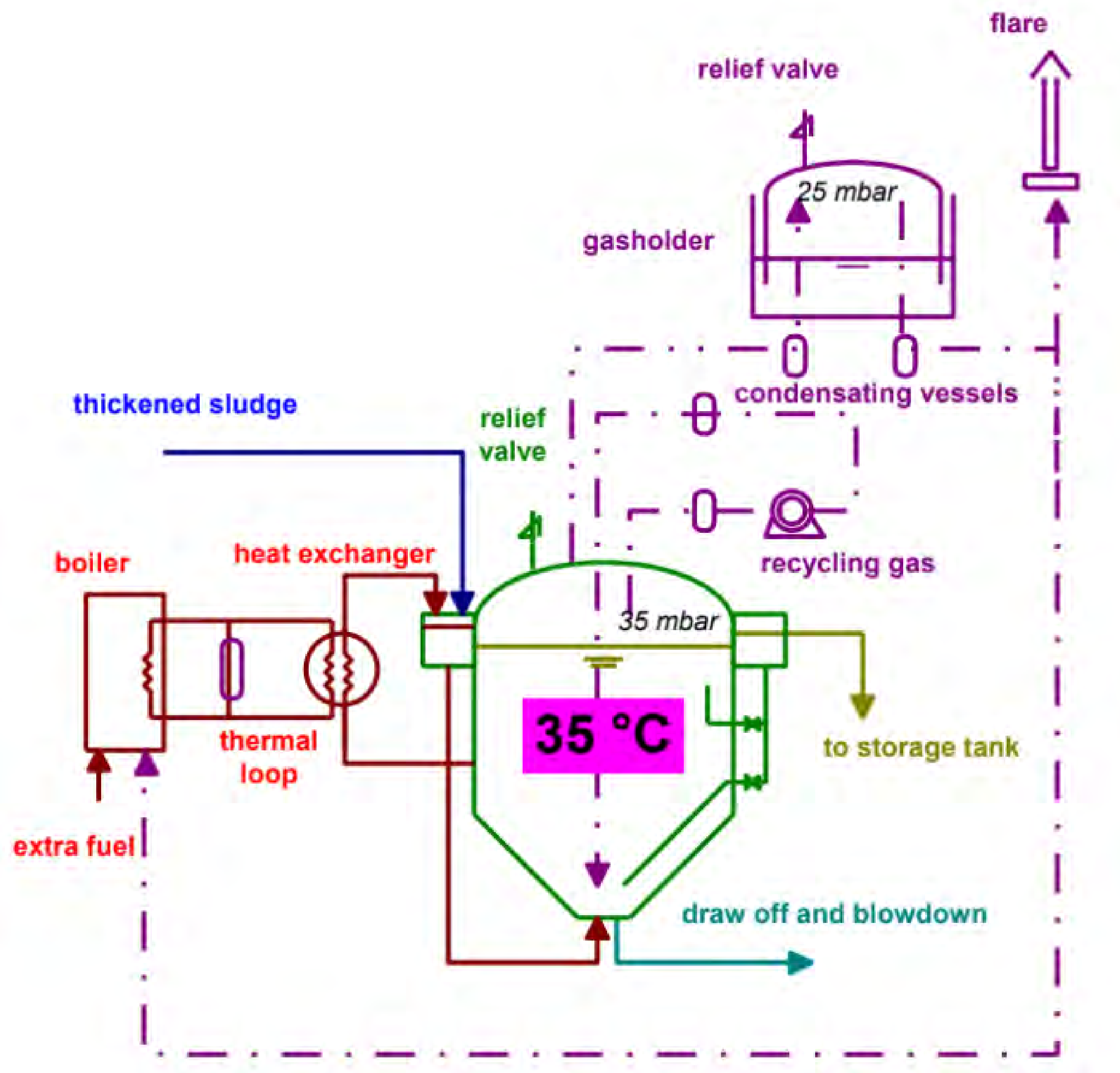

Figure 4-3: Schematic of an Anaerobic Digester (Mesophilic Conditions)

Anaerobic digestion processes provide an environment that maintains optimum conditions for microorganisms which convert the organic material into a cell mass and release a gaseous by-product. This gas, known as *biogas,* can be utilised as an energy resource to fuel other operational units within the sludge minimisation. Biogas is typically used as a fuel source for on-site boilers or Combined Heat and Power units (CHP, also called co-generation “cogen” units). The waste heat from these boilers and cogen units is utilised to maintain the optimum digester temperature.

There are two main temperature conditions for anaerobic digestion: mesophilic (35-38 °C) and thermophilic (55-57 °C). The Stage 1 digester tanks for the SMF are proposed to operate at mesophilic conditions. The key reasons for this choice are:

» MAD is a well-established, and more common digestion pathway.
» The overall OPEX for thermophilic anaerobic digestion is higher due to the higher operating temperature and extra chemical consumption on the subsequent dewatering steps.
» Odour control around thermophilic digesters is more difficult.

The Stage 1 digestion process consists of two digester tanks which run in parallel at 50% capacity. The sludge is drawn from the thickened sludge tank and is pumped to the Stage 1 digesters. The below table outlines the design parameters for the Stage 1 digestion process.

Table 4-7: Stage 1 Digestion Design Parameters

Stream Parameter	Inlet	Outlet	Comments
Sludge heating (HX1)			
Sludge flow	31.4 t/h	31.4 t/h	From mass balance
Temperature	27 °C	38 °C	
Sludge displacement	Pump	pump	
MAD			
Sludge flow	15.7 t/h	15.2 t/h	From mass balance
Sludge %DS	5.7%	2.6%	From mass balance
Sludge temperature	15 °C	38 °C	
Sludge VSS (g/kg)	48	17	
Biogas flow	-	432.6 m^3/h	From mass balance
Biogas temperature	-	38 °C	
Equipment Parameter			**Comments**
Heat exchanger (HX1)			
Dimensions per unit	5.6m^3		3 units: 2 duty; 1 standby Based on vendor information
Model	Counter current model		
Digester tank			
Dimensions per unit	3,700 m^3 (3,330 m^3 effective volume)		2x units operating in parallel at 50% capacity
Sludge residence time	480 hrs		
Digester configuration	Fixed gasholder cover for biogas storage		
Mixing type	Gas mixing		Pump recirculation mixing overheat exchanger provides back-up mixing
Digestate tank			
Dimensions per unit	105 m^3		2x unit operating in parallel at 50% capacity
Sludge residence time	12hrs		Residence time allows long and thus efficient runs on the downstream centrifuges

4.2.3.1 Initial Sludge Death (Pre-Digestion)

Sludge from the thickened sludge tank passes through heat exchangers located in the ground floor of the main process building and is initially heated from prior to entering the digester tanks. Temperature is controlled through measuring the digester temperature and throttling the hot stream through the heat exchanger.

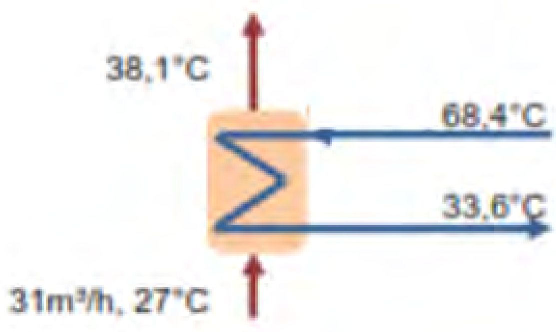

Figure 4-4: Schematic of Sludge Heating Process Pre-digestion (Source: Lackeby).

4.2.3.2 Digester Mixing

The efficiency and overall effectiveness of the digestion process is heavily attributed to the performance of the digester mixing process. Typic sludge retention time within the digester tanks last approximately 15 days. Continuous sludge mixing is therefore required to allow circulation of the digester contents and promote the decomposition process to produce biogas, as well as reduce the amount of solids deposition in the tank.

There are a wide variety of mixing processes for digesters. Several digester mixing options were considered, including:

- **Mechanical stirring mixers**: mixing processes which utilise low speed / high diameter or high speed / low diameter rotating impellers to mix the digester contents
- **Confined gas injection mixing**: a portion of the biogas is collected from the digesters, compressed and then reinjection into the system through submerged fine tubes (gas lifter with central eductor or gas pistons)
- **Unconfined gas injection mixing**: a portion of the biogas is collected from the digesters, compressed and then reinjection into the system through a pattern of bottom diffusers, or through a series of radially placed gas lance or bottom diffusers
- **Pump recirculation mixing**: a portion of the liquid sludge contents are withdrawn from the digester tank by an external recirculation pump and then discharged back into the tank

A summary of the key advantages and disadvantages of each digester mixing option is outlined in Table 4-8 and high level scoring of the mixing options is outlined in Table 4-9.

Table 4-8: Summary of key advantages and disadvantages of digestion mixing technology

Technology	Advantages	Disadvantages
Mechanical stirring mixers	» Low operational costs » Minimal scum build-up » Good mixing efficiency	» Prone to ragging and impeller / shaft wear » Higher maintenance requirements » Not suitable for larger diameter digester tanks
Confined gas injection mixing	» Very good mixing efficiency, less dead zones in comparison to mechanical systems » Higher operational costs	» Configuration with central gas eductor not suitable for tanks with biogas holder domes » Potential foaming issues; noted to be site dependent » Potential corrosion of piping and equipment
Unconfined gas injection mixing	» Very good mixing efficiency, less dead zones in comparison to mechanical systems » Higher operational costs » Suitable for larger digesters	» Potential foaming issues; noted to be site dependent » Potential corrosion of piping and equipment
Pump recirculation mixing	» Good top and bottom digester mixing » Minimal scum build-up » Higher operational costs » Allows recirculation of sludge deposits	» Potential blockage of nozzles » Prone to impeller wear

Table 4-9: Evaluation Summary of digestion mixing options

Criteria	Mechanical Stirring	Gas Mixing (confined)	Gas Mixing (unconfined)	Pump recirculation mixing
Mixing Performance	+	+	+	+
Power requirements	+	-*	+	-*
Ease of maintenance	-	+	+	0
Compatibility with gas holder cover	0	-	+	+

** The analysis of this option has been amended following a peer review undertaken by GHD in February 2021.*

Confined gas injection mixing with a central gas eductor through the top-centre of the digester tank has been discounted due to the configuration of the digester tanks (hemispherical gas holder domes on top as discussed in subsequent section). This would be impractical to construct and maintain.

Mechanical stirring mixers have been discounted as this mixing system is more suited for smaller digester tanks.

We have applied sequential unconfined gas injection mixing to our concept design based on the above key advantages. This type of mixing is also well established in New Zealand, including at the following locations:

- Christchurch WWTP (1960, 1981, 2009).
- North Shore WWTP (1996).
- Levin WWTP (1996).
- Palmerston North (1970, 1985).
- Pukete WWTP (1981).

Unconfined gas mixing provides efficient mixing of the central zone of the digester tanks and assist in the breakage of scum formation at the top of the digester tanks. Sequencing of the gas injection around the perimeter of the digester tank allows specific areas of the digester content to become more agitated at a given time, promoting vertical and lateral movement. Side entry sequential gas injection is recommended, due to the configuration of the

Additional supplementary mixing processes, such as pump recirculation mixing of sludge, can be applied in conjunction with gas injection mixing. Sludge extraction points for this mixing process are located in two levels around the perimeter of the digester tank. This aids the digestion process by minimising the sludge deposits and scum formation within the bottom and top of the digester tanks. This supplementary mixing system has also been employed in Digesters 5 and 6 of the Christchurch WWTP.

There are three main outputs streams from the digester process:

- Digested sludge (approx. 2.6%DS), which is stored in two digestate tanks with a capacity of 105 m^3 each, situated directly adjacent to the Stage 1 digester tanks.
- A small portion of the output sludge, which is recirculated back in the system.
- The gas by-product (i.e. biogas), which is pushed out to the biogas treatment system.

4.2.3.3 Biogas Treatment

The digesters operate at a slight overpressure that continuously expels the biogas out of the digesters to a biogas treatment system. The treated biogas is then collected and stored in a biogas holder. Treatment of the biogas is required prior to utilisation to remove harsh components, such as hydrogen sulphide (H_2S) and siloxanes, which can create corrosion, silica formation and other operational problems in CHP systems.

Typical biogas treatment packages include the below-listed conditioning steps. Additional conditioning steps can be added to optimise the system. Further analysis will be undertaken in the next stages of the design.

- **H_2S reduction** – H_2S is typically removed using a scrubbing system with proprietary media. In order for effective removal of H_2S, the biogas must be 100% water saturated
- **Dehydration / Moisture removal –** Moisture from the treated gas is typically removed by initially cooling it down through a shell and tube heat exchanger, condensing via a separator vessel, and then reheating. The output moisture content reduces to 50-80%, which is suitable for siloxane treatment
- **Siloxane Removal** – siloxanes are removed via a scrubbing vessel. Other forms of siloxane removal, such as carbon adsorption are also possible.
- **Gas Pressure Boost** – gas blowers are required to push the biogas through the different stages of the treatment system, in the case that there is not enough pressure from the digester system to provide this flow

The below table outlines the design parameters for the biogas treatment system.

Table 4-10: Biogas Treatment Parameters

Stream Parameter	Inlet	Outlet	Comments
Biogas treatment			
Biogas flow	497 m^3/h	472 m^3/h	Input: Includes flows from Stage 1 and 2 Digestion Output: enters biogas holder domes
Biogas temperature	38 ^oC	38 ^oC	
CH_4 composition	66%	66%	From mass balance
CO_2 composition	34%	34%	
H_2S composition	500 ppm	50 ppm	Based on vendor information
Siloxane composition	15 mg/ m^3	negligible	Based on vendor information
Equipment Parameter			**Comments**
Biogas treatment			
Dimensions	100 m^3		Elements of biogas treatment package determined by chosen CHP unit requirements
Biogas storage			
Dimensions per unit	Approx. 884 m^3		2x hemispherical domes on top of Stage 1 digester tanks. Dimensions based on digester tank diameter
Gas residence time	2hrs		To be further optimised

4.2.3.4 Biogas Storage

Due to the limited available space at Moa Point, it is proposed that biogas holders are installed as hemispherical domes on top of the digester tanks (i.e. gasholder covers) to minimise land use. This type of holder has been installed in the Invercargill Clifton WWTP in 2018, and it is noted to be the first of its kind to be installed within New Zealand. It is anticipated that the maximum storage time for these biogas holders (given the flow rate) is 2 hours. As this is relatively small, the operating philosophy will comprise an as constant as possible feed to the digesters, because that proves to keep the biogas flow as flat as possible. In case of peaks which the storage cannot cater for a flare will be installed. Excess biogas is flared out.

The components of a typical tank-mounted gas holder are shown in Figure 4-5. These gas holders consist of an inner and outer membrane, which is reinforced by a support air blower in order to maintain the internal dome pressure at a constant level to withstand outer forces such as wind.

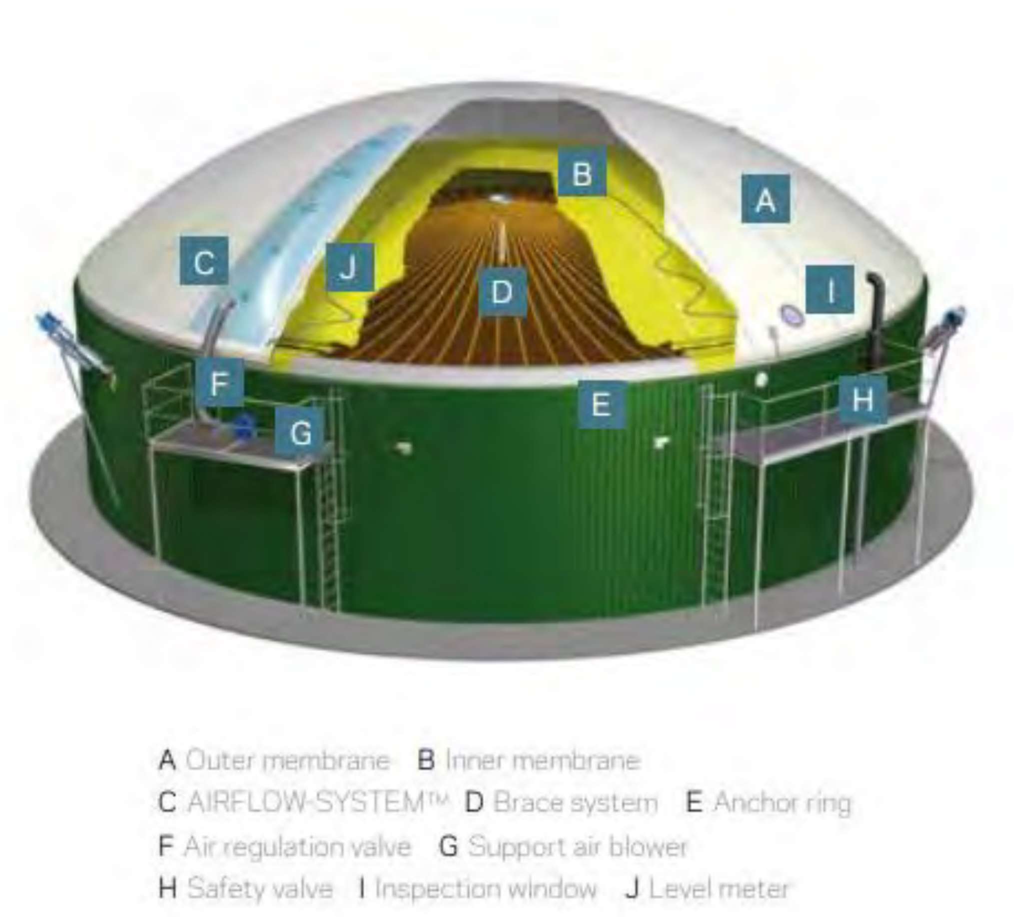

Figure 4-5: Schematic of biogas holder dome (Source: Sattler Ceno Ltd)

4.2.4 Stage 1 Dewatering Process

Digestate (the digested sludge) overflows from the top of the Stage 1 Digesters into digestate tanks, which provides short term buffering storage before downstream processing. Pumps draw digestate from the tanks and feed it to the Stage 1 dewatering process, which is designed to dewater the sludge to approximately 25 %DS, while maximising solids capture.

Four commonly available dewatering technologies have been considered, namely:

- **Belt Filter Press:** drainage of water from sludge using physical pressure and gravity. Sludge is typically thickened prior to belt press dewatering, and significant amounts of coagulant are required. Between 18 – 25 %DS output is typically achieved from this process on an organic sludge.

- **Centrifugation:** dewatering through rapid rotation of a cylindrical bowl (1200 – 2800 rpm) to separate solids from wastewater. Between 16 – 30 %DS output is typically achieved from this process.
- (**Heated) Filter Press**: dewatering via filtration of water through serial chamber banks. Sludge is pumped under high pressure through filtration cloth which collect solids and filter through water. Between 30 – 35 %DS is typically achieved from this process.
- **Screw press:** dewatering via pumping of flocculated sludge into a cylindrical screen basket containing a slowly rotating helical screw. Between 16 – 22%DS is typically achieved from this process.

The key advantages and disadvantages of the dewatering technologies are outlined in the tables below.

Table 4-11: Advantages and Disadvantages of dewatering technologies

Technology	Advantages	Disadvantages
Belt filter press	» Fast start-up and shut down	» Significant operating costs » Regular replacement of parts required » Less efficient on organic sludge
Centrifuge	» Small footprint » Fast start-up and shut down » Low capital costs	» Significant operating costs » Regular replacement of parts required » Requires flocculant to be effective » Significant amount of polymer required
Filter press	» Best dry solids result of all dewatering technologies	» More applicable to small capacities with a high dryness demand » Regular replacement of parts required » High on labour; significant operating costs
Screw press	» Low polymer consumption » Low operating costs	» Performance highly dependent on the VS% of sludge » Significant capital cost » Technology incompatible with grit

Table 4-12: Evaluation Summary of dewatering options

Criteria	Belt filter press	Centrifuge	Screw Press	Filter press
Space requirement	0	+	0	0
Dewatering Performance	+	+	- (variable)	+
Power requirement	0	-	+	0
Long-term equipment reliability	+	+	-	0

The capital cost of the screw press technology is estimated to be the highest amongst all options considered; however, its polymer requirement and associated operating costs is estimated to be the lowest. While typical screw press technologies produce a dry solids concentration of 16 – 22%, the dewatering performance is highly dependent on the total volatile solids concentration of the sludge and is incompatible with grit. This would pose a significant process risk for the Wellington SMF.

Filter press technologies obtain the highest dry solids concentration out of all options considered. However, it is only suited for small capacity systems, and is therefore not a recommended option for sludge processing given the projected increase in sludge production.

Both centrifugation and belt filter press technologies are noted to have higher operating costs when compared to the other listed dewatering technologies. However, both also are noted to have lower capital costs. Belt filter presses are noted to operate less efficiently on organic sludge and have therefore been discounted from further consideration.

From the information above, the centrifugation process appears to be best suited for the proposed SMF. Centrifugation require a smaller footprint, which is of great advantage given the limited available space at Moa Point. It is noted that this similar dewatering process is used for the existing Carey's Gully SDP and is noted to be performing well.

As shown in Figure 4-6, centrifugation occurs in a rotating horizontal cylindrical bowl with a screw conveyor as shown below. Polymer is added and mixed with the sludge to enable flocculation, and the feed enters the centrifuge at the inlet distributer and is accelerated in radial motion. The centrifugal force caused by the rotating of the bowl and screw induces a rapid settling rate. The screw and bowl rotate in the same direction. Sludge is carried by the screw towards the solids discharge outlet. The centrate flows in the opposite end and drains away by gravity.

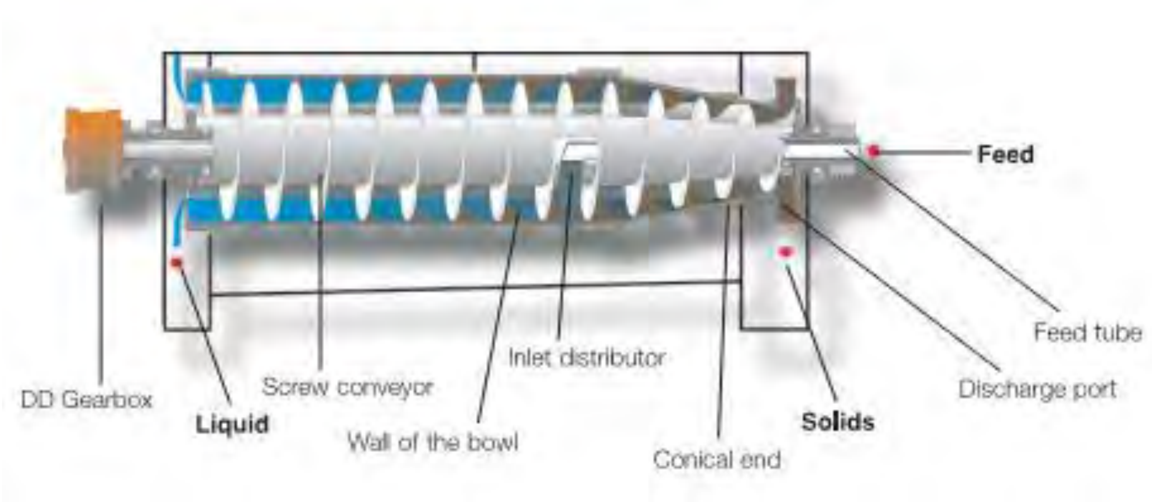

Figure 4-6: Schematic of a Centrifuge

The below table outlines the design parameters of the Stage 1 dewatering process.

Table 4-13: Key Design Parameters for Stage 1 Dewatering Process.

Stream Parameter	Inlet	Outlet	Comments
Sludge flow	17 t/h	1.5 t/h	From mass balance
Sludge temperature	36 ^{o}C	36 ^{o}C	
Sludge %DS	2.4%	25%	From mass balance
Centrate flow	-	15.5 t/h	From mass balance
Centrate temperature	-	36 ^{o}C	
Polymer dosing	1.6 t/h	-	From mass balance
Equipment Parameter			**Comments**
Volume allocated for centrifuges	132.5 m^3		3 units: 2 duty, 1 standby

4.2.5 Thermal Hydrolysis Process (THP)

THP involves "cooking sludge" in order to make it more digestible for anaerobic bacteria. This process occurs at elevated temperature and pressure to achieve optimal results, while minimising time and land footprint required for the process equipment. On a cellular scale, THP breaks down the cell walls of the sludge, allowing molecular organic matter to become more available for digestion which otherwise would have remained locked up in the material. This concept is illustrated in Figure 4-7.

Figure 4-7: Schematic of Cell Wall Breakdown during THP Pre-treatment.

Due to the high temperatures involved, THP processes can potentially generate colour compounds and recalcitrant nutrient compounds from complex organic molecules in the sludge. These compounds, some of which are water soluble, can impact on nutrient removal and ultraviolet disinfection performance when returned to the main wastewater treatment process (for instance in post-THP dewatering centrate). DLD processes are considered to present a lower risk as the organic molecules are typically broken down in the first digestion stage, but at the conceptual level it is prudent to allow for side stream treatment if needed to protect the main wastewater treatment process. Moa Point WWTP does not currently have any nutrient removal requirements in their discharge consent, but the site uses UV disinfection to comply with its required pathogen discharge limits. The potential treatment requirements are discussed in Section 4.2.7.

4.2.5.1 Process Configuration

The process is commercially available in two configurations:

» Semi-batch
» Continuous

The semi-batch process uses a set-up with a receiving tank, called pulper, a bank of parallel reactors (between 2 and 5) and a flash tank, as outlined in Figure 4-8. The process runs at 16-18% dry solids. This dewatered sludge is continuously fed into the pulper. The pulper has the role to homogenise and pre-heat the sludge to a temperature close to 100°C, using steam recovered from the flash tank.

From the pulper, the warm sludge is fed continuously to the reactors, in a sequential process that ensures sealed batches of sludge in each reactor. Once a reactor fills up, sludge flows to the next available one. When a reactor is full it is closed off and live steam is pumped to raise the reactor temperature to 165 °C at a pressure of approximately 6 bars. It then sits for 20-30 minutes. When hydrolysis is completed the now sterilised and hydrolysed sludge is passed to the flash tank, which operates at atmospheric pressure. The steam generated by the pressure release is returned to the pulper to preheat the incoming sludge.

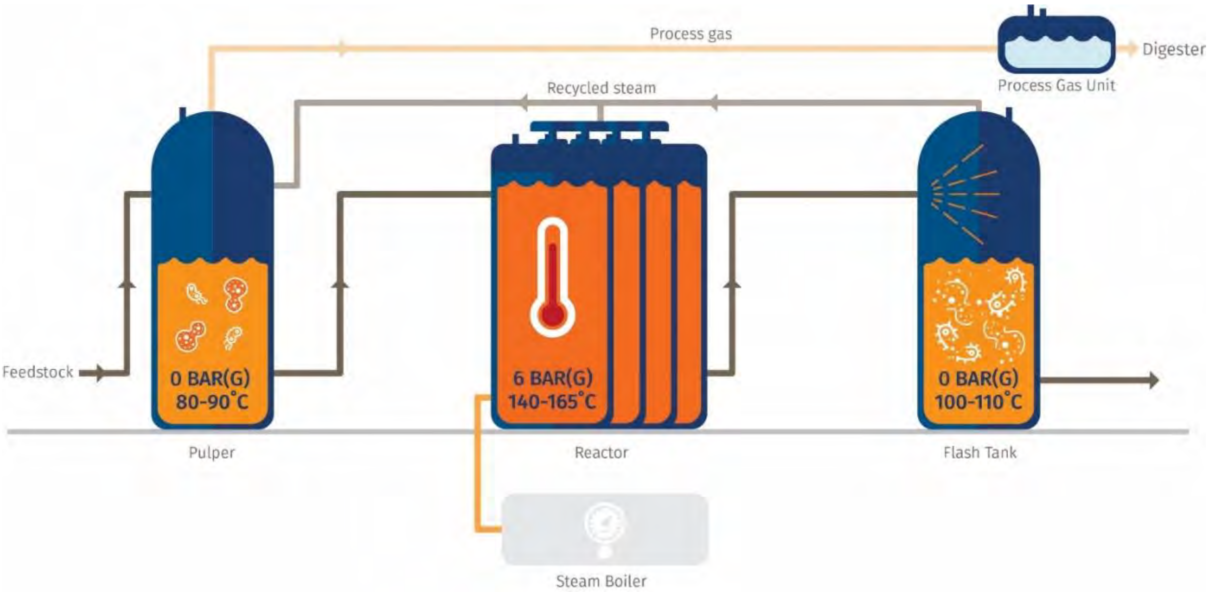

Figure 4-8: Overview of Semi-batch THP Process.

The continuous process does not have a pulper or flash tank and it has just one reaction vessel, as outlined in Figure 4-9. The process runs at 23 – 25% dry solids. The dewatered sludge is continuously fed to a dynamic mixer where live steam is mixed with the sludge. The hot sludge mixture (165 °C) flows into a reactor that is designed to ensure plug flow and thus a narrow residence time distribution. After 30 minutes the hydrolysed sludge leaves the reactor where it is quenched with dilution water to below 100°C.

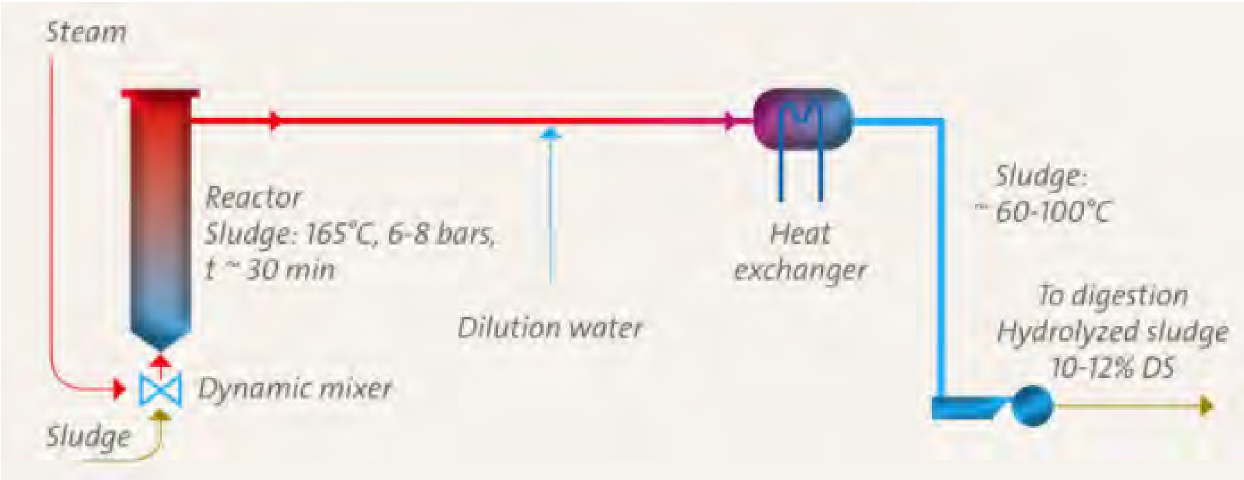

Figure 4-9: Overview of Continuous THP Process.

It is noted that both configurations can be implemented in the Wellington Sludge Minimisation process. The design parameters for the THP are outlined in the below table.

Table 4-14: Key Design Parameters for THP Process

Stream Parameter	Inlet	Outlet	Comments
Sludge flow	1.5 t/h	3.8 t/h	Inlet from Stage 1 dewatering
Sludge temperature	36 ^{o}C	99 ^{o}C	
Sludge %DS	25%	10%	From mass balance
VSS (g/kg)	165	66	From mass balance
Sludge Dilution			
Tepid water flow	1.9 m^3/h	-	From mass balance
Water temperature	33 ^{o}C	-	
Steam generation			
Steam flow (from CHP)	0.4t/h	-	From mass balance
Steam temperature	184^{o}C	-	
Equipment Parameter			Comments
THP Dimensions	768 m^3		1 unit

4.2.6 Stage 2 Digestion Process

The Stage 2 digesters utilise the same design principles as the Stage 1 digestion process, as was outlined in Section 4.2.3, albeit at a smaller scale with a more stabilised sludge inlet. The table below outlines the design parameters of the Stage 2 digestion process.

Table 4-15: Key Design Parameters for Stage 2 Digestion

Stream Parameter	Inlet	Outlet	Comments
Sludge cooling (HX2)			
Sludge flow	3.8 t/h	3.8 t/h	From mass balance
Temperature	99 °C	40 °C	
Sludge displacement	Pump	pump	
MAD			
Sludge flow	3.8 t/h	3.8 t/h	From mass balance
Sludge %DS	10%	8.3%	From mass balance
Sludge temperature	40 °C	40 °C	
Sludge VSS (g/kg)	66	51	
Biogas flow	-	64.4 m^3/h	Enters biogas treatment package
Biogas temperature	-	40 °C	
Equipment Parameter			**Comments**
Heat exchanger			
Dimensions per unit	4.3m^3		3 units: 2 duty; 1 standby
Model	Counter current model		
Digester tank			
Dimensions	780 m^3 (702 m^3 effective volume)		2x units operating in parallel at 50% capacity
Sludge residence time	408 hrs		
Digestate tank			
Dimensions	105 m^3		2x unit operating in parallel at 50% capacity
Sludge residence time	48 hrs		Commonality with stage 1 digestate tanks. Enables long centrifuge runs and flexibility in case of maintenance

As per the Stage 1 digestion process, three main output streams from the digestion process are produced:

- Digested sludge, which is stored in two digestate tanks with a capacity of 105 m^3 each, situated directly adjacent to the Stage 2 digester tanks.
- A small portion of the output sludge, which is recirculated pack in the system.

» The gas by-product (i.e. biogas), which combines with the Stage 1 biogas for treatment prior to storage.

4.2.7 Stage 2 Dewatering Process

4.2.7.1 Dewatering

This process follows the same principles as the Stage 1 Dewatering Process, as outlined in Section 4.2.4, albeit at a smaller scale and a higher target %DS output. Screw conveyors are positioned below the centrifuges and take dewatered sludge immediately out of the centrifuge drop shaft. Conveyors transport dewatered sludge into the dewatered sludge silos. Dewatered sludge is fed into the Thermal Dryer package described further below. The centrate is drained by gravity to the process wastewater system.

The following table provides the key design parameters for the stage 2 dewatering process.

Table 4-16: Key Design Parameters for Stage 2 Dewatering Process

Stream Parameter	Inlet	Outlet	Comments
Sludge flow	5.3 t/h	1.2 t/h	From mass balance
Sludge temperature	33 °C	33 °C	
Sludge %DS	5.9%	32%	From mass balance
Displacement type	pump	screw conveyor	
Centrate flow	-	4.4 t/h	From mass balance
Centrate temperature	-	33 °C	
Polymer dosing	1.6 t/h	-	From mass balance
Equipment Parameter			Comments
Centrifuges space allocation	132.5 m^3		3 units: 2 duty, 1 standby

4.2.7.2 Centrate Treatment

As discussed in Section 4.2.5, the Stage 2 dewatering process may require centrate treatment to protect the main wastewater treatment process from potential UV disinfection deterioration due to light-absorbing compounds produced in the THP process. Allowance has been made in the cost estimate for a centrate treatment system as follows:

» Clarification via dissolved air flotation (DAF) to remove residual solids. The solids removed will be returned to either the thickened sludge tank or the Stage 1 digestate tank
» Ozonation of the clarified centrate
» Return treated stream to IPS.

To limit the size and cost of the system only the affected centrate stream will be treated.

4.2.8 Sludge Drying Process

Dewatered sludge from the Stage 2 centrifuges is fed to the thermal dryer.

Based on previous project experience and a comparison of commonly available technologies which achieve a dry solids concentration of about 90%, three thermal drying technologies were considered, namely:

» **Drum dryer:** this is a form of direct drying whereby sludge and hot air (combustion gas) passes through a rotating steel drum in the same direction. The drum causes the sludge product to rotate as the hot air passes through, allowing the sludge to be heated and dried. By-product gas from the process is recycled back to the dryer inlet.

» **Belt dryer:** this is form of indirect drying whereby sludge is spread across a perforated belt and is dried as it meets high temperature air, typically heated by a thermal fluid. The moisture-rich gas is condensed, mixed with fresh air, re-heated and re-recirculated back to further dry sludge.

» **Paddle dryer**: this is a form of indirect drying using mechanical agitation, typically counter-rotating shafts, for mixing and heat transfer.

Key advantages and disadvantages of the thermal drying technologies are outlined in the tables below.

Table 4-17: Advantages and Disadvantages of Drying Technologies

Technology	Advantages	Disadvantages
Drum Dryer	» Technology established in New Zealand (New Plymouth and Lower Hutt)	» High fire risk – need to control oxygen levels; nitrogen blanketing system required » Very energy intensive – operates at very high temperatures 400-800 ^{o}C » High odour risk » Requires a sludge recycle and mixing » Caking up of the mixer » Frequent breakdowns and extensive maintenance costs
Belt Dryer	» Lower risk of dust explosion » Lower fire risk » Low grade heat recovery possible with additional capital expenditure » Technology established in New Zealand (Christchurch WWTP) » More reliable, less maintenance required – limited moving parts	» Odour risk » Mechanical failure risk (sludge feeding system)
Paddle Dryer	» Lower fire risk » Mechanical interaction allows self-cleaning » Lower odour risk » Thermally efficient	» Technology not yet established in New Zealand » Potential paddle mixer wear » Requires a sludge recycle and mixing » Caking up of the mixer » Dried sludge is produced as powder

Table 4-18: Evaluation Summary of Drying Options.

Criteria	Drum Dryer	Belt Dryer	Paddle Dryer
Long-term equipment reliability	0	+	0
Maintenance requirement	-	+	0
Health and Safety	-	+	+
Odour Control	-	-	+

We propose to utilise indirect, belt drying for the SMF based on its current success in existing WWTP operations, lower fire and dust explosion risk ratings, and their ability to allow low-grade heat recovery.

The table below outlines the design parameters for the thermal drying process.

Table 4-19: Key Design Parameters for Thermal Drying Process

Stream Parameter	Inlet	Outlet	Comments
Sludge flow	0.9 t/h	0.3t/h	From mass balance
Sludge temperature	33 ºC	50 ºC	
Sludge %DS	32%	90%	From mass balance
Displacement type	pump	Conveyor	
Tepid water flow	10 t/h	10 t/h	From mass balance
Tepid water temperature	33 ºC	67 ºC	
Condensate flow to IPS	-	0.6 t3/h	From mass balance
Condensate temperature	-	70 ºC	
Equipment Parameter			**Comments**
Dryer package dimensions per unit	1,152 m^3		2 units running in parallel
Power source	Waste heat from CHP, natural gas (back-up)		

Figure 4-10 outlines a typical belt dryer unit. Sludge enters the thermal dryer unit and is spread evenly across a perforated conveyor belt. The sludge is transported through sections of the drying unit, where it comes into direct contact with heated air which dries the product. This moisture rich off-gas is condensed, reheated and recirculated back to the drying unit.

The conveyance speed of the belt can be adjusted to optimise the DS% output by varying residence times within the dryer unit. Typical operating temperatures for belt dryers are between 100 - 180 ºC.

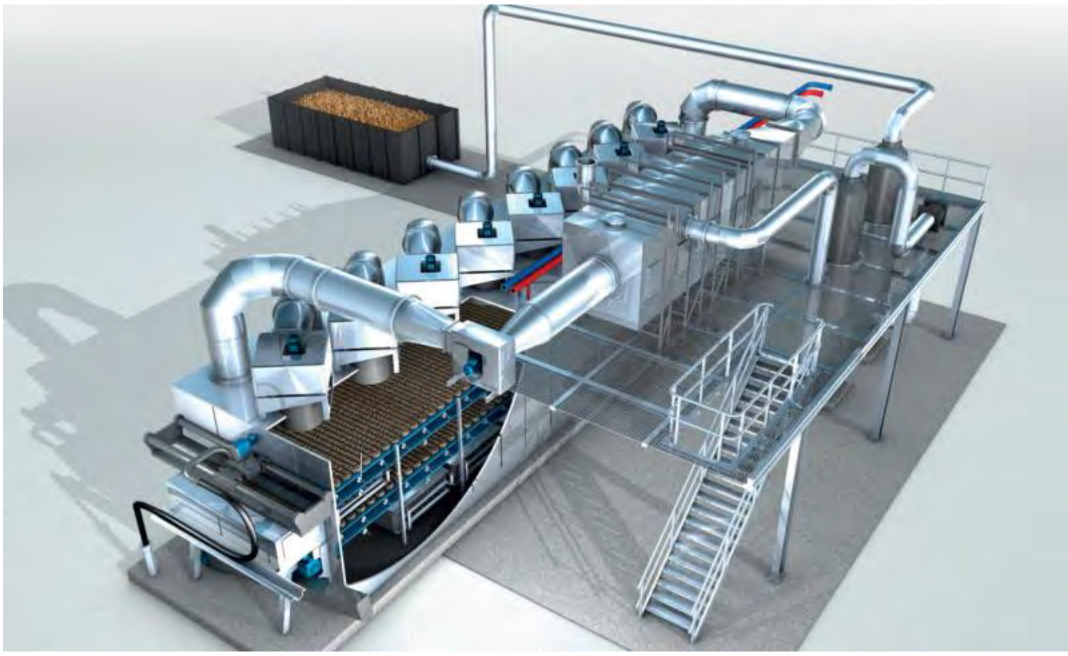

Figure 4-10: Typical Belt Drier (Source: Huber Technology Ltd)

4.3 Ancillary Processes

4.3.1 Combined Heat and Power (CHP) System

CHP systems use a fuel source to generate heat and electricity. For the Wellington sludge minimisation system, the fuel used is the biogas produced in the digesters, the heat will be used for the digesters and the dryer, and the electricity generated will offset the power required to run the system.

There are several different types of CHP generators available, but the most commonly used in municipal wastewater applications with biogas are internal combustion engines, microturbines and gas turbines.

For the concept design, it is assumed that duty/assist gas cogeneration engines will be used for the CHP system, with heat recovered from the engine and exhaust gas as illustrated in Figure 4-11. Selection and optimisation of the preferred technology will be undertaken as part of vendor plant procurement.

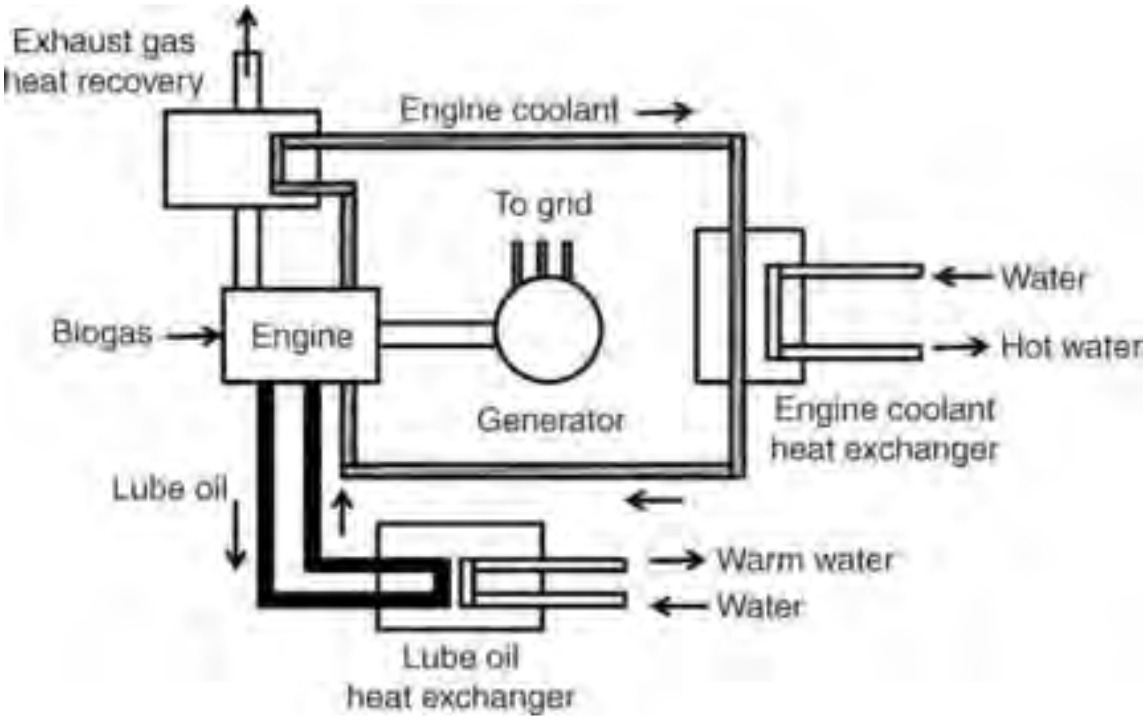

Figure 4-11: Co-generation Flow Diagram

Key sizing details for the CHP system are presented in Table 4-20.

Table 4-20: Key Design Parameters for the CHP System.

Property	Value	Comment
Fuel	Biogas, 65% Methane	From mass balance
Electrical Output	1.1 MWe	Assuming 35% conversion of biogas into electrical energy
Generator Type	Internal combustion engine	
Number of Units	2xduty	

4.3.2 Odour Management

The ventilation air from the plant areas will need to be treated in order to comply with the requirements of the site designation, which is expected to require that there is no objectionable odour beyond the site boundary. However, the specific requirements, including the location of odour monitoring points and specific monitoring and management requirements, will need to be determined through the consenting process (refer Section 7.3.3).

Ventilation air treatment does not include biogas or flue gas treatment, for which separate process philosophies are included in this report.

The technology applied for treatment of foul air at the existing Moa Point WWTP has proven highly effective and very reliable. This setup is a three-stage chemical scrubbing plant in two parallel lanes. The alternatives to chemical scrubbing are:

- **Bark bed biofiltration –** Bark bed systems hold a few layers of media through which air is filtered. Water sprays on the top keep the bed moist, which promotes biological activity. There is also chemical activity in such filter; H_2S reacts with lime blended into the top layer. Seaview WWTP, Karori WWTP and Carey's Gully SDP employ such systems. On the designated site for the Wellington SMF, it would not be possible to accommodate an odour control system of this kind.
- **Biological scrubbing** – These scrubbers consume much less chemicals than chemical scrubbers. The only chemical required is a nutrient dosing. Unfortunately, these scrubbers mainly focus on removing H_2S and up to 99%. This removal rate might not be enough to comply with the odour limits under all circumstances, so a post-filtration step with activated carbon will be required. Also, in the SMF we will likely witness ammonia odours released in the digestion of sludge. Ammonia is not typically removed on a biological scrubber, so additional technology would be needed. Lastly the biological scrubbers need to have significantly larger diameters than chemical scrubbers which presents a space problem.

Due to its current effective operation in the existing Moa Point WWTP and compliance to current consent conditions, we propose to also utilise chemical scrubbing for our proposed SMF.

The main weakness at Moa Point is the difficulty of balancing flows. The Moa Point system is a negative pressure system with only one set of fans determining the end-of-network pressure. Some points in the network are far away from the scrubbers and foul air piping through the building is tortuous. The clarifiers and inlet channels are for instance hard to get sufficient air abstraction from.

For the SMF, it is proposed to section the site up in areas, each with a dedicated abstraction system in order to optimise odour ducting length and configuration:

1. Air from the THP building to be drawn through the Thermal Dryer room and towards the foul air treatment.
2. Air from the IPS building to be drawn through the IPS wet wells and towards the foul air treatment.
3. Air from the ground floor of the main process building to be drawn up to the centrifuge and thickener area and drawn out at the points of highest contamination which will be the machines themselves.
4. Air from the foul air treatment room (the room itself) to be drawn through the plant room beneath it and towards the foul air treatment.
5. Air from the air lock and Western WWTP sludge reception system to be drawn into the CHP room and machine.

For all of these areas, the concept of progressive contamination is followed: clean outside air is drawn into a space where the contamination is low and then progressively into spaces where air contamination is higher. Spaces with the highest levels of contamination will be the influent pump station wet wells and the top level of the thickening area.

Air flows in area 5 (air lock and Western WWTP sludge reception system) do not lead to the foul air treatment. Instead this air will be drawn in by the CHP plant which is estimated to require 2400-3000Nm^3/h of air for the combustion of biogas.

There is flow synergy between areas 1 and 2 (i.e. THP and IPS buildings); these sections will share a common spare abstraction fan. Between section 3 and 4 (i.e. main process building and foul air treatment rooms) there is also synergy in terms of flow; these sections will share a common spare abstraction fan. The assumed ventilation rates are summarised in Table 4-21. Design air changes for each area ventilated are between 4.5 and 10 changes per hour.

Table 4-21: Summary of ventilation rates for main plant rooms

Plant Area	Room Volume (m^3)	Ventilation Rate(m^3/s)
Main Process Building (Areas 1 and 3)	6305	6.1
Digester Building (Area 4)	3059	2.6
IPS Building (Area 2)	1500	3.5
Total Ventilated Volume	11728	12.2

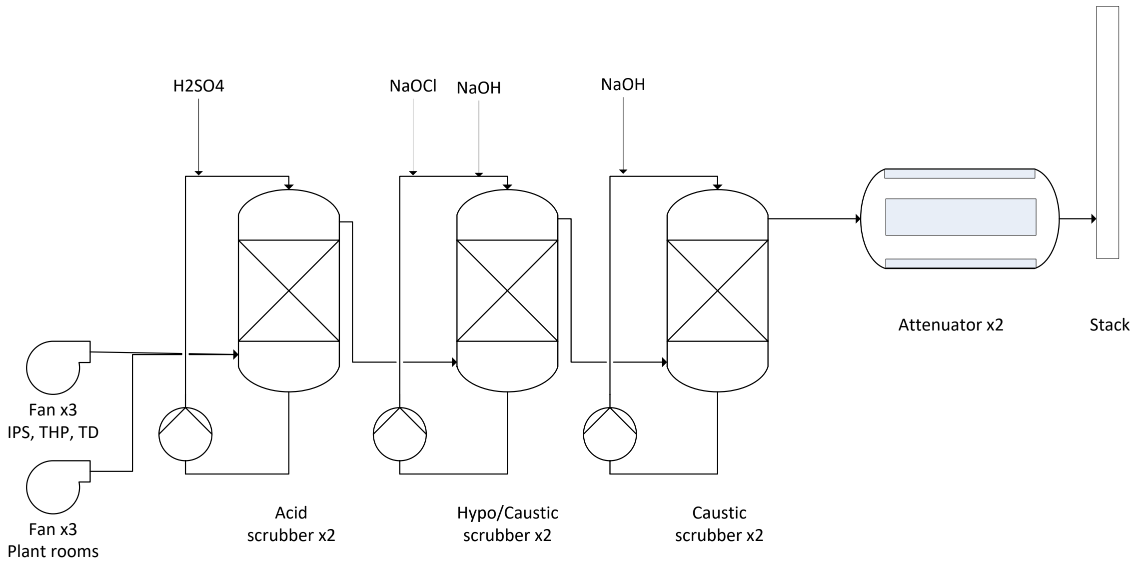

Figure 4-12: Schematic Overview of Three-stage Odour Scrubbing System.

The scrubbing system will be a two-lane parallel, three-stage counter flow configuration dosed with:

- **Stage 1:** Sulphuric acid (H_2SO_4) in order to capture ammonia.
- **Stage 2:** Sodium hypochlorite (NaOCl) and sodium hydroxide (NaOH) in order to capture H_2S and organic malodorant compounds (e.g. mercaptans).
- **Stage 3:** Sodium hydroxide (NaOH) for polishing.

The total of this system thus comprises of 6 vertical scrubbing columns. Each of them has a bottom sump, a packed bed of plastic media and a dilute chemical pumped loop over the column. The recirculation loop is dosed with fresh chemical based on pH or ORP level (in case of NaOCl) in the bottom of the bed of the respective scrubber. Pumped liquid is distributed over the packed media bed by means of spray nozzles. The media bed has a low pressure drop and high contact area.

A mist eliminator will be fitted between stages in order to prevent liquid carry over to the next system.

Part of the content of the sump is purged to the IPS in order to expel reaction products. In order to compensate for lost volume, make-up water is added to the scrubbers during operation.

4.4 Construction Staging Options

Recognising near-term project budget constraints consideration has been given to the ability to stage the development of the new SMF. This analysis is based on the following conditions, aligned to the most critical project objectives:

1. The first stage must generate a significant reduction in solids to landfill.
2. Assets constructed in a first stage must not become (partially) superfluous in a second stage.

The design basis (projected year 2073) sludge production will not be met during the time between first and second stage construction, so it would be acceptable to have (part of) the process sized for a reduced capacity, provided that there are no constraints during the first few years of production.

The below analysis of construction staging options assumes that the second stage of the proposed facility is to be built fin year 2028, or sooner. Hence, the sludge amounts forecast for 2028 have been considered. For the year 2028, it has been modelled that up to 80% of the ultimate 2073 design amount will be produced that year.

Three potential staging options have been identified and quantitatively and qualitatively evaluated based on the conditions set out above, as well as criteria on constructability and thermal balance, which are considered critical to the success of construction and ongoing operation. The 3 staging options identified include:

- **Construction Staging Option 1:** Initially construct a Thermal Dryer. In a second stage, build 2 stages of digestion including the THP unit. This option is referred to as “**Thermal Drying**”.
- **Construction Staging Option 2:** Initially construct one stage of anaerobic digestion, followed by thermal drying. In a second stage build the Thermal Hydrolysis plant and the Stage 2 digestion. This option is referred to as **MAD-TD**.
- **Construction Staging Option 3:** Initially construct 2 stages of digestion and the intermediary Thermal Hydrolysis plant. In a second stage build the Thermal drying. This option is referred to as *“***D-THP-D***”*.

An overview of each option is provided below.

4.4.1 Construction Staging Option 1: Thermal Drying

This option will reduce the mass of solids to landfill to about 30% in comparison to the base case, so it passes the first criterion of substantially reducing volume to landfill. However, it should be noted that the sludge will not have been stabilised, so will be subject to “re-activation” (or greater levels of biological activity) when placed in the landfill. This will not necessarily relieve the fundamental operational and space constraints at the landfill, which re sought by this project.

The key considerations in this staging option are:

- The dryer will need a heat source, which under Construction Stage 1 cannot be supplied from biogas. Therefore, an external heat source must be deployed. For future boiler compatibility with the biogas, the only viable option is natural gas. This is reticulated in Wellington. Purchase of natural gas presents a considerable operational expense. This will significantly increase the carbon footprint of the operation.
- This option would need to be constructed for today's (and short-term future) amounts of dewatered sludge, akin to that currently generated at the SDP at Carey's Gully. A Thermal Drying capacity of 1.67 tonnes/hr of evaporated water will be required. In the completed process scenario, the thermal drying capacity needs to be 0.6 tonnes/hr of evaporated water. Therefore, this option fails on criterion number 2, because the capacity provided for Construction Stage 1 is well in excess of the ultimate drying capacity required. This would create significant issues in fitting other processes on the site in subsequent stages.
- In this scenario the thickeners and first stage of dewatering process would need to be constructed in Construction Stage 1. Without thickening, the Stage 1 dewatering process will not be able to accommodate the sludge flows because of centrifuge capacity. Constructing both Stage 1 and 2 dewatering processes this scenario would still not eliminate the need for thickening to be installed as well.
- In terms of construction, this option is complex. This is because the digesters constructed under Construction Stage 2 would need to be constructed behind a live drying facility. Although not unsurmountable there will be access challenges.
- Any performance guarantees from a technology provider would initially need to be broken up in three parts in order to enable an ultimate performance guarantee:
  - Thickener performance must be identified and agreed upon.
  - Centrifuge performance must be identified and agreed upon.
  - Thermal Dryer performance must be identified and agreed upon.

In Construction Stage 2, two more process elements need to be slotted in between the previous three in order to arrive at an overall performance guarantee. This creates substantial commercial complexity when procuring the plant.

4.4.2 Construction Staging Option 2: MAD-TD

This process sequence was evaluated as one option in the Multi Criteria Assessment process and scored well compared to other options. Of note, this option reduces the amount of sludge to landfill back to 13% of the current situation, and only 3 percentage points (or 25%) short of the preferred option. Criterion 1 is therefore readily easily achieved for this option.

The key considerations in this staging option are:

- By constructing the Stage 1 digestion process as well as the thermal drying process, the facility would be able to fuel itself. No external fuel would need to be deployed apart from start-up fuel, which is the case in any scenario. A benefit of this option is a well-balanced heat supply compared to the demand. No fuel needs importing and not much heat is wasted / rejected.
- Thermal Drying capacity needs to be 0.73 tonnes/hr of evaporated water. This means that overcapacity of 21% in Thermal Drying would need to be constructed to satisfy this staging scenario. The overcapacity could be addressed by:

- Identifying commercially available sizes of drying plants. The best size for the ultimate capacity may be able to cope with the overcapacity reasonably well; or
- Bypass some of the dewatered sludge and send it directly to landfill. This worsens the reduction in solids to landfill but would still rank it as the best out of the 3 staging options for this criterion.
- In this construction staging option, the THP unit can be initially left out as well as the Stage 2 digestion and Stage 2 dewatering process. This will present a significant saving on the Construction Stage 1 costs. Constructing the Stage 2 digestion process units on the live facility will provide some challenges, yet not unsurmountable.
- The performance guarantee from a technology provider would initially need to be broken up in two parts in order to enable an ultimate performance guarantee:
  - The performance from the plant inlet up to the Stage 1 dewatering outlet must be identified and agreed on.
  - Thermal Dryer performance must be identified and agreed upon.

Upon Construction Stage 2, the intermediate process must be identified and agreed upon. This will be less commercially complex for procurement than Construction Staging Option 1.

4.4.3 Construction Staging Option 3: D-THP-D

This option will reduce solids to landfill to approximately 30% compared to the current base case. This is considered sufficient to satisfy criterion 1.

The large benefit of this option is that it presents the “front end” of the ultimate design process. It therefore automatically meets Condition 2. In addition, the actual process performance will be able to inform the procurement stage of the downstream equipment, which is a key benefit that the other options do not present.

The key considerations of this construction staging option are:

- Having the D-THP-D process in place will generate significant amounts of biogas. The CHP facility will have to be built and production of excess power is expected. This also entails excess heat. It would be beneficial if a heat outlet could be found prior, otherwise unused heat will be sent out with the flue gas. Part of this heat will at a later stage supply the thermal dryer.
- In this construction staging option, all plant equipment, except for the thermal drying unit, is installed in the first stage of construction. All other processes and ancillaries will need to be constructed in stage 1. In terms of construction, this is the easiest option: The drying process is placed at the front of the facility which makes construction access the best of all options.
- The performance guarantee from a technology provider can initially cover the entire front part of the process up until the Stage 2 dewatering process. In the second stage of construction, a performance guarantee over the dryer alone is needed. The guaranteed product out of the back end of the facility will be best and most representative of reality in this staging option.

4.4.4 Construction Staging Option Recommendation

The following table summarises the comparison of the proposed staging options.

Table 4-22: Evaluation Summary of Construction Staging Options.

Criteria	1. Thermal Drying	2. MAD-TD	3. D-THP-D
Reduction in solids	Pass	Pass	Pass
Overall investment in assets	Fail	Pass	Pass
Thermal balance	-	+	0
Constructability	-	0	+
Overall process guarantee	-	0	+
Use of learnings for second stage	-	0	+

As summarised in the above table, the Thermal Drying staging option is not the recommended way forward.

Of the remaining options:

» D-THP-D generates a large amount of excess heat. If an outlet for that can be found this will definitely be the preferred option. However, finding a heat outlet that has a demand in summer is a challenge.

» MAD-TD has a few characteristics that do not make it ideal, but the thermal balance of it is a significant benefit.

On the basis of the evaluation above, the preferred option is assumed to be Option 3 – to construct a D-THP-D process under construction stage 1, and a thermal dryer under construction Stage 2.

4.5 Key Process Design Changes for Alternative Preferred LD + TD Option

4.5.1 LD + TD Process Overview

The LD + TD option involves THP, anaerobic digestion and a thermal dryer. The combination of these processes achieves a relatively low volume, high %DS output sludge. The biogas that is generated from the anaerobic digestion process can be used to generate electricity and heat to power the processes and maintain temperature in the THP and thermal drying processes. An overview of the process is provided below, with a more detailed process flow diagram for the alternative LD + TD option included in Appendix E.

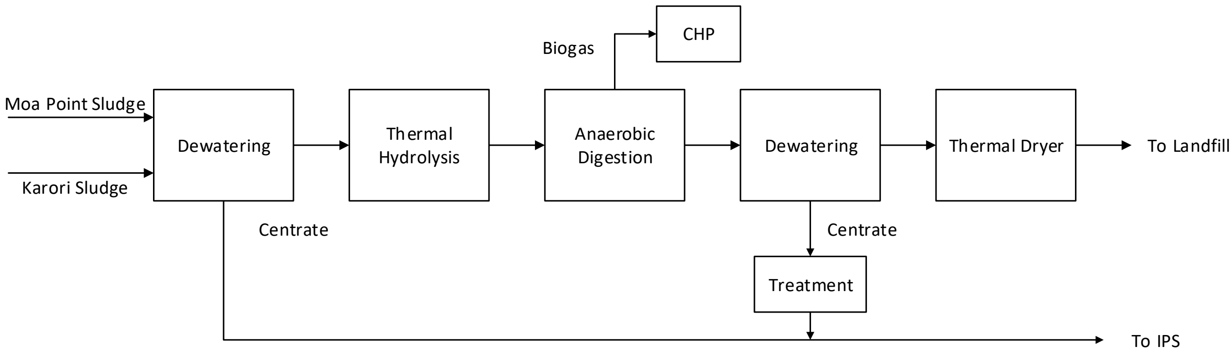

Figure 4-13 - Process Schematic for LD+TD

Under this process, raw sludge from the Moa Point and Western WWTP is mixed and pre-dewatered via centrifugation. Centrate from this initial dewatering step is returned back to the IPS. It is noted that the LD + TD option bypasses the initial thickening and anaerobic digestion stages presented in the DLD + TD option, which reduces the volume of sludge entering the centrifuge for dewatering. As this initial dewatering stage accommodates a larger volume of sludge, the LD + TD facility will require larger centrifuges.

Pumps draw the dewatered sludge to the high-temperature THP unit for pre-treatment prior to digestion. Discussions with potential vendor suppliers indicate that there are alternative THP models of the same footprint size which can accommodate the increased dewatered sludge throughput. The hydrolysed sludge exiting from the THP unit is quenched with dilution water and cooled down to approximately 40 ^{o}C.

As noted in Section 4.2.5 of the Concept Design Report, THP processes can generate colour compounds and recalcitrant nutrient compounds. These compounds can then impact nutrient removal and ultraviolet disinfection performance if they are returned to the main wastewater treatment process. This is noted to be a higher risk in the LD + TD option, as the DLD + TD option involves an initial digestion stage which breaks down the organic molecules prior to entering the THP unit. The proposed mitigation of this risk for the Wellington sludge minimisation facility is to treat the centrate from the dewatering units downstream of the LD process (i.e. the stage between the digesters and the dryer) to remove the colour compounds which may impact on UV disinfection performance. In the LD + TD facility a larger volume of centrate will be produced at this stage and so a larger side stream treatment unit will be required.

Cooled, hydrolysed sludge enters the mesophilic digester tanks which mix the sludge contents, convert the organic material into cell mass and release biogas as a by-product. As outlined in Section 4.2.3 of the Concept Design Report, there are three main outputs from the digester process:

» Digested sludge, which undergoes further dewatering prior to entering the thermal dryer unit
» A small portion of sludge, which is recirculated back in the system
» Biogas which goes to the biogas treatment system prior to entering the Combined Heat and Process (CHP) unit for heat and electrical energy recovery

Table 4-23 presents the key changes in process design form the DLD + TD to LD + TD option.

Table 4-23: Summary of key changes in process design from DLD + TD to LD + TD

Process Area	Key Changes for LD + TD option
Raw Sludge Storage and Pumping	No change to proposed concept design for base DLD+TD option.
Sludge Thickening Process	No need for an initial thickening step for the LD + TD option.
Digestion Process	Proposed plant reduced to only one digestion stage, post-THP. Sizing of key plant equipment is to be similar to the Stage 1 DLD + TD digestion process equipment.
Dewatering Process	Larger centrifuges required for Stage 1 and 2 dewatering processes to accommodate increased sludge throughput. This increase in centrifuge sizing is expected to be minimal, no more than about 10%.
THP	Change in THP unit model to accommodate for increased sludge throughput. No anticipated increase in THP dimensions required (i.e. alternative models available of similar footprint size, according to vendor suppliers). Larger side stream treatment unit required for THP by-products.
Drying Process	No significant change to proposed concept design for base DLD + TD option.
CHP Unit	No significant change to proposed concept design for base DLD + TD option.
Foul Air Treatment	No significant change to proposed concept design for base DLD + TD option.

4.5.2 Changes to Key Process Inputs and Outputs for LD + TD Option

The below table outlines the key changes in sludge inputs and outputs. The below sludge inflow values are based on the 2073 design basis values.

Table 4-24: Comparison of process inputs and outputs for DLD + TD and LD + TD options[1]

Parameter	Unit	DLD + TD	LD + TD[2]
Total Daily Sludge inflow	tDS/day total tonnes/day	21 377	21 377
Inlet Sludge Dry Solids concentration	%DS	0.8% Moa Point 22% Karori	0.8% Moa Point 22% Karori
Inlet Sludge Volatile Solids fraction	%VS	85%	85%
Daily Sludge outflow	tDS/day total tonnes/day	7.0 7.8	7.7 8.5
Final Sludge Dry Solids concentration	%DS	90%	90%
Final Sludge Volatile Solids fraction	%VS		
Biogas Produced	m^3/day	11,327	10,527

Notes:

[1] Outlined sludge output values are based on preliminary concept-level calculations. These are subject to further refinement depending on vendor supplier specification provisions.

[2] Overall sludge output values for the LD + TD option has been obtained based on initial vendor information. A full heat and mass balance for all processes involved in the LD + TD option has not been undertaken. This is to be evaluated in the next stage of design.

5 Site Options Assessment and Selection

5.1 Section Overview

This section presents an overview of the process to identify, assess and select a preferred site option for the proposed Wellington SMF. This includes an assessment of potential sludge transfer pipeline options for sites not directly adjacent to the Moa Point WWTP, in recognition of potential resilience issues with the current pipelines.

5.1.1 Key Findings

The following table summarises the key findings of the site options selection process.

Section Reference	Consideration	Key Findings
5.1	Assessment criteria for process shortlist identification	A long list of potential site options was identified based on available spatial data and assessment against the below key criteria: » Size » Vehicle access » Noise and odour » Utilities access » Topography » Land use and designation Using these criteria, feasible sites were identified which fell generally into two groups, designated A and B, as follows: » Sites in **Group A** are all located **close to Moa Point WWTP**, and » Sites in Group B are all located close to Carey's Gully SDP
5.2	Site options short list	Two shortlisted site options (located at Moa Point and Carey's Gully) were determined through further geotechnical, planning investigations as well as engagement with WIAL and Southern Landfill operators to identify key site constraints.
5.3	Pipeline Options Analysis	Three alternative sludge transfer pipeline routes were investigated after the failure of the Mt Albert Tunnel pipelines in 2013 and 2020, with consideration to: » Pipeline route efficiency » Topography of route » Surrounding environment » Obstacles (bridges, culverts) » Utilisation of existing pipeline route Outcomes from this assessment (i.e. TOTEX costs, technical constraints identified) were inputted into the Carey's Gully site option for the MCA workshop.
5.4	Preferred site option	Moa Point has been identified as the preferred site option for the SMF.

5.2 Site Options Analysis

An initial workshop was held with key Connect Water personnel in February 2020 to identify potential sites using available spatial data from WCC, Greater Wellington Regional Council (GWRC) and Land Information New Zealand (LINZ), and based on the key criteria defined in the table below.

Table 5-1: Summary of key criteria for initial site options identification (long list).

Criteria	Fatal Flaw Description
Size	Limited space and impractical shape for sludge processing operations
Vehicle access	Inability to accommodate heavy vehicle access for loading / unloading operations
Noise and odour	Close proximity to sensitive residential areas
Utilities access	Lack of / inability to access to power and utility connections
Topography	Lack of flat, open land for vehicle movements and large building and process plant areas
Land use and Designation	Foreseen difficulty with land acquisition due to district plan rules and zoning, designations, existing land use, community amenity value, land ownership, Selected Land Use Register (SLUR) status

Using these criteria, feasible sites were identified which fell generally into two groups, designated A and B, as follows:

- Sites in **Group A** are all located **close to Moa Point WWTP**, and
- Sites in Group B are all located close to Southern Landfill.

Several other options were identified in the workshop as being “marginally feasible” but were not considered worth pursuing, based on the initial assessment against the key criteria outlined in Table 5-1. These include:

- A new dewatering facility near one of the existing wharves / docks at Shelly Bay. This option had been considered as it could be used for sludge dewatering and then transportation by barge to Seaview WWTP for drying through the existing (and expanded) rotary drum thermal dryer.
- There are a number of Council-owned sports fields and recreational areas in the suburbs surrounding Moa Pt WWTP and Southern Landfill, and on the sludge, pipeline routes between the two. However, the activities associated with sludge management would create significant impacts for current users of these areas, and their neighbours, and obtaining consent to construct the new Sludge Management Facility would be very difficult. This is made even more difficult in areas of the Town Belt (of which many of the options are located).

5.2.1 Longlist to Shortlist Approach

Further analysis was then undertaken for the identified potential sites in Group A and B, to identify any key (“fatal”) flaws in the proposed options. The approach taken included:

- Group A sites: investigations were undertaken first to identify technical constraints with the options initially identified. This was done to inform discussions undertaken with Wellington International Airport Limited in May – June 2020, who either owns the land on which the sites are located, or whose operation could be affected by locating a SMF on the sites.
- Group B sites: consultation with the Southern Landfill operator was initially undertaken in March 2020 to discuss the range of options. This identified some key constraints with most of the site options selected, requiring that most Group B sites be negated from further consideration. Following this, further technical investigations were undertaken to identify technical constraints at the remaining Group B sites.

5.2.2 Shortlist of Site Options for MCA

Based on the fatal flaw analysis to arrive at the short list, only two short listed potential sites were ultimately been identified, as shown in Figure 5-1 for Group A (near Moa Point WWTP) and B (Carey's Gully) respectively.

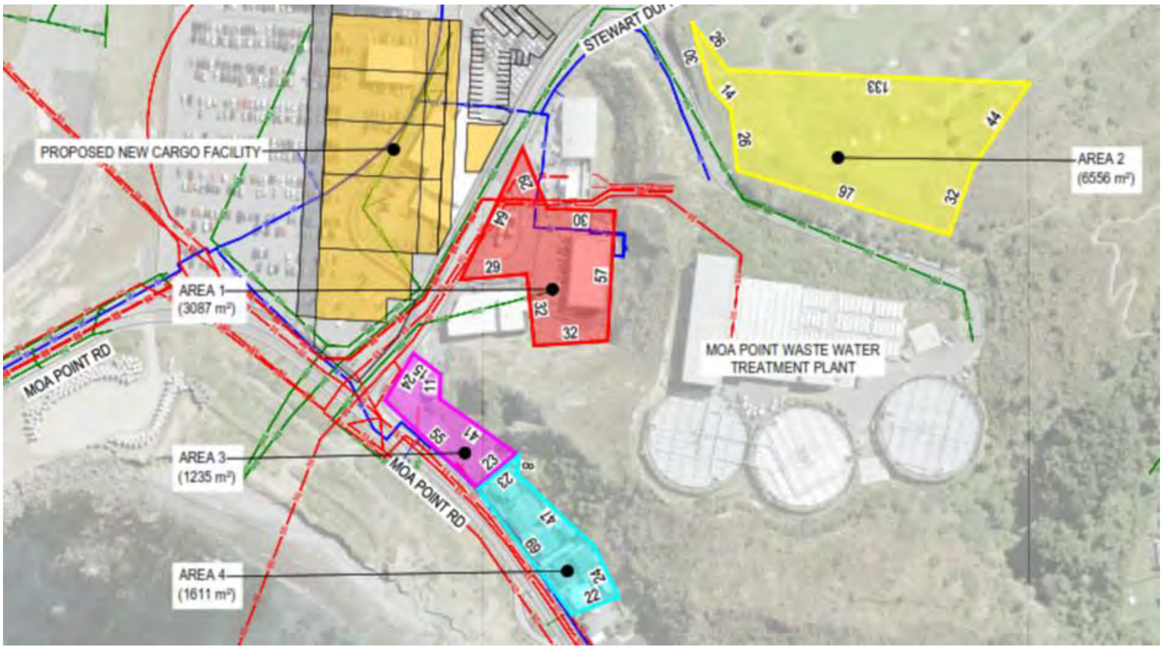

Figure 5 1: Potential site areas located at Moa Point WWTP (Areas 1 - 4 highlighted)

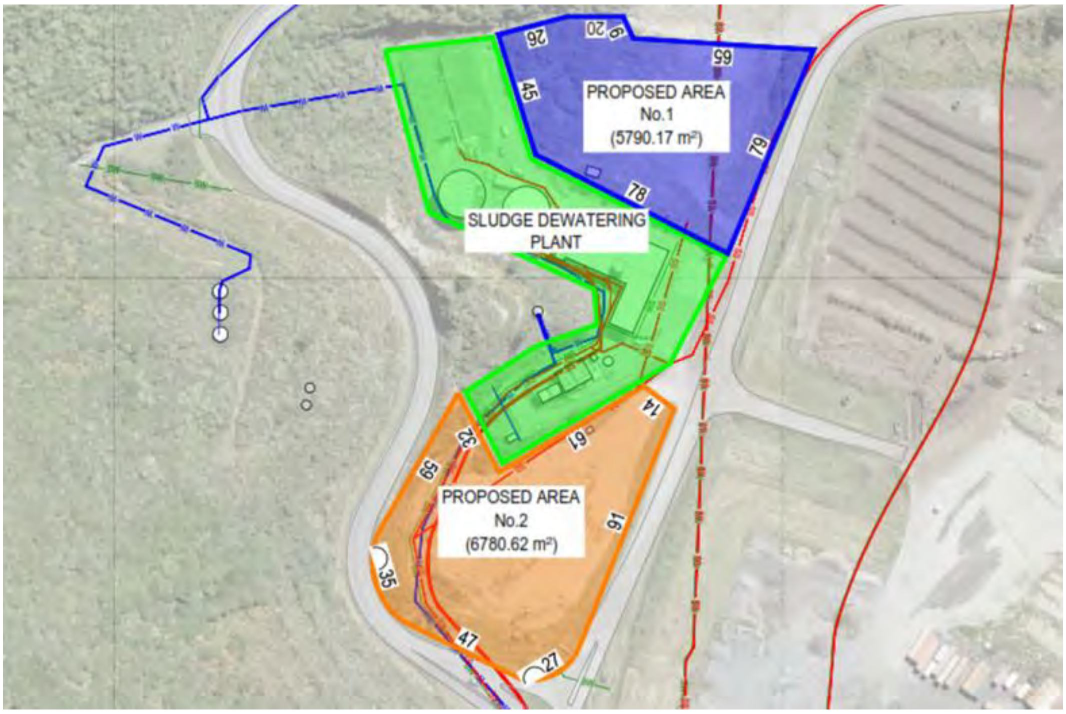

Figure 5-1: Potential sites located at Carey's Gulley (Areas 1-2 highlighted)

Subsequent to the identification of these short-listed site options, process layouts for the various shortlisted process options were overlaid. For the Moa Point WWTP site options, preference was given to Area 1 (as shown in **Error! Reference source not found.**) as agreed with Wellington International Airport Ltd. This is because Area 2 is directly adjacent to proposed airport operational areas in the airport's master plan. Areas 3 and 4 were generally less preferential due to their proximity to the coats (and its amenity value) and residents.

Table 5-2 provides an overview of the findings gathered from the technical investigations undertaken for each shortlisted option.

Table 5-2: Findings from Technical Investigations

Consideration	Moa Point Site Option	Carey's Gully Site Option
Geotechnical risks, including:	Slope stability of face west of Moa Point WWTP may present some geotechnical challenges, but not as significant as other geotechnical risks at Carey's Gully.	Likely presents higher risk than Moa Point due to landfill material on sites. Likely to lead to substantially higher costs for management of geotechnical risks.
Mapped geology	Greywacke rock	Underlain by landfill material and greywacke rock of the Rakaia Terrane.
Anticipated Soil Profile	Variable thickness (estimated 5m to 20m) of fill and/or sand overlying greywacke rock	Landfill material of variable strength / composition, and high potential for subsidence due to varying depths of fill. Underlain by greywacke rock.

Consideration	Moa Point Site Option	Carey's Gully Site Option
Groundwater	Estimated to be within 5m	Shallow based on limited available investigations.
Fault rupture risk	Low	Low - As no active faults are mapped through site the risk of direct fault rupture is assessed to be low
Liquefaction and cyclic softening risk	Low to medium	High
Lateral spreading risk	Low	Low
Tsunami risk	Moderate	Low
Flooding risk	Low	Low
Slope stability risk	Moderate	Low to moderate for southern site. Moderate to high for northern site.
Electrical Supply	Neither site presents any more significant issue relative to the other but checks of capacity in the network and transformers will need to be undertaken.	
Planning and Land Use Issues, including:	The proposed SMF would require new planning approvals at both a district and regional level. Likely to be more complex for Moa Point due to land use designations of airport, and resident / stakeholder interests.	Established activity at Carey's Gully may make consenting pathway easier, depending on outcome of landfill expansion. However, stakeholders are mobilised and may be "fatigued" by consultation.
District level approvals	Requires amendment /of a large and complex designation which is complicated by Wellington Airport and Miramar Gold Course land designations. Agreement and written approval from Wellington International Airport would be required for any subsequent Designation for the SMF.	It is recommended that the existing Southern Landfill Designation (Designation 61: Carey's Gully) is utilised, which includes a 'proposed sludge processing plant' within the scope of the Designation. An Outline Plan would be required.
Regional level approvals	Consents likely required for discharge to air and discharge of stormwater. The activity status would be Discretionary.	
Contaminated land	Moderate to high risk of contamination, but likely to be less of an issue than for Carrey's Gully site. Detailed site investigations will be required.	High likelihood of widespread contamination with substantial amount of works to remedy. Detailed site investigations will be required.
Likelihood of notification	Highly likely to be notified and could face more significant issues through public / stakeholder consultation than for Carey's Gully, due to proximity to residents and changes to land use and the nature of the activity.	Highly likely to be notified and could face issues during public / stakeholder consultation due to mobilised public over current landfill consenting.

5.2.3 Changes to Site Option Short List Post-MCA Workshop

During the MCA workshop held in July 2020, it was noted that Area 2 of the Moa Point site (refer **Error! Reference source not found.**) has been earmarked for the Moa Point WWTP expansion to accommodate for the projected increase in population within Wellington City.

5.3 Pipeline Options Analysis

Following the failure of both Mt Albert Tunnel pipelines in 2013 and 2020, WWL requested Connect Water to undertake an assessment of alternative pipeline route options to transfer sludge from the Moa Point WWTP to Carey's Gully. This is because the expected life of the pipelines, of up to 30 years, is within the design horizon of the new SMF. Therefore, if the new plant is to be located at Carey's Gully, costs for pipeline replacement (as well as ongoing operation and maintenance costs) need to be included in the whole of life cost estimates for these options.

5.3.1 Pipeline Options Identification Approach

A high-level visual assessment of route options was undertaken by Connect Water in March 2020. This included a drive-over of three different options, taking into consideration the following factors which will have an impact on cost:

- Pipeline route efficiency
- Topography of potential routes
- The environment in which the pipelines need to be installed
- Any significant obstacles such as bridges and culverts where these could be identified.
- Utilising the route of the existing pipelines (excluding tunnels) where appropriate.

Once the routes were identified, a feasibility assessment was undertaken, including hydraulic assessment and initial Level 1 cost estimation for each pipeline route option. Results from this feasibility assessment are summarised in Table 5-3. Note that no further optimisation of pipeline routes has been undertaken beyond identifying the routes through a drive-over. Further optimisation should be considered at the next stage of design if required, i.e. if Carey's Gulley becomes the preferred site option.

Based on the approach outlined above, three alternative sludge pipeline options were identified, as shown in Figure 5-2.

Figure 5-2: Sludge transfer pipeline options

The following table provides a summary of the pipeline options identified. Given the relatively similar capital cost estimates, a preferred pipeline option has not been selected at this stage, but the costs have been incorporated into process options which include siting the plant at Carey's Gully. Further detailed analysis will be required should this site option be preferred.

Table 5-3: Comparison of Sludge Pipeline Options

Parameter	Option 1P – Northern Route via Crawford Road	Option 2P – Central Route via Mt Albert Road	Option 3P – Coastal Route via The Esplanade
Route Efficiency	Good – of the three routes presented, this is the shortest route.	Poor – the route takes several windy, hillside roads.	Good – While this route is longer than Option 1, it is a relatively straightforward alignment.
Difficulty of Installation	This route features a significant length of installation in arterial roads. This is likely to cause significant disruption.	This route features steep grades but is largely installed in residential streets which minimises disruption and allows for more straightforward installation.	This route features a coastal road which is likely to include number of difficult conditions such as a coastal ground and atmospheric conditions for the installation, stormwater mains and retaining structures.
Hydraulic Design	Based on the limited hydraulic design undertaken to date, all options would require 4 – 5 pump stations according to the criteria of limiting total discharge head to 40m for centrifugal pumps. Some optimisation may be possible, which would favour Options 1 and 3.		
Planning and Consenting	The route runs adjacent to areas of Open Space Zoning along Crawford and Adelaide Roads. Should the pipeline be located fully within legal road reserve the activity can continue without resource consent as a Permitted Activity. However, should the pipeline encroach into any of the Open Space Zone B or C land, resource consent would be required under Rule 23.2.1B as a Restricted Discretionary Activity.	The route runs through Open Space Zone C land when crossing over from Mount Albert Road to Adelaide Road, and adjacent to Open Space Zone B land that is also identified as a Heritage Area when following Lyall Parade. This route would require resource consent under Rule 23.2.1B as a Controlled Activity and under Rule 23.3.3 as a Restricted Discretionary Activity.	As with Option 2, the route runs adjacent to Open Space Zone B land that is also identified as a Heritage Area when following Lyall Bay Road. This requires resource consent under Rule 23.2.1B as a Controlled Activity.

5.4 Preferred Option

Based on the multi-criteria assessment workshop outcomes and post-workshop analyses (described further in Section 3.8), the preferred site location option was the Moa Point site.

It is noted that Moa Point is already established as a site for WWTP processes, whereas the Owhiro Bay area was highly utilised by the community. Additionally, establishing the facility at Moa Point avoids the need for the sludge transfer pipeline from Moa Point to Carey's Gully, thus avoiding the risk of pipeline failure and discharge to waterways, which is culturally abhorrent. This site scored the highest with the preferred process option selected in the MCA workshop - DLD + Thermal Dryer plant.

Considerations for the design and construction of the plant at this site are described in the following section.

6 Spatial and Constructability Requirements

6.1 Section Overview

This section presents the concept development of the proposed SMF at the Moa Point site, including:

» Key considerations of the civil design, including site utilities and pavement systems.
» Geotechnical engineering considerations.
» The basis of design for structures, including the proposed structural engineering design philosophy for key structures.
» Considerations for electrical and control systems design.

6.1.1 Key Findings

The following table summarises the key findings of the process design.

Section Reference	Consideration	Key Findings
6.2.1	Site and Plant Layout Considerations	The Moa Point site layout has been optimised to satisfy construction and operational requirements with limited land space, as well as WIAL requirements. Site and plant layout optimisation included the following key features: » Stacked arrangement of key equipment, while remaining below 39m height limit set by WIAL » Biogas storage located on top of digester tanks » 5m space allowance for vehicle and crane access
6.2.2	Natural Gas Supply	An estimated 400kW of energy is required from natural gas to provide start-up and back-up energy supply for the thermal dryer plant. Network modelling undertaken by Powerco Ltd indicates that 25,000 kWh/d is available and sufficient to run the standalone dryer.
6.2.3	Stormwater System	It is proposed that any new stormwater systems be connected to the existing network. The Rational Method specified in the WWL Regional Standards was used to estimate the expected runoff flows and determine the concept design of the stormwater reticulation system.
6.2.4	Water Supply	It is proposed that a new potable water network be constructed to supply the various process areas to the site, from a single watermain. The watermain was sized to meet the requirements of WWL Regional Standards which stipulates the internal diameter to be at least 150mm.
6.2.5	Process Wastewater	It is proposed that this wastewater be collected at a common process drain system that would be reticulated around the ground floor of the main process building and

Section Reference	Consideration	Key Findings
		then discharged to sewer (to be separated from stormwater).
6.2.6	Roading and Pavement Systems	Pavement systems are recommended to consist of two layers of 150mm thick NZTA M/4 AP40 and a surfacing of 50mm AC14.A, to meet the heavy vehicle requirements.
6.3	Geotechnical Considerations	Rockfall hazard from the west facing slope adjacent the AGS building is noted to be the greatest geotechnical risk to the proposed development of this site. It is proposed to stabilise the rock slope using rockfall protection measures (prevention) as opposed to limiting the travel of rockfall through use of barriers.
6.4	Structural Considerations	The main buildings and primary treatment tanks shall be considered as Importance Level 3 (IL3) structures. The design working life of both the main buildings and primary treatment tanks shall be taken as at least 50 years.
6.5	Electrical and Control Systems Engineering Considerations	To accommodate the new upgrades, it is proposed to locate a new substation on site which will house dual HV transformers and switchgear. All HV works and equipment would be provided by the local network utility provider (Wellington Electricity). The new facility's Programmable Logic Control (PLC) system will be provided to match the existing systems installed on the Moa Point WWTP and IPS sites.
6.6	Key Site Layout Changes for Alternative Preferred Option	The reduction of key process elements reduces spatial constraints and allows the possibility of retaining the existing Cyclotek building within the site envelope.

6.2 Civil Engineering Considerations

6.2.1 Site and Plant Layout Considerations

Having developed the process design, site layout options were considered, and a preferred layout option identified based on consideration of three key factors:

- Operational Constraints.
- Requirements for construction and operation adjacent to an operational airport.
- Constructability of structures and plant.

Each of these considerations is discussed below.

6.2.1.1 Operational Constraints

The SMF consists of a number of process buildings and structures which need to be accommodated on the limited site area. To do so, several key features have been incorporated into the site layout development:

- To minimise the buildings footprint, it is proposed that the equipment generally be arranged in a stacked arrangement over two or more levels within core process areas. These areas have been arranged based on the need to minimise pipework and cable runs, place common operations together, and enable efficient use of space. The key groupings of processes within the site layout are:
- Sludge thickening and dewatering – contained within a single building over two levels.
- Sludge drying – located next to the thickening and dewatering plant, to enable the efficient transfer of sludge. A sludge load-out facility is located directly adjacent to this also. Services for the sludge thickening, dewatering and drying processes have been placed below these plants within the main plant building containing these key processes.
- Stage 1, and Stage 2 digesters, and their associated ancillary processes. To further maximise space, the odour control system has been located within the building footprint of the Stage 1 Digester Plant Room.
- As previously discussed, it is proposed that the biogas holders are integrated with the digester structure by locating them on top of the digesters as a space saving measure.
- The site layout has been developed to accommodate critical vehicle and crane access to the process buildings and structures.
- Vehicle access is incorporated for daily Karori sludge unloading to the facility, the loadout of dried sludge from the facility within a single area. Chemical loading, maintenance vehicle and crane access are also provided to the digesters and the inlet pump station for maintenance purposes.

The development of the facility would require the demolition of the Cyclotek Pharmaceutical Ltd and the AGS buildings, both leased by WIAL. Options for retaining the Cyclotek building were explored. However, there is insufficient room on the site for the DLD process without utilizing this space. Figure 6-1 and Figure 6-2 below indicate the vehicle tracking for the Karori sludge loading, the loadout of dried sludge, access for chemical loading, collection of dried sludge, and access to the inlet pump station.

These vehicle tracking requirements have a significant bearing on site layout and have led to the placement of load-in / out facilities directly adjacent to Stuart Duffy Drive, to prevent excessive movement of heavy vehicles through the site once operational. Discussions with WIAL have confirmed that sludge load-out trucks can undertake turning within the yard of the proposed adjacent cargo facility to the wets of Stuart Duffy Drive.

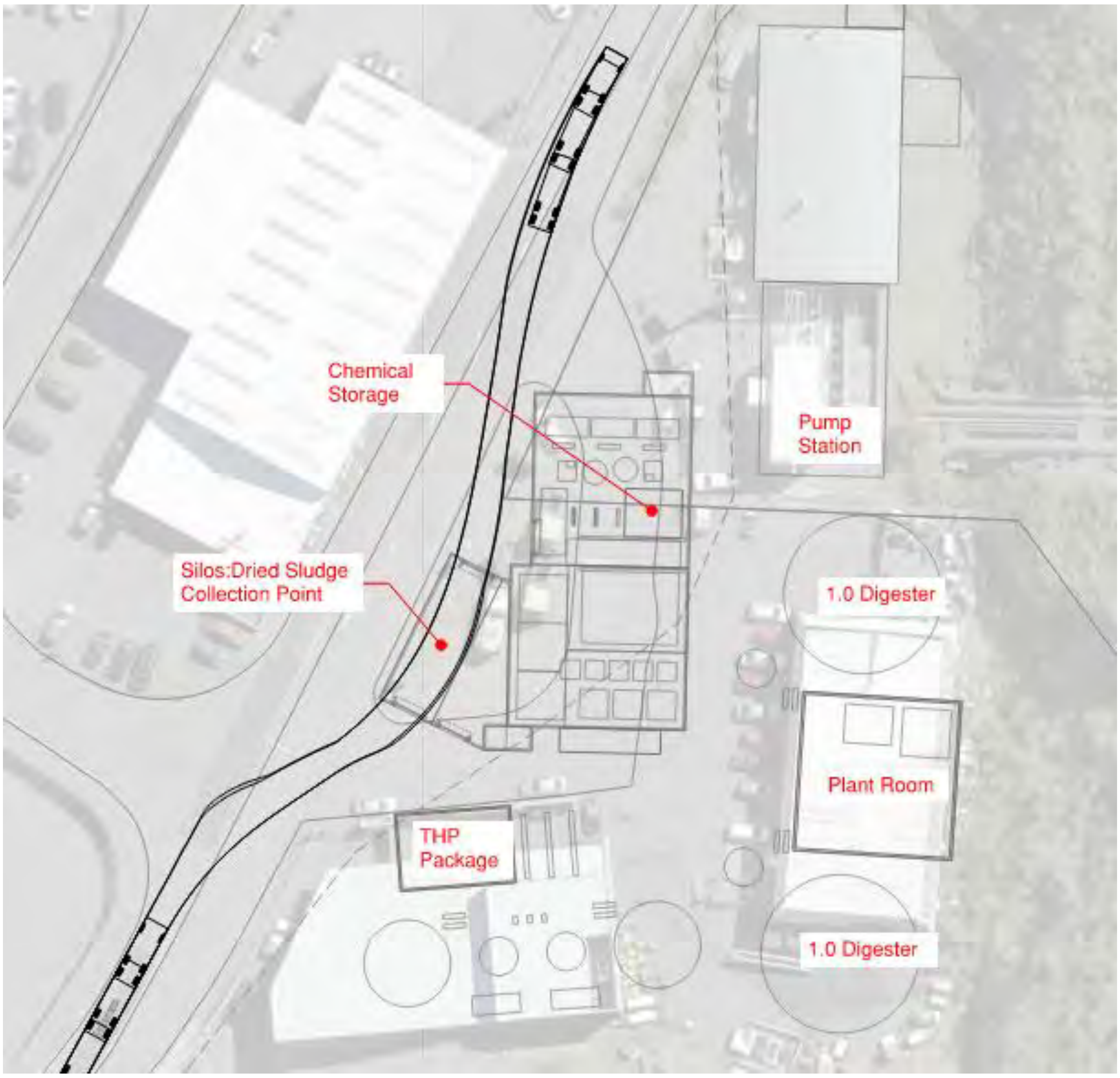

Figure 6-1: Schematic of Vehicle Tracking for Typical Sludge Load-out.

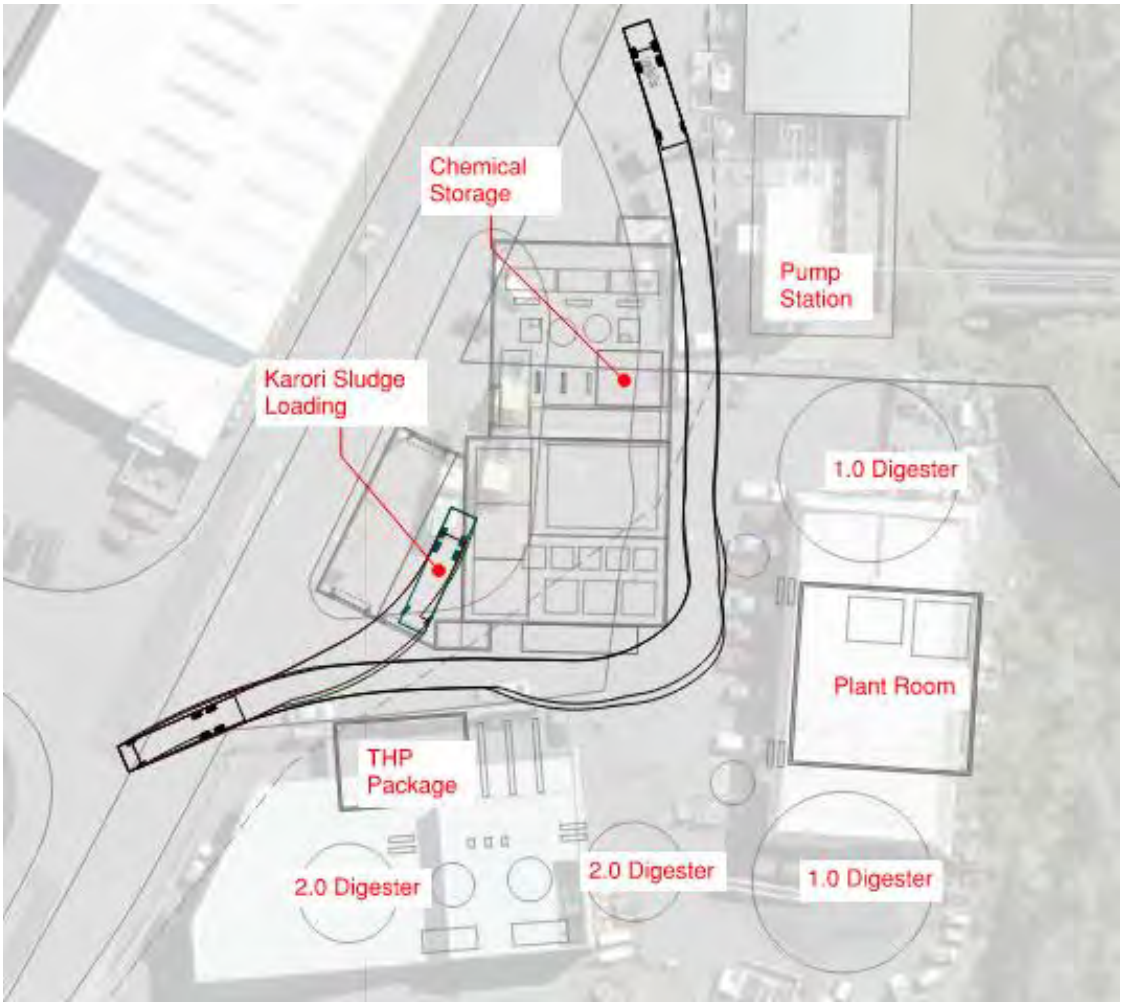

Figure 6-2: Schematic of Vehicle Tracking for Karori Sludge Load-in (Using a Rigid Skip Truck).

6.2.1.2 WIAL Requirements

Due to the proximity of the site to Wellington International Airport, height restrictions are placed on structures as stipulated in the Wellington City District Plan. Figure 6-3 provides an overview of the Wellington International Airport Airspace Designation which shows the free air space required and building height restrictions in the vicinity of Wellington Airport, of which this site lies within.

As indicated in Figure 6-3, the key restriction on height for the proposed new SMF comes from a 1:7 slope plane originating at the centre line of the airport runway and ascending over the proposed Moa Point site. Based on this, and the nearest point of the proposed site to the airport runway, the maximum height for structures is approximately 39m above ground level. Note that this will need to take account for any routine craneage for maintenance purposes, which may limit the height of buildings and structures below this elevation.

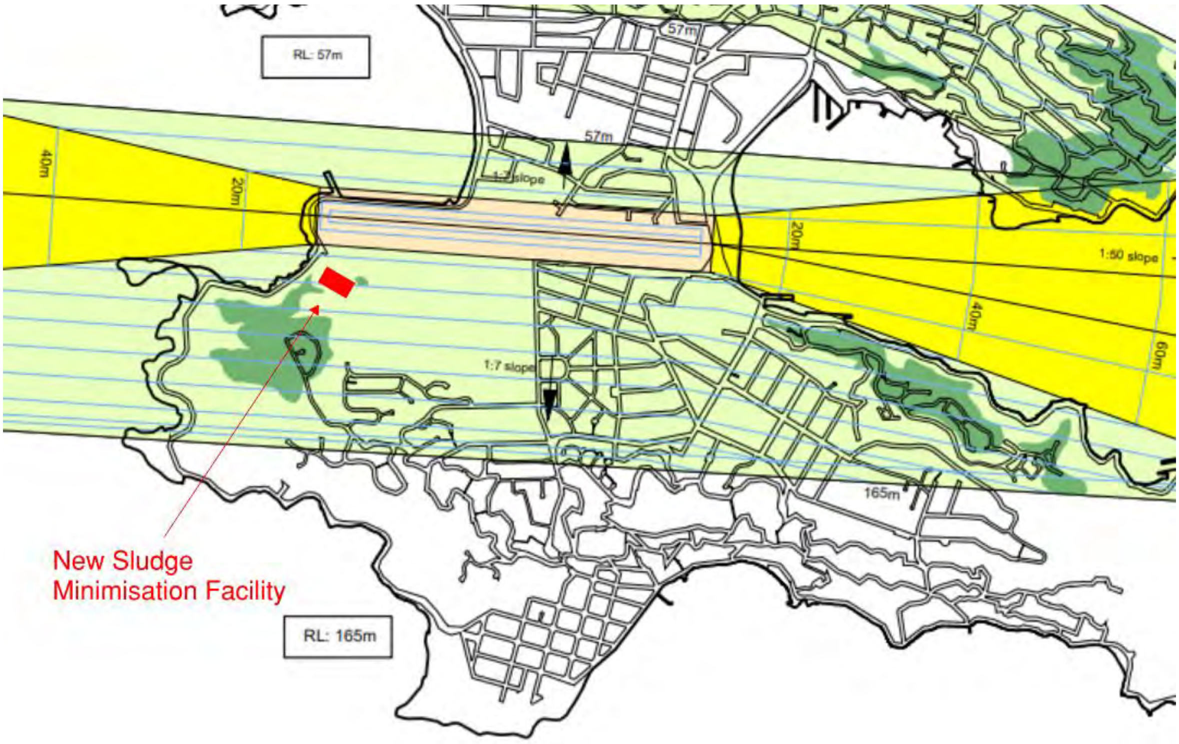

Figure 6-3: Wellington Airport Airspace Restrictions. Source: Wellington City District Plan.

6.2.1.3 Constructability

The proposed site layout also considers the availability of space that would be required for construction. Space allowance has been made for cranes to be assembled and disassembled during construction and in the event of major maintenance requirements, i.e. removal of equipment from the digesters. A minimum corridor width of 5m on access roads has been allocated between key structures for vehicle and crane access.

A buffer has been provided between all key structures, and the toe of the southern and eastern rock slopes, based on a 45° theoretical plane from the base of the excavation of foundations for key structures. This is particularly critical to maintain slope stability (refer Section 6.3.2.3).

6.2.2 Natural Gas Supply

Natural gas will be required to provide start-up and back-up energy supply for the thermal dryer plant. This is estimated to require approximately 400 kW of energy. A gas supply network exists at Moa point Road within the proximity of the proposed site. Initial gas network modelling undertaken by Powerco Ltd (the network operator) indicates that 25,000 kWh/d is available and sufficient to run a standalone dryer. This could be supplied from the existing grid with a new 50mm PE gas line connected to the existing DN150 PE main. Powerco have indicated that no upfront customer financial contribution would be required for installation of the gas supply pipework and meter. Refer to Figure 6-4 for the proposed gas connection for the new sludge plant.

Figure 6-4: Proposed Gas Connection for the new Sludge Minimisation Facility.

6.2.3 Stormwater System

The existing site stormwater system at the site consists of yard sumps connected to a series of 150mm reinforced concrete pipes which convey rainwater by gravity to sea. The invert levels of the existing stormwater manholes are unknown at this stage of the project but will be confirmed after a detailed site survey.

It is proposed that any new stormwater systems be connected to the existing network. A grated channel drain would be provided at the toe of the embankment to collect surface water. Building roof rainwater will be conveyed into the stormwater system through downpipes. Surface runoff will also be channelled to the stormwater system by yard sumps, grated channels and access road kerbing. The new stormwater system will discharge into the 600mm concrete pipe along Steward Duff Drive.

To determine concept design of all components of the proposed stormwater reticulation, the Rational Method specified in the WWL Regional Standards[4] was used to estimate the expected runoff flows. Preliminary hydraulic analysis and sizing of the stormwater services was carried out using the Colebrook-White Equation. A minimum slope of 1:200 was used at this stage for all the stormwater pipes which will be refined in the detailed design. The stormwater system should be designed to accommodate a 1:50 year flood. Refer to the drawings in Appendix E for the site layout which includes both existing and proposed stormwater network.

[4] *Regional Standard for Water Services*. (May 2019) Wellington Water Ltd.

One key consideration of the stormwater design will be to mitigate the impacts of climate change. Rising sea level may cause stormwater to back up within the network. To mitigate any potential impacts of climate change, an integrated design approach is needed with Wellington International Airport Limited, because proposed developments on the western side of Stuart Duffy Drive, which are likely to contribute stormwater to the same network, will impact this significantly. We propose that a cost risk allowance be included within the capital cost estimate by agreement at the proposed project risk workshop. Refer to Section **Error! Reference source not found.** for further information on the project risk management process.

6.2.4 Water Supply

Existing potable water infrastructure data was obtained from the WCC GIS Maps. A 150mm PVC-U watermain from Stewart Duff Drive, behind the existing pump station, services the existing AGS building.

It is proposed that a new potable water network be constructed to supply the various process areas to the site, from a single watermain. Concept sizing indicates that a 180mmNB PE100 watermain would be required, from which 32mm PE100 branches come off to distribute water to all the process areas. The watermain was sized to meet the requirements of WWL Regional Standards which stipulates the internal diameter to be at least 150mm. Water demands for the processes will need to be confirmed during detailed design. Polyethylene (PE100) pipe materials were selected to meet the resilience requirements for WWL networks.

6.2.5 Process Wastewater

Process wastewater consists of filtrates from sludge thickeners and centrifuges, supernatant from off spec wastes, and general washdown from processes equipment. It is proposed that this wastewater be collected at a common process drain system that would be reticulated around the ground floor of the main process building and then discharged to sewer (to be separated from stormwater).

Estimates of the flows were used for the preliminary sizing of the key process waste pipelines. Initial concept sizing indicates that the process wastewater network would consist of 180mmNB PE100 pipes and 1050mm diameter manholes. The process wastewater will be redirected back to the inlet pump station for treatment. To do this, the wastewater will need to be connected at the first manhole on the main incomer sewer upstream of the influent pump station, or directly to the distribution chamber immediately upstream of the split wet wells at the pump station.

6.2.6 Roading and Pavement Systems

As previously noted, the access road for the facility allows for a B-Train truck to drive under the dried sludge silos and a Medium Rigid Truck to bring the Karori sludge to be loaded into the raw sludge hopper. To meet these heavy vehicle requirements, the pavement would consist of two layers of 150mm thick NZTA M/4 AP40 and a surfacing of 50mm AC14.A, which would be confirmed at the detailed design stage. Trial pits will be required for the detailed pavement design.

6.3 Geotechnical Engineering Considerations

6.3.1 Basis of Design

6.3.1.1 Proposed Development

The SMF is proposed to be located in a relatively flat-lying site between Wellington International Airport and the Moa Point WWTP. The site is currently occupied by the pump station for the Moa Point WWTP to the north, the AGS building in the centre-east, and the Cyclotek building to the south (Figure 6-5).

The proposed development is understood to include removal of the AGS and Cyclotek buildings to allow redevelopment of the area for the construction of the sludge thickening plant and a series of digesters.

Figure 6-5: Site Plan Showing Previous Investigation Locations and 2020 Site Investigation Locations

6.3.1.2 Site Description

The site is northeast of the intersection of Moa Point Road and Stewart Duff Drive. The area is relatively flat at about 5-6m in elevation (metres above mean sea level, Wellington 1953 Datum), located at the toe of an west facing slope of about 60° to 70° which is about 30m high (the Moa Point WWTP is located at the crest of the slope). The lower part of the slope (debris fan) slopes at about 35° to 40°.

Historical aerial photographs indicate the site was formerly a rocky peninsula which was quarried from as early as 1938 through to the 1950s as part of the Wellington International Airport construction. The west facing slope is the former quarry slope, however in the late 1980s the construction of the AGS building (which was formerly the Moa Point WWTP Milliscreen Building) resulted in steepening of the lower 10m of this slope. Photographs from that time suggest a landslip occurred shortly after construction, and instability appears to have been ongoing with debris periodically accumulating at the slope toe behind the AGS building.

6.3.1.3 Geotechnical Hazards and Constraints

A geotechnical desktop study was carried out in May 2020 for the Sludge Minimisation Project (Connect Water 2020a)[5], identifying the rockfall hazard from the west facing slope adjacent the AGS building as presenting the greatest risk to the proposed development of this site.

Previous measures to manage rockfall behind the AGS building have included scaling by abseiling contractors to remove loose blocks. Recent rock fall assessments for this slope (Beca, 2019)[6] indicated further rockfall at the site to be “likely” to “almost certain”, putting the slope at “moderate” to “high” risk (assessed against the 2007 AGS guidelines[7]).

Based on field observations and 2-dimensional rockfall modelling, the Beca (2019) report recommended remediation of the hazard using passive rockfall protection barriers to minimise the risk of rockfall striking the AGS building.

However, given spatial constraints and to maximise the available area to accommodate the development it is proposed to stabilise the rock slope using rockfall protection measures (prevention) as opposed to limiting the travel of rockfall through use of barriers. The basis of design for the recommended rockfall protection measures is outlined below.

6.3.1.4 Ground Model

As the site is within a former quarry, the ground level is anticipated to be underlain by rock of the Rakaia Terrane (Wellington Greywacke) at very shallow depth. Wellington greywacke consists of a

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[5] Connect Water, 2020a. *Sludge Minimisation Utilisation and Reclamation Facility: Geotechnical Desktop Study – Moa Point.* Prepared for Wellington Water.

[6] Beca, 2019. *AGS Building Slope Stabilisation: Geotechnical Input to Detailed Design of Rockfall Barrier*. Prepared for Wellington International Airport.

[7] AGS, 2007. *Practice Note Guidelines for Landslide Risk Management 2007*. Australian Geomechanics, 42(3).

fine-grained sandstone with variable amounts of interbedded argillite. Greywacke is typically extensively faulted, tilted and folded, with very closely to closely spaced joints[8].

The desktop study and recent field mapping (Connect Water, 2020b)[9] noted the *in-situ* greywacke rock of the former quarry slope to have closely to very closely (20-200mm) spaced and often persistent defects (several metres in length). Bedding (or a dominant planar joint set), near parallel to the slope face (55°-70°), daylights in the west-facing slope. Rock slabs undergo planar/translation sliding along these joints, breaking up into cobbles and boulders (up to 900mm diameter, but predominantly <200mm diameter) downslope, forming a debris fan. Some other persistent joints intersect the main slope-parallel set and form wedge failures. Most of the instability is in the centre of the cut area, with minor debris from rockfall events observed to the north and south of the slope. Smaller failures were also observed on the southern slope.

As part of the concept design study for the Sludge Minimisation Project, geological mapping of the cut slope was undertaken to ground-truth the above desktop study findings and to provide a ground model for the stabilisation design. This work included manual measurements of rock defects at isolated outcrops and along 8 sections of the cut slopes surrounding the site. The manually measured data were supplemented by defect measurements obtained from a point cloud of the southern and eastern cut slopes. The measurements from the point cloud provided data for elevated areas which could otherwise not be reached (on foot). The point cloud was derived from a laser scan of the site.

6.3.1.5 Site Subsoil Class

The site is expected to be underlain by greywacke rock at very shallow depth. An unconfined compressive strength (UCS) test for moderately weathered greywacke rock at the WWTP site, undertaken by Beca Stevens (1990)[10], indicated a strength of about 25 MPa. As such, in accordance with NZS1170[11], site Subsoil Class B ('Rock') is recommended to be adopted for the site.

6.3.1.6 Slope Stability

At the time of writing of this report, a geotechnical interpretive report is currently in progress, using the mapped defect data to understand the kinematically possible failure mechanisms for the slope. This work will inform the detailed design of the concept stabilisation option outlined below.

Preliminary findings suggest that the dominant failure mechanism on the eastern slope (the slope striking north-south, running along the eastern side of the AGS building) appears to be planar sliding due to the presence of bedding and/or persistent defects of unfavourable orientation with respect to the slope and slope angle. Block sizes up to 900mm diameter were observed at the toe

[8] Begg, J.G., and Johnston, M.R., 2000. *Geology of the Wellington area*. Institute of Geological & Nuclear Sciences 1:250 000 geological map 10. 1 sheet + 64p. Lower Hutt, New Zealand: Institute of Geological & Nuclear Sciences Limited.

[9] Connect Water, 2020b. *Wellington Sludge Minimisation, Utilisation & Reclamation Facility (SMURF): Geotechnical Factual Report*. Prepared for Wellington Water.

[10] Beca Stevens, 1990. *Geotechnical Investigation Proposed Sites A and B Wellington Sewage Treatment Plant*. Prepared for Wellington City Council.

[11] Standards New Zealand, 2004. *NZS 1170.5:2004. Structural design actions - Part 5: Earthquake actions - New Zealand*.

of the slope. The area which appears worst impacted by the slope failure is behind the AGS building.

Along the west-east striking slope to the south, evidence of previous (and potential future) smaller-scale failures was observed. There appeared to be a risk of small toppling and planar failures, wedge failures (predominantly behind the Cyclotek building), as well as frittering of smaller rock fragments. The maximum block size observed at the base of the southern slopes was 400-600mm in diameter. The areas worst affected were toward the eastern end of the slope.

6.3.2 Geotechnical Stabilisation Design

6.3.2.1 Surficial Slope Stabilisation

The current proposed layout of the Sludge Minimisation development will not require the existing cut slopes to be cut any further, nor will there be any new cuts to be formed at the site.

To maximise the available area, active slope stabilisation using rock anchors and mesh is preferred over passive measures (such as rockfall barriers).

Assuming no additional cutting is required only 'surficial' stabilisation (i.e. approximately upper 2m thickness) is proposed to address the observed instability of the eastern slope and parts of the southern slope. This may comprise rock anchors and mesh to minimise the risk of future rockfall events impacting the new development.

The concept design of the slope stabilisation includes:

- Cleaning/scaling loose material and vegetation from the slope, and removal of the accumulated colluvial blanket on the lower part of the slope (though not trimming the slope itself, as this could trigger further instability).
- Installing drilled and grouted rock anchors and mesh on the slope.
- If the rockmass is significantly weaker (or soils are encountered) in the less steeply sloping upper part of the slope it may be preferable to install a pattern of soil nails (in place of rock anchors). Weepholes may also be required.
- Where the rockmass is highly fractured, and there is a risk of smaller blocks of rock frittering from behind the mesh, matting could be placed between the slope and mesh. An alternative would be to cover such areas with shotcrete.
- To improve the visual impact of the slope treatment, where possible, vegetation could be reinstated on the upper (less steeply sloping) part of the cut slope.

Based on the defect data collected to date, preliminary analyses indicate that a rock anchor layout with horizontal and vertical spacing of between 1.5m and 2.0m would be adequate to stabilise the upper 2m of rock to minimise the risk of future rockfalls.

The details of the stabilisation design - including rock anchor spacing and length, rock anchor and mesh type, and whether matting or shotcrete are to be used - will be determined during later design stages.

6.3.2.2 Cut Slope Construction

While the current layout does not require additional cutting (neither of existing cut slopes nor forming new ones), should the preferred layout change and cutting be required then the 'surficial' slope stabilisation described above will not be appropriate treatment; detailed cut slope design involving deeper slope reinforcement would be required.

Further cutting of existing cut slopes and/or the formation of new cut slopes at the site would require staged construction, with benches and batters progressively stabilised with anchors and mesh. Kinematic and limit equilibrium analyses would need to be undertaken to determine suitable slope angles, bench widths and heights, as well as slope reinforcement designs.

6.3.2.3 Construction Considerations

Construction Sequencing

The first step in construction is expected to be the demolition of the existing AGS and Cyclotek buildings and clearance of the site. Once the AGS building has been removed the colluvial debris below the eastern slope can be removed, making way for the installation of the proposed slope treatment, ahead of construction of the proposed development.

Construction of the rock anchors and mesh will likely be undertaken using a combination of roped access and access from ground level using an elevated platform.

Excavations Near the Toe of the Slope

Should excavations be required, a buffer from the slope toe will be required to maintain slope stability, as recommended below:

For excavations less than 2m deep in rock, proposed excavations will need to maintain a buffer equal to a theoretical 45° plane from the base of the excavation to the toe of the rock (i.e. 1 horizontal to 1 vertical from the toe of the rock slope to the base of the excavation; see Figure 6-6).

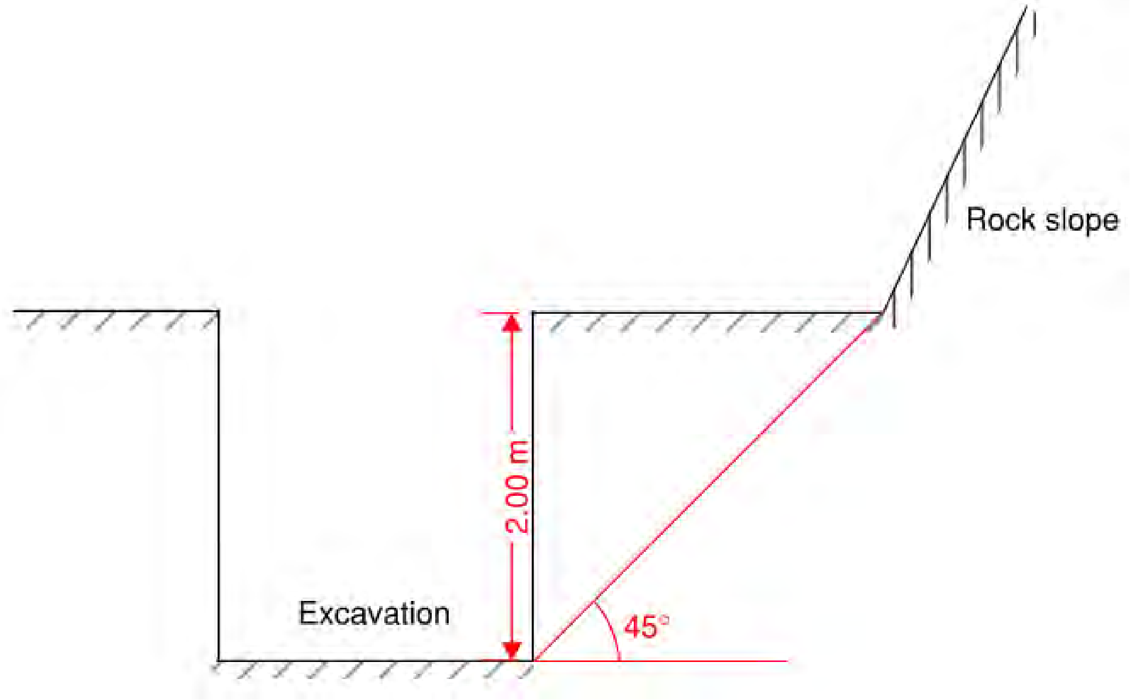

Figure 6-6: Sketch Showing the Minimum Buffer (45° from the Toe of the Excavation) Required from the Toe of Excavations up to 2m Deep.

For excavations greater than 2m deep, or if soils are encountered, specific geotechnical advice will be required prior to proceeding with the excavation

Space Requirements

As part of the site layout design, a nominal horizontal distance of at least 3m from the toe of the existing cut slope should be maintained to allow for periodic maintenance of the slope treatment.

6.4 Structural Engineering Considerations

6.4.1 Basis of Design

6.4.1.1 Structural Engineering Design Standards

The following structural design standards will apply to the construction of the new SMF. All standards referenced shall be the latest cited version.

NZS 1170.0	Structural Design Actions Part 0: General Principles
NZS 1170.1	Structural Design Actions Part 1: Permanent, Imposed & Other Loads
NZS 1170.2	Structural Design Actions Part 2: Wind Actions
NZS 1170.5	Structural Design Actions Part 5: Earthquake Actions – New Zealand
NZS 3101	Concrete Structures Standard
NZS 3106	Design of Concrete Structures for the Storage of Liquids
NZS 3404	Steel Structures Standard
NZS 4230	Design of Reinforced Concrete Masonry Structures
NZS 3603	Timber Structures Standard
AS 1657	Fixed Platforms, Walkways, Stairways and Ladders – Design, Construction and Installation
AS 1418	Cranes, hoists and winches

6.4.1.2 Design Loads

The following design loads are key to the structural design of the SMF.

Dead Loads

Dead loads include the self-weight of all construction materials. Material weights are assumed as shown below, in accordance with NZS1170.1 unless noted otherwise.

Mass Concrete	24 kN/m^3
Reinforced Concrete	25 kN/m^3
Structural Steel	78.9 kN/m^3

Superimposed Dead Loads

These are to be specifically calculated at a more detailed design stage.

Live Loads

Live loads include any temporary or transient forces that act on the building or structural elements, as noted below.

Operating floors within buildings (areas under equipment)	As calculated. 5 kPa minimum.
Operating floors within buildings (areas around equipment)	5 kPa[1]
External equipment platforms (areas under equipment)	As calculated. 5 kPa minimum.
External equipment platforms (areas around equipment)	5 kPa[1]
External access platforms	2.5 kPa[1] or 1.1 kN point load
Stairs (internal / external)	2.5 kPa

[1] These loads are considered minimum loads and increased allowance shall be made as appropriate for maintenance / temporary dismantle loads.

Live loads that include pipework, process equipment, pumps etc will be as calculated, specific to the project. This shall include the self-weight of equipment including all associated items such as pipework, valves, insulation, fireproofing, electrical cables and supports and the like, plus the maximum weight of the contents.

In determining seismic loads, the actual weight of pipework / process equipment / pumps etc shall be used and shall be considered as a dead load. Live load contribution shall be determined based on free areas around equipment and shall be based on a live load of 3.0 kPa with an appropriate area reduction factor and the earthquake-imposed action (live load) combination factor ψ_E= 0.3.

Seismic Loads

The main buildings and the primary treatment tanks shall be considered as Importance Level 3 (IL3) structures. This is based on NZS1170.0 Table 3.2 “Structures that as a whole may contain people in crowds or contents of high value to the community or pose risks to people in crowds” with the specific example being “Power-generating facilities, water treatment and waste water treatment facilities and other public utilities not designated as post-disaster”

The design working life of both the main buildings and primary treatment tanks shall be taken as 50 years. This is defined as the period that the structure is assumed to perform for its intended purpose with routine / expected maintenance but without major structural repair being necessary. This is both the durability working life of the structures and the environmental exposure period to assess seismic loading.

The following seismic factors are relevant to the Moa Point site:

- Hazard factor Z = 0.4 Wellington
- Site Subsoil Category – to be determined
- Near Fault Effects – to be calculated in accordance with NZS1170.5, for long period structures
- Spectral Shape Factor – as per NZS1170.5.
- For periods longer than 4.5 seconds (used in tank design), extrapolation of the seismic spectra in accordance with guidance from the NZS1170.5 Commentary will be adopted.

- The site hazard spectra for vertical loading (used in tank design) will be calculated using the methodology from NZS1170.5. (Note this approach uses a different scaling factor than the 0.7 factor from NZS3106.)

Building / Structures Design:

SLS1 R =0.25 (based on annual probability of exceedance (APE) 1/25 years)

ULS R= 1.3 (based on APE 1/1000 years)

Tanks / Liquid Retaining Structures

SLS1 R =0.25 (based on APE 1/25 years)

SLS2 R = 0.75 (based on APE 1/250 years)

ULS R = 1.3 (based on APE 1/1000 years)

Following different magnitude earthquake events, the following level of damage is considered acceptable in the serviceability criteria for tanks and liquid retaining structures:

- In a serviceability limits state (SLS1) event, 1 in 25-year APE, the tanks are to remain operational with no damage and will retain water. Ductility $\mu = 1.0$ for horizontal and vertical impulsive, and all convective modes.
- In a SLS2 event (1 in 250-year APE), the tanks may be out of service for a few days to fix minor damage e.g. to connections. They will retain water. Ductility $\mu = 1.0$ for horizontal and vertical impulsive, and all convective modes.
- In an ultimate limit state (ULS) event (1 in 1000-year APE), the tanks will not collapse. They may be out of service for 1-2 months to fix major damage such as cracking and connection failures and may not be able to retain liquid after this event. The tanks may need to be drained for repairs after this event. Ductility $\mu = 1.0$ for convective modes and $\mu = 1.25$ for vertical impulsive mode and impulsive mode.

Hydrostatic Loads

Hydrostatic and hydrodynamic forces shall be calculated in accordance with NZS3106 based on agreed operating levels, which may differ for static and earthquake loading cases. Sufficient freeboard shall be provided to allow for maximum wave oscillations, generated by earthquake acceleration, to be accommodated with no overtopping of the tank or loading of roof structures.

Earth Pressure Loads

Earth pressure loads are to be considered based on depth of embedment and backfill material properties. Allowance shall be made for vehicle surcharge effects where appropriate.

Wind Loads

Wind loads shall be calculated in accordance with the appropriate provisions of NZS 1170.2, with basic data as follows:

- Wind Region W.
- Terrain Category (to be determined).
- Regional wind speed ULS V1000 = 53 m/s.
- Regional wind speed SLS1 V25 = 43m/s. Regional wind speeds are based on an IL3 building with a 50-year design working life.

6.4.2 Structural Design Philosophy

For the purposes of this concept design and development of the Level 2 cost estimate presented in Section **Error! Reference source not found.**, we have developed high level structural design concepts which incorporate building and structures from previous projects where possible, but updated to reflect the specific design load requirements for the proposed location and application of this project. Note that the structural design philosophy adopted will need to be confirmed through later design stages and will be dependent on factors such as the proposed construction methodology. As described in the procurement strategy in Section **Error! Reference source not found.**, a collaborative design approach incorporating the proposed methodology of the preferred contractor(s) will need to be incorporated into the design process.

The following table provides a summary of the design philosophy adopted for concept design purposes.

Table 6-1: Structural Design Philosophy

Key Element of Project	Key Consideration	Proposed Design Approach
Digester Tanks	Material	The two commonly used materials in digester design are glass coated bolted steel tanks and reinforced concrete tanks. Given the close proximity of the tank to the coastal environment, which creates greater potential for corrosion, the proposed material is reinforced concrete for both the walls and the tank floor. Further consideration to material can be given during the next design stage.
	Construction technique	The height of the proposed tanks (the Stage 1 digester tanks have a proposed sidewall height of 21m) are expected to create significant challenges for precast concrete construction. Therefore, the proposed approach is to construct the tanks as in-situ 3m high sections with horizontal construction joints, and segments with vertical construction joints. This will likely require specialized re-usable moulds. The estimated thickness of the sidewalls to their full height is 450mm. Both vertical and horizontal post tensioning is proposed to meet strength and serviceability requirements.
	Foundation	The structural design incorporates a concrete circular foundation extending 1500 mm beyond the outside of

Key Element of Project	Key Consideration	Proposed Design Approach
		the tank walls with a nominal depth of 1650 mm at its perimeter.
Digestate Tanks	Material	The three commonly used materials for tanks of this size are glass reinforced plastic (GRP), glass coated bolted steel tanks and reinforced concrete tanks. Given the high seismic loads which generate significant hold down and sliding forces, glass coated bolted steel tanks are considered to be the preferred initial solution. The proximity to the coast can be alleviated by the use of a high specification external protection system.
	Foundation	The foundation consists of a nominally 550 mm thick raft slab, a concrete plinth upon which the tank would be bolted, with a 1000 mm deep shear key around the raft perimeter.
Thickening and Dewatering, and Dryer Building	Configuration	The Thickening and Dewatering Building will incorporate two floors – a ground floor containing tanks and minor plant and equipment, and a first floor to the full area of the building containing the main thickening and dewatering process. This configuration has been selected as it best balances the need for close proximity of process equipment to each other, the use of gravity to convey sludge to storage where possible, chemical load-in / load-out, and placing large loads (such as storage tanks) at ground level where possible. The Dryer Building incorporates three floors. The ground floor contains service equipment, while the first and second floors contain the dryer and air handling systems respectively. The configuration is largely driven by space constraints and process requirements, especially around the handling of sludge into and out of the dryer.
	Material	There are two commonly used materials for the main structure of process buildings of this type that have been adopted for other projects. 1. reinforced concrete columns, beams and floor slabs. 2. structural steel columns and beams with a reinforced concrete floor. The upper roof level would be supported by structural steel portals or by glulam timber frames. It is assumed for the purposes of concept design cost estimates that the preferred construction method is structural steel columns and beams with a reinforced concrete floor. The external envelope is considered to be concrete panels at low level with colorsteel long run cladding above. However, there is significant opportunity to consider alternatives as part of constructability assessments at

Key Element of Project	Key Consideration	Proposed Design Approach
		the next stage of design, in conjunction with the proposed construction methodology of the preferred contractor(s).
	Superstructure	At this stage of design, it is proposed that: the building be constructed of 200 thick pre-cast concrete panels at low level on an epoxy-coated braced frame steel structure. The internal floors of the building are supported by steel columns. The exact configuration will need to be considered as part of detailed plant layout and structural design load requirements. Shear walls are likely to be required between the Thickening and Dewatering Building, and the adjacent Dryer building. These would likely be constructed of 300 thick reinforced concrete. It is assumed that other internal walls would be constructed from 200 thick masonry block work. The top levels of the buildings would incorporate steel cross bracing on the external walls.
Digester Plant Rooms / Buildings	Configuration	Refer to comments on Thickening and Dewatering Building above.
	Material	Refer to comments on Thickening and Dewatering Building above
	Superstructure	Refer to comments on Thickening and Dewatering Building above

6.5 Electrical and Control Systems Engineering Considerations

6.5.1 Existing Electrical Infrastructure

6.5.1.1 High Voltage Supply

The Moa Point WWTP and Inlet Pump Station sites are served by an 11kV ring supply cable (95mm^2 Copper PILCSTA) that enters from the Stewart Duff Drive. The Moa Point WWTP connection passes the Main Building to the onsite sub-station whilst the Inlet Pump Station enters the substation directly from Stewart Duff Drive. Due to the high H_2S atmosphere, a frequent cleaning and maintenance regime on the high voltage (HV) substations and switchgear is required.

Both the sites power supplies consist of two 2000 kVA transformers located within their main building envelopes. The transformer and switchgear form part of the original installation circa 1998. The existing transformers are each rated to supply a total current of 2880 Amps.

The low voltage supply cables from the transformers connect to individual main air circuit breakers (ACB) located within the main switchboard (MSB). The site distribution is broken into dual bus supplies with each transformer supplying approximately half of the site. This cabling has been detailed as 3x 630mm^2 XLPE/PVC copper single core cables per phase with a single 630mm^2 cable utilized as the neutral.

Wellington Electricity (WE) have indicated there may be capacity within the existing network to accommodate an increased load if required, however this would need to be confirmed by the Network Asset Team. Upgrades to the existing high voltage network may be required to allow for any increased power requirements. Once the electrical demand for the confirmed new facility is known, and the site layout is confirmed, an assessment to determine electrical upgrades will be required. This will include identifying locations for the new HV substation, switchgear, generator and main switchboard.

Figure 6-7: Pumping Station Substations 1 & 2 2000kVA and Moa Point Substation 3 & 4 2000kVA

Figure 6-8: Inlet Pumping Station Main building.

6.5.1.2 Site Electricity Distribution

A high level review of the electrical metering time of use information provided by Veolia for the Moa Point WWTP has been undertaken and used to extrapolate the maximum daily Kilowatts, Amps and kVA used for the site during the time period covered (1 July 2015 to 31 May 2018).

The maximum site demand identified was approximately 3.5 MVA. There appears to be some remaining capacity in the existing site infrastructure of approximately 500kVA (720A) which could be utilised for any future site developments. The information provided did not include details on the Inlet Pump Station site and it has been understood that the site wide SCADA system may not be communicating with the revenue meters currently.

Installation of additional process plant will require further site investigations to ensure suitable power and space provisions are available. Modifications/extensions to the existing MSB and Power Factor Correction Unit (PFCU) may also be required to accommodate this work.

Main Switchboard (MSB)

The MSB's are located within dedicated rooms with the Moa Point WWTP having a ventilated MSB Room which is located to the side of the Transformer Room on the main building. The MSB at the Inlet Pump Station is located within the Main Building which looked to be naturally ventilated.

Both MSB layouts include two main ACB's supplying dual main switchboard - bus sections A and B. The output side of each switch serves a 3200Amp copper busbar arrangement which interconnects to the MSB mounted fuse disconnector switches. Submain power supplies then distributes to the site wide network of Distribution Boards (DB), Motor Control Cabinets (MCC) and various other site equipment e.g. external control cabinet etc.

Dedicated revenue meters and power monitors allow quick review of the transformer loading, power factor, phase currents etc.

Power Factor Correction Unit

A power factor correction unit is used to improve the ratio of useful power (kW) to the total apparent power (kVA) consumed by electrical equipment on site. By adjusting this ratio to try and achieve as close to unity power factor as possible the amount of actual consumed power is reduced hence decreasing the overall power consumption on site. PFC is provided at the Moa Point WWTP (refer Figure 6-7) and the Inlet Pump Station (refer Figure 6-8).

Standby Emergency Generator

Based on the information provided by the Maintenance Contractor (Veolia), consisting of As-Built drawings and Condition assessment dated 2018, both sites are backed by a single Caterpillar 3516, 1600kW, 1825kVA Standby Generator.

The generators are connected to the MSB bus sections via an automatic transfer system which monitors incoming power supplies and starts the generator upon loss of mains power supply.

Little information on the generator was available at the time of compiling this report.

6.5.1.3 Programmable Logic Control (PLC), Controls and Telemetry

The site wide SCADA/PLC system is based on a Modicon Control system utilising Intouch Wonderware Version 10 as its SCADA platform.

6.5.2 Electrical Design

To accommodate the new upgrades, it is proposed to locate a new substation on site which will house dual HV transformers and switchgear. All HV works and equipment would be provided by the local network utility provider (Wellington Electricity) with specific requirements needing to be coordinated and confirmed during the next stage of design.

The new facilities MSB and backup generator set complete with integral diesel storage will be adjoined to the new substation enclosure. The proposed location is at the southern end of the Main Process Building, at first floor level, so that this equipment is less susceptible to inundation from tsunami. The generator will be sized to accommodate essential services only, the exact requirements for this system are to be confirmed at a later stage.

The new MSB shall consist of two main ACB's supplying dual main switchboards - bus sections A and B. The output side of each main switch serves a copper busbar arrangement which interconnects to the MSB mounted moulded case circuit breakers. Submain power supplies then distributes to the site wide network of DB's, MCC's and various other site equipment e.g. external control cabinet etc.

Dedicated Revenue Meters and Power Monitors would allow a quick review of the transformer loading, power factor, and phase currents etc.

Power Factor Correction for the new installation is recommended.

A condition assessment undertaken in May 2020[12] identified some high priority upgrades which may impact the integration of existing infrastructure with the new facility and items that required remedial action.

All new electrical and PLC/SCADA equipment is required to be installed in suitably ventilated rooms to avoid potential corrosion issues that result from H_2S present in the atmosphere at a sludge processing facility.

The indicative location of the new electrical infrastructure is shown on drawing BE-K1001 in Appendix E.

6.5.3 Control Systems

The new site PLC system will be provided to match the existing systems installed on the Moa Point Treatment and Pumping Station sites. This would be installed to communicate with the existing control system allowing high level control, monitoring & viewability.

[12] *Wellington Sludge Minimisation, Utilisation and Reclamation Facility - Condition and Capacity Assessment of Existing Electrical Infrastructure*. (May 2020). Connect Water (CH2M Beca Limited).

6.6 Key Site Layout Changes for Alternative Preferred LD + TD Option

The reduction of key process elements and associated infrastructure for the LD + TD option minimises the spatial constraints associated with the highest scoring DLD + TD option. These are outlined in the below sections and detailed in Appendix E.

Further work will be undertaken in the next stage of design to assess civil, geotechnical, structural and electrical engineering considerations for the LD + TD option.

6.6.1 Removal of Stage 2 Digester equipment

As noted in the previous section, the LD + TD option only requires a single digestion stage. This removes the need for the Stage 2 digesters and ancillary equipment located in the southern end of the proposed DLD + TD site layout, as shown in Figure 6-9 below.

Figure 6-9: DLD + TD Stage 2 digesters and ancillary equipment to be excluded in LD + TD option

6.6.2 Removal of Thickener Equipment

The three gravity belt thickener units that were to be located on Level 1 of the DLD + TD main process building (as shown in Figure 6-10) are to be removed, as this process will is not required for the LD + TD option. This allows room to accommodate the THP unit and the increased dimensions of the Stage 1 and 2 centrifuges.

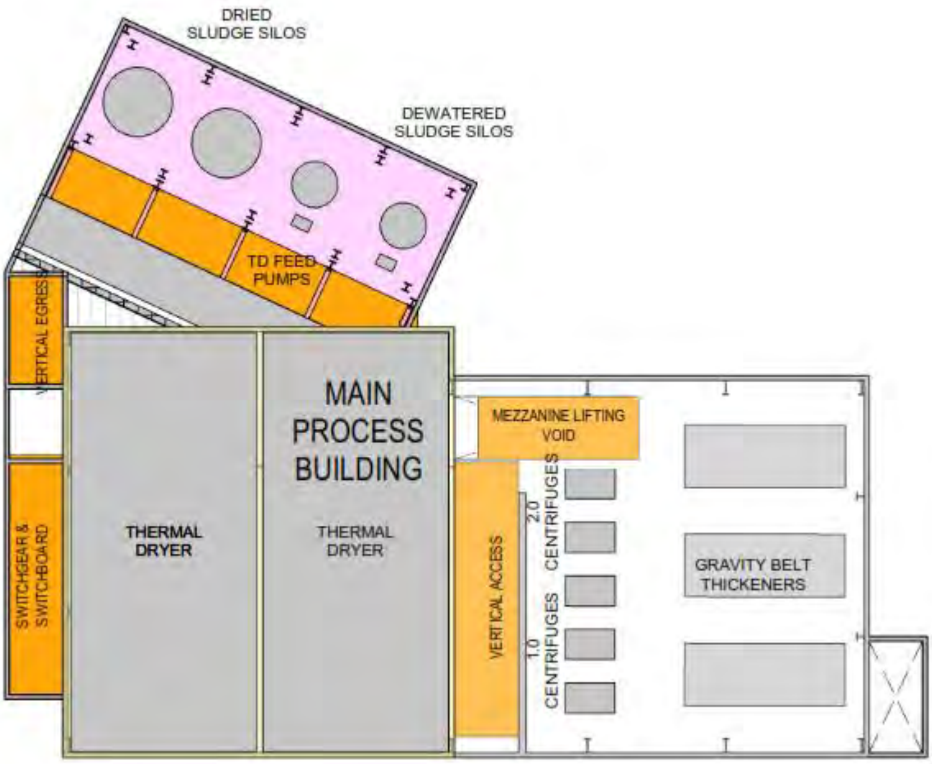

Figure 6-10: Level 1 of main process building for DLD + TD facility

6.6.3 Removal / Relocation of Existing Cyclotek Facility

Reconfiguring the site with the removal of the thickener and digester equipment allows space in the southern end of the Moa Point site. This could allow the existing Cyclotek facility to remain.

It is, however, still recommended to relocate the existing Cyclotek facility away from the SMF site. Relocation of this facility would reduce the spatial constraints of the SMF, particularly during the construction phase as there is insufficient land available for construction laydown (within the Moa Point site envelope). This would also allow some key construction equipment to be stored within the SMF site envelope.

Additionally, there are noted concerns with odour, noise, vibration and dust emissions that will occur during the construction and operation of the proposed SMF, which have the potential to disrupt ongoing operations at the Cyclotek facility. Relocation of the existing Cyclotek facility would therefore avoid future interface issues.

7 Project Delivery Strategy

This section presents the proposed strategy for delivery of the Wellington SMF, including:

- The proposed strategy for procurement of vendor(s) and constructor(s) for the new facility.
- The proposed programme for design and construction of the new facility.
- The capital cost estimate for the proposed new plant, and the basis on which this has been developed in alignment with WWL's cost estimation manual.
- The proposed strategy for obtaining consents for the new facility.
- A strategy for information management (BIM) given the significant interface risks with design and construction of the plant.

7.1.1 Key Findings

The following table summarises the key findings of the process design.

Section Reference	Consideration	Key Findings
7.2	Procurement Strategy	The preferred procurement model for the SMF is an "ECI +co-delivery" model, provided that the capital cost estimates exceed $100 million. This has been determined through assessment of options against MBIE procurement guidelines and discussions with WWL. The following key factors / considerations have been noted to be of central importance of the delivery model for this project: » The use of "pure" alliance vs competitive alliance style model » Use of four-stage approach for "pure" alliance model » Applicability of established "standardised" alliance agreements and documentation, or utilisation of UK-based alliance or advanced collaboration models
7.3	Capital Cost Estimate	Level 2 capital cost estimates have been developed in accordance with the WWL Cost Estimation Manual (Rev.0 2019). Capital cost estimates for the single-stage construction of the DLD+TD and LD + TD plants are outlined below **<u>DLD + TD</u>** » Baseline estimate: $125,068,000 » 95th percentile estimate: $187,700,435 **<u>LD + TD</u>** » Baseline estimate: $114,987,000 » 95th percentile estimate: $172,748,400 Note: the above figures exclude associated WWL management fee.

Section Reference	Consideration	Key Findings
7.4	Consenting Strategy	For Wellington City Council approvals, the recommended approach is to alter the existing Moa Point Drainage and Sewage Treatment Plant Designation (Designation 58). The following discretionary activities will require resource consent applications for Greater Wellington Regional Council approvals: » Discharge of contaminants to air from the operation of the SMF » Discharge of stormwater from the site » Earthworks exceeding 3,000 m^2 for the construction of SMF
7.5	Stakeholder and Community Engagement Plan	A stakeholder and community engagement plan has been developed for the following key target audience: » Taranaki Whānui » Ngati Toa » WCC Waste Management Team » WCC Consents » GWRC Consents » WIAL » Cyclotek Industries » Moa Point Community Reference group » Miramar Golf Course

7.2 Procurement Strategy

An initial procurement strategy presentation was made to WWL in April 2020, prior to the process and site options having been selected. Feedback was sought from WWL at this time. Now that a preferred process and site has been selected, for which specific risks have been identified, this section of the Concept Design Report refines the previously presented procurement options incorporating WWL feedback.

The principal feedback received from WWL is that a single contractor model is preferred, so that interfaces can be managed by a single contractor managing all vendor supply and other subcontract activities. This is the basis upon which the procurement strategy presented in this document is based.

7.2.1 Key Features Influencing Procurement Approach

In terms of procurement, it is worth noting that:

- The thermal hydrolysis part of the process will have a heavy influence on design of the upstream and downstream thickening, digestion and dewatering processes. There are only two potential vendors globally for the thermal hydrolysis plant (Veolia and Cambi), and both have indicated that they could provide all of the key process vendor equipment, albeit through sub-contracts in some instances. Retaining control of main plant and equipment under a single supplier would provide obvious benefits from a process performance perspective. Note that a third potential vendor has been approached but has few reference sites so is not considered to be a strong contender for this project but may wish to participate in an open market process.

- A high degree of co-ordination is required in particular aspects of the design / construction, most notably:
- Between the plant and the main structures. The configuration of the plant 9n terms of what support structures are required) will have a significant bearing on the structural design of the buildings etc, and this also presents opportunity for optimisation to save time and cost.
- Between the main process equipment and ancillary plant. A high degree of interface management is needed to ensure that there are no gaps in the scope between suppliers.
- The site has some **tight spatial constraints**, whereby construction method will influence design. Specific construction methodologies, such as for the digesters, will need to be established to complete design.
- A high degree of co-ordination is needed with live operating plant/infrastructure, including:
- The adjacent Influent Pump Station, which is critical to Wellington's wastewater system and cannot be interrupted for prolonged periods.
- The existing sludge pumping operations at Moa Point WWTP.
- The airport's adjacent operations.
- The Cyclotek Pharmaceuticals Ltd facility.

7.2.2 Understanding the Nature of the Project (for Procurement Purposes)

Appendix B of the NZ Transport Agency's (NZTA's) Procurement Manual for Activities Funded Through the National Land Transport Package[13] sets out specific criteria for selection of the delivery model. As recommended by WWL, it has been adopted to determine how each key criteria may influence the procurement strategy, as described further below.

7.2.2.1 Complexity and Uncertainty

Based on the narrative provided in NZTA's Procurement Manual, the complexity of this project has been determined to be very high, on the basis that:

- The project has very high structural complexity, measured by the number of varied components and the interdependence of these components. There is a strong relationship between the particular vendor plant used and the size and configuration of the buildings and tanks. This creates a high degree of potential variability in size and configuration of the plant and structures depending on which specific technology is selected. Furthermore, there are a significant number of interfaces between different vendor packages, and poor interface management may have a bearing on performance of the plant, and/or voidance of any performance guarantees offered.
- The project has very high technical complexity, measured as the extent to which untested or new technical issues need to be addressed in delivering that activity. Unless there is a high degree of interaction between the designer(s), plant vendor(s) and construction contractor(s), there is a high degree of potential change and new technical issues to resolve as the project progresses.

[13] *New Zealand Transport Agency Procurement Manual Version 5.* (October 2019). New Zealand Transport Agency.

7.2.2.2 Scale

In terms of the type of suppliers or group of suppliers needed to deliver the project, the scale of this project is deemed large in that:

- The scale and technical risk of the project lends itself to large, reputable international vendors who have the capability to manage multiple plant items under a single vendor supply package.
- The scale of the project lends itself to "Tier 1" construction contractors.

7.2.2.3 Timing and Urgency

The current timeframe for delivery is June 2023, at which time the new plant needs to be operational. This programme may be subject to change depending on whether the programme baseline can be adjusted at the completion of the Concept stage. However, programme is likely to be pressured and will likely have an impact on the preferred service delivery model.

7.2.2.4 Innovation Potential

The key objectives of this project include:

- The application of international expertise in sludge processing technology;
- Minimising whole of life cost.

Furthermore, the proposed site has very tight space constraints and complex interfaces between construction works and with neighbouring activities. On that basis, there is strong scope for innovation to enhance value, but given that these innovations may have a strong influence on the design, innovation input from vendors and construction contractors would be required early (in the design process).

7.2.2.5 Risk Management

In preparing this procurement strategy, we have engaged with leading contractors and vendors who have relevant skills and experience in the supply and construction of a plant of this type. This has formed an initial assessment of key risks that should be considered in the procurement strategy, together with risks identified in a joint workshop between WWL, Connect Water and Veolia personnel at project commencement.

The following table provides a summary of the key risks.

Table 7-1: Summary of Key Project Risks Relating to or Directly Impacted / Addressed by Procurement.

Key Risk	Allocated Risk Score	How Procurement may Impact / Address this Risk
Description: Optimal whole of life cost (TOTEX) option not selected. **Cause:** CAPEX budget limit reduces opportunity to invest in options that reduce operating costs and therefore TOTEX. **Consequence:** SMURF costs more to run over the long term.	High	Whole of life cost has been a key (but not the only) factor in selection of the preferred process and site. Whole of life cost will need to be a factor in assessing and selecting a preferred main plant supplier, given that energy, operational resourcing and biosolids disposal will play a significant part in long term OPEX.
Description: Procurement held up by consenting delays. **Cause:** Extraordinary consent conditions, notified process leading to protracted consenting process, construction activity impacting consent conditions. **Consequence:** Potential project delays and/or additional costs to resolve.	High	Procurement plan needs to include a procurement programme with identified hold points for selection and award of procurement packages based on specific project risks / milestones.
Description: Market attractiveness to Tender. **Cause:** Veolia competitive advantage; busy construction market, inappropriate transfer of risk to contractors (perceived or actual). **Consequence:** inflated costs, potential to not engage vendor for preferred solution, lack of interest from construction market.	High	Vendors have been engaged as part of concept design process. Undertake early contractor engagement to understand their perspectives on risk and risk transfer. Early feedback from contractors suggests that the risks involved will require some form of early contractor involvement (ECI) or alliancing model, and do not lend themselves to other procurement models (such as D&B)..
Description: Lack of coordination between vendor design and balance of plant. **Cause:** Poor communications and management between vendor and other designer. **Consequence:** Re-work, additional cost to rectify, delays.	High	Use of early contractor involvement or alliancing model for strong design co-ordination would greatly benefit the project.
Description: Design of plant heavily dependent on construction technique.		

Key Risk	Allocated Risk Score	How Procurement may Impact / Address this Risk
Cause: The proposed design may not take into account the specific skills, experience and/or resources of the main contractor and their preferred method of construction. This is particularly relevant for the **Consequence:** Re-work, additional cost to rectify, delays.		
Description: Inadequate operations handover and instruction. **Cause:** Lack of investment in training and handover process; programme pressures. **Consequence:** Operational errors, increased maintenance, facility costs more to run than expected.	**Medium**	Need to consider contract structure and how operations team will be involved through the design, construction and commissioning phases.
Description: Procurement doesn't provide solutions within requirements (non-conforming). **Cause:** Vendors not properly engaged to identify if proposed process solutions can meet requirements. **Consequence:** Additional delay and rework to address risk.	**Medium**	Vendors have been engaged as part of concept design process. This project may benefit from some form of early contractor involvement (ECI) or alliancing model.
Description: Solutions consider broad range of globally available technology. **Cause:** Lack of engagement with international vendors. **Consequence:** Most optimal solution to meet project objectives not identified / selected.	**Medium**	Early vendor engagement has been undertaken, and preferred solution is only available from 2 – 3 vendors. Procurement plan needs to consider how international vendors can partner with local installation /. Main contractors to make pathway for their inclusion easier.
Description: Probity risks with delivering major project with preferred supplier **Cause:** Veolia have been engaged early to provide process design that may or may not include Veolia technologies. **Consequence:** Reputation	**Medium**	A robust procurement plan needs to be developed and approved by WWL to confirm conformity with WWL's procurement policy / requirements. Direct engagement with WWL's procurement team is needed during procurement planning.
Description: Availability of the right construction monitoring and observation staff.	**Medium**	Identify early who will undertake commissioning and get them involved in the project during design.

Key Risk	Allocated Risk Score	How Procurement may Impact / Address this Risk
Cause: Tight labour market, busy with other projects. **Consequence:** Poor quality management / assurance during construction.		
Description: Utilities availability during commissioning. **Cause:** Extreme test runs cause additional utilities demand. **Consequence:** Cannot appropriately test plant.	**Medium**	This project would benefit from main plant vendor early contractor involvement, during which these issues can be identified / resoled between the vendor, designer and operators.
Description: Lack of coordination between construction and operations staff. **Cause:** Lack of planning and communication between operations and construction team. **Consequence:** Delays in project to address operational needs; poor performance of existing plant due to impacts from construction.	**Medium**	This project may benefit from early contractor involvement or alliancing models to proactively plan for construction impacts with existing operations. The design could then incorporate detailed construction staging based on feedback form both the construct and operations team.
Description: Economic drivers change, changing the optimum solution. **Cause:** Changes in OPEX cost structure upon which options are evaluated / selected. **Consequence:** Most optimal solution not selected based on information available at time of options evaluation / selection.	**Medium**	Whole of life cost will need to be a key factor in assessing and selecting a preferred main plant supplier, given that energy and operational resourcing will play a significant part in long term OPEX. Sensitivity analysis needs to be overtaken on a range of rates for these key operational inputs.
Description: Airport operations cause interference with construction process. **Cause:** Close proximity of proposed plant to airport operations. **Consequence:** Programme delays and/or additional costs arise from delays caused by airport operational requirements.	**Medium**	

7.2.2.6 Supplier Market

Early consultation with contractors indicates that current forward workload is strong, particularly in the context of government incentives to accelerate projects. This has led to strong feedback that the transfer of risk in some service delivery models, such as design & build, will significantly diminish market attractiveness to be engaged in a procurement process for this project. The extent of this feedback warrants special consideration of supplier market conditions on the procurement strategy. Feedback received indicates that the extent of risk lends the project to an alliancing (or at least) strongly collaborative) contracting model.

Additional complexities will arise (and are likely to present significant barriers to engagement in the procurement process) if it requires “forced” relationships between the proposed plant vendor(s) and the contractor(s). This warrants further consideration in the procurement strategy, given that pre-selection of a vendor may present perceived or actual risks to prospective construction contractor(s), particularly if these contractor(s) (in lead positions) are required to take on plant performance guarantees.

7.2.2.7 Summary of Criteria

The following table provides an overview of the key criteria and how they may impact selection of the service delivery model.

Table 7-2: Summary of Criteria for Selection of a Service Delivery Model for the Wellington Sludge Minimisation Project.

Criteria	Nature of Project	Considerations for Procurement Strategy
Complexity and uncertainty	» Very high technical and structural complexity. » Uncertainty arises from relationship between size and configuration of structures with specific vendor plant requirements.	» This project lends itself to involved early contractor engagement, strong links between construction methodology and design, and a strong collaborative culture. » Early establishment of relationships between all parties will be required.
Scale	» The scale and technical risk of the project lends itself to large, reputable international vendors who have the capability to manage multiple plant items under a single vendor supply package. » The scale of the project lends itself to “Tier 1” construction contractors.	» Tier 1 contractors are likely to add significant value to the design and project planning processes by bringing their maturity of knowledge of construction and general project risk.
Timing and urgency	» The current programme is highly pressured, and even if re-baselined, is likely to be pressured.	» Reducing waste in the procurement process will be important so that it does not add undue delay. » Understanding critical programme risks by drawing on the knowledge of vendors and contractors through early

Criteria	Nature of Project	Considerations for Procurement Strategy
		collaboration will be critical to effective schedule management.
Innovation potential	» Innovation from international vendors and construction contractors has the strong potential to enhance value to meet key project objectives, including minimising whole of life cost and bringing international expertise to bear.	» To maximise opportunities for value enhancement, early engagement of preferred international vendors, and construction contractors, will be required, so that these innovations can be appropriately incorporated into the design process without adding scope or programme risk.
Key risks	The following key risks have been identified: » Market attractiveness to tender » Whole of life cost not optimised » Consenting implications on programme » Lack of co-ordination / interface management between vendor plant and balance of plant » Design dependence on construction technique	» Careful consideration is needed to ensure that risk apportionment reflects market appetite » There is a strong need for early contractor and vendor engagement in a collaborative model to optimise whole of life cost, appropriately manage the complex interfaces between plant and structures, and ensure that construction technique is appropriately incorporated in the design.
Supplier Market	» Forward workload for contractors is expected to be strong, particularly in the context of government incentives to accelerate projects. » There is little appetite for projects that lead to large transfer of risk (such as via D&B delivery models). » There are concerns about forcing a relationship between an international vendor and a local contractor, especially where process performance guarantees are expected.	» Applying a collaborative service delivery model provides the best chance of establishing a commercial environment that attracts contractors. This would also support the early development of relationships between vendors and contractors to support desired project outcomes.

In summary, the criteria for selection of a service delivery model for this project shown in Table 7-2 strongly favours a collaborative model involving early contractor engagement to support the design process so that complexity, innovative approaches and particularly risk management can be proactively managed. Adoption of a collaborative model will enhance market attractiveness of the project, which may be critical in the current construction market. This also aligns to the risk profile of the project outlined in Table 7-1.

7.2.3 Delivery Under a Single Contract Model

Previous engagement with WWL has confirmed that a single contract model is preferred (whereby all works, including the supply of plant, are procured under a single contract). The key reason for this is to appropriately manage the large number of interfaces expected for a plant of this scale and complexity. This is likely to be exacerbated by the very tight site area available for construction activity.

On the basis that a single contract delivery model is preferred, and the criteria for selection of a service delivery model noted earlier, there is a strong driver to establish a collaborative service delivery model. This is reinforced by MBIE's delivery model selection diagram for construction works, shown in overleaf.

Table 7-1 also indicates the likely "zone" in which this project falls and is consistent with early contractor and vendor feedback as previously noted. As shown in **Error! Reference source not found.**, the alternative delivery models that might be appropriate are:

- Early Contractor Involvement.
- Packaged based delivery model
- Panel of suppliers (not applicable for a single project).
- Alliancing.

Each of these models are discussed further below.

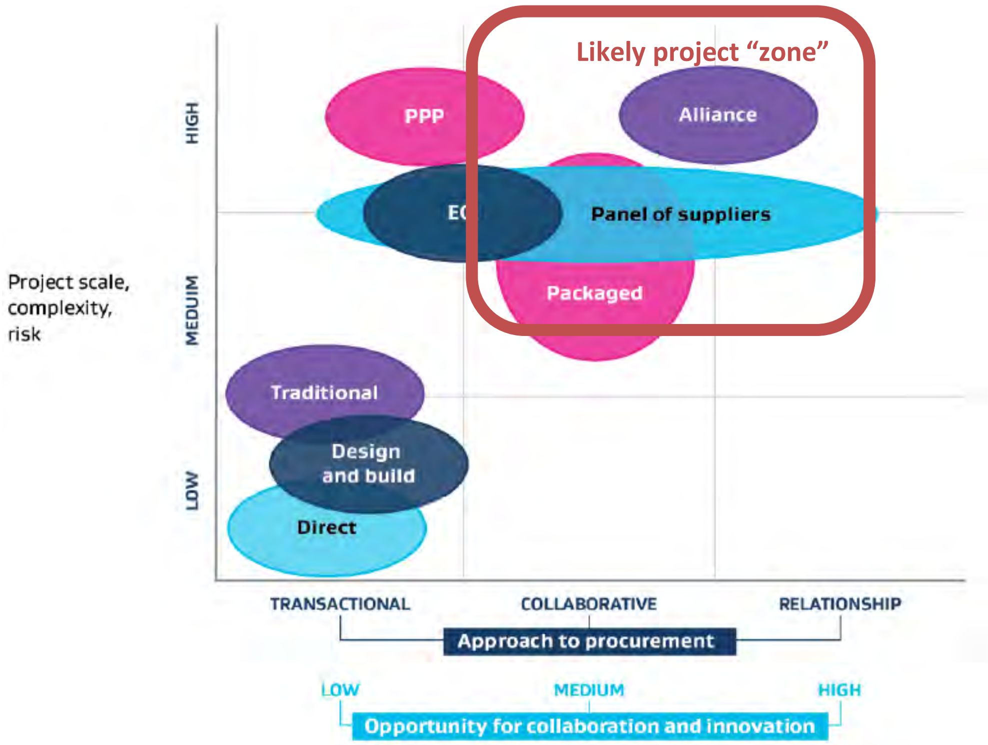

Figure 7-1: Delivery Model Selection Diagram.

7.2.3.1 Early Contractor Involvement

Overview

Early contractor involvement (ECI) as a delivery model is usually applied to traditional or novated design and build delivery model to seek early advice and involvement from a contractor into the constructability of a project. It has generally been used in larger, complex / high-risk projects where proactive risk management is required. While it does foster early relationships, it is less relationship-based than other collaborative models.

ECI is typically implemented in a two-stage procurement process, comprising of:

- Stage 1 – tenders are invited from suitably qualified lead contractors, usually based on relevant experience, resources, and may include some cost components (such as management fees, margin and P&G elements) based on a concept / preliminary level of scope definition.
- Stage 2 – the second stage tender period involves the contractor working alongside the client's design team or technical advisors to provide input to the design. A tender price is established based on this design, often through an open-book tender process. The second stage tender concludes when a contract is awarded, or when the client notifies the contractor that it will not be awarding a contract.

Applicability

As previously noted, ECI models establish early, collaborative working relationships and are generally suited to large scale, complex or medium to high-risk projects. cause it allows an integrated team time to gain an early understanding of requirements, which facilitates innovation and value for money. The following table provides an overview of the circumstances where ECI is particularly applicable, when coupled with a traditional delivery model (design and construct), based on guidelines provided by the Ministry of Business, Innovation and Environment (MBIE). The table also summarises how applicable this circumstance is to the Wellington Sludge Minimisation Project.

Table 7-3: Summary of Circumstances where ECI with a Traditional Delivery Model May be Applicable.

Circumstances for Use	Applicability to this Project	Remarks
Of Early Contractor Involvement:		
The project risks are difficult to quantify fully, and innovative approaches are needed to manage this	High	» Construction risks will be difficult to quantify without specialist input from construction contractors
Project delivery timeframes are constrained	High	» Current project timeframes are very tight
Contractors are interested in moving away from a transactional model towards a collaborative model, where there is insufficient capability or capacity to fully resource a relationship-based model such as an alliance	High	» Initial constructor and vendor feedback support this

Circumstances for Use	Applicability to this Project	Remarks
There's identified value in participating in a collaborative arrangement to drive innovative outcomes and knowledge transfer	Moderate	» Initial constructor and vendor feedback support this
There's a need to obtain cost certainty while demonstrating transparency	High	» Budgets will be set early in the project and understanding the cost prior to construction commencing will be important.
There are uncertain or complex design or construction interfaces, and flexibility in scheduling and delivery is required.	Very High	» Construction and design interfaces present a significant risk.
With Traditional Delivery Model:		
The works are routine, uncomplicated works of small to medium size and duration	Poor	» The works are complex as previously noted due to process / structure integration and tight space availability
Timeframes are enough to complete the design and then follow up separately with the construction works	Poor	» Current project timeframes are very tight
Requirements for innovation are less important, as requirements are straightforward, and scope is well defined	Moderate	» Innovation will most likely come from process vendors early, with some limited potential for further innovation to mitigate construction risk.
The client is willing to retain all of the design risk	Moderate	» Based on initial feedback from WWL
There's likely to be a large pool of tenderers and strong competition	Poor	» Current economic climate and government stimulus likely to make for tight resource availability. Projects need to be attractive to obtain multiple tenders.
There's need for a high degree of cost certainty at the time of contract award	High	» Budgets will be set early in the project and understanding the cost prior to construction commencing will be important.
There are appropriately skilled and experienced resources available to administer and manage the contract	High	

In summary, while ECI would provide an opportunity to proactively manage risk and complexity in a collaborative model, the traditional delivery model with which it would be coupled is not well suited to the Wellington Sludge Minimisation Project, primarily due to prevailing market conditions, the project programme, and the scale / complexity of the project. On this basis, we do not recommend this option is pursued.

7.2.3.2 Packaged Based Delivery Model

Overview

Under the packaged based delivery model, the project would be broken down into small packages (such as for supply of various items of vendor equipment) that can be tendered as and when the design for each package is complete. There are two approaches to packaging:

- Construction management.
- Management contracting.

Each involves significantly different risk to WWL due to the different contractual relationships involved.

With construction management, WWL would enter into direct contracts with trade contractors and engage a construction manager to manage the trade contractors. The construction management approach presents slightly more risk to WWL as there would be no single contractual point of responsibility for trade contractors. Given the significant number of trades and the interfaces involved, this is unlikely to be favoured.

In management contracting, WWL would engage a management contractor who enters into direct contracts with each trade contractor. This approach would align to WWL's desire for a single contract delivery model.

With both methods the construction manager and management contractor are engaged early in the design phase to advise the designers on the constructability of the project. This may provide project cost and time savings, and potentially enhanced quality, if the process is managed well. The construction manager or management contractor also manages the breakdown of the project into smaller packages, supervises the tendering process for each package, and manages the contracts once awarded.

The management contractor work would be bid for based on a percentage management fee. One of the key features of this model is that it would not provide cost certainty at the outset of awarding the management contract, because each trade package would not have been tendered.

Applicability

The following table provides an overview of the circumstances where a package-based delivery model is particularly applicable, based on guidelines provided by the Ministry of Business, Innovation and Environment (MBIE). The table also summarises how applicable this circumstance is to the Wellington Sludge Minimisation Project.

Table 7-4: Summary of Circumstances where a Package Based Delivery Model May be Applicable.

Circumstances for Use	Applicability to this Project	Remarks
The client wants to retain overall control of the project, including design aspects, to ensure flexibility to amend the design without incurring excessive cost	**Low**	» Strong desire to set down design prior to construction and undertake little change
The project is of a specialised nature, for example, a project with a large proportion of highly complex specialist services that cannot be purchased through a single contractor	**Very High**	» Very applicable, due to large amount of mechanical plant supply and install, M&E services etc
The risk of potential cost overruns is acceptable, where completion is critical to the client's operational needs	**Poor**	» Budgets will be set early in the project and understanding the cost prior to construction commencing will be important.
There are complexities that warrant expert advice from an experienced construction manager or management contractor who can provide constructability advice on the design, and can coordinate and administer delivery of the construction works	**Very High**	» Construction risks will be difficult to quantify without specialist input from construction contractors » Design largely depends on construction method
The works can be readily broken down into separate packages	**High**	» Opportunity to break down works into small packages if desired, especially by process area
A fast-track approach to design and construction is required to achieve the earliest possible completion.	**Moderate**	» Current project timeframes are very tight, and opportunities to de-risk current issues with sludge management/disposal should be explored.

7.2.3.3 Panel of Suppliers

A panel of supplier's delivery model is used when clients are delivering multiple projects over a long time period, rather than a single, one-off project. Therefore, while the general project complexity and risk profile fits with a panel of suppliers delivery model according to Table 7-4, it is not applicable for this single project. Furthermore, there are no plans to build other similar plants in the near future which would warrant this approach. Therefore, this delivery model has not been considered further.

7.2.3.4 Alliancing

Overview

The alliance delivery model is a relationship-style arrangement, that brings together the client and one or more parties to work together to deliver the project, sharing project risks and rewards.

Collaborative procurement methods are usually used for highly complex or large infrastructure projects that would be difficult to effectively scope, price and deliver under a more traditional delivery model.

Some key features of an alliance can include:

» good faith and trust provisions with a “no blame, no disputes” philosophy.
» an open-book approach to contract pricing.
» decisions made unanimously on a “best-for-project” basis, rather than a “best-for-the-individual participants” basis.
» joint development of a target out-turn cost agreed between the participants.
» pain/gain share arrangements where costs below and above the target cost are shared between the parties based on a pre-agreed percentage split.

Applicability

The following table provides an overview of the circumstances where an alliancing delivery model is particularly applicable, based on guidelines provided by the Ministry of Business, Innovation and Environment (MBIE). The table also summarises how applicable this circumstance is to the Wellington Sludge Minimisation Project.

Table 7-5: Summary of Circumstances where an Alliancing Delivery Model May be Applicable.

Circumstances for Use	Applicability to this Project	Remarks
Project scope and risks are highly uncertain	**Moderate**	» Construction risks will be difficult to quantify without specialist input from construction contractors
There are significant time constraints	**Moderate**	» Current project timeframes are very tight
The project is technically highly challenging	**Very High**	» The works are complex as previously noted due to process / structure integration and tight space availability, adding technical complexity » Large amount of mechanical plant supply and install, M&E services etc
There are complex external factors, eg political, environmental or stakeholder-related ones	**Very High**	» The project is highly visible to community, and performance will come under significant scrutiny » Strong stakeholder input required during design and construction (especially Wellington Airport and neighbours).
Innovative or cutting-edge solutions are required	**Moderate**	» Innovation will most likely come from process vendors early, with some

Circumstances for Use	Applicability to this Project	Remarks
		limited potential for further innovation to mitigate construction risk. Process design decisions will have knock-on impacts for construction.
There is a need for flexibility, eg in scheduling and programming	Very High	» Ability to be flexible around Wellington Airport operations is critical
A collective approach is considered advantageous for the management of project risks and challenges	Very High	» Construction risks will be difficult to quantify without specialist input from construction contractors » Particular risks require a collaborative approach to be proactively managed, as previously described.
There's a desire for knowledge sharing and transfer between the parties	High	» This will be critical to manage interfaces between vendor plant and balance of plant » This will be critical for operations handover.

7.2.4 Preferred Delivery Model

On the basis of the assessment provided above against available MBIE procurement guidelines, the particular risks and complexities presented by this project presented early, and the delivery model selection criteria previously discussed, the preferred delivery model is an alliance model. Following the identification of the delivery model options noted above, Connect Water consulted further with WWL to confirm the preferred option. WWL have agreed that an alliance type model would be preferred given the complexities and risks of the project previously noted, but noting that:

» Alliances can carry significant establishment and ongoing management costs. When establishing the delivery model for this project, consideration needs to be given to reducing these costs by adopting the collaborative mechanisms of an alliance but not necessarily applying all of the features of an alliance that might attract additional cost. For this reason, the preferred delivery model noted here has been defined as a "ECI+ co-delivery model".

» This type delivery model may become marginal if the capital cost of the project is below approximately $100m. This has been confirmed through further discussion with contractor and consultant personnel (with experience in alliances), which suggests that the scale of the project may have an impact on the applicability of an alliance. Current estimates suggest that the project, if implemented in a single stage, will cost greater than $100 million. This would still make an alliancing model, or a similarly collaborative model, viable.

7.2.4.1 Key Considerations for Establishment of an ECI+ Co-Delivery Model

While further detail will be required through the development of the detailed procurement plan, there are some key factors / considerations that should form a central part of the delivery model for this project. These include:

- The use of a “pure” alliance style model versus a competitive alliance style model:
- A competitive alliance model would require the formation of alliance teams to competitively tender the work, and would generally require greater administration, time and cost through the tender period.
- A pure alliance model would enable a preferred team to be selected prior to undertaking any significant design, scope or tender. This could potentially reduce administration and costs and would reduce the timeframe through the first stage of the alliance establishment process (described further below). Given that input of the constructor would benefit the consenting stage (which is the next stage of the project after the current Develop phase), applying a pure alliance model would be of benefit.
- Under a pure alliance model, a four-stage approach could be used:
- Stage 1 – identify design and plant vendor suppliers. Some of these suppliers could be identified through competitive tendering processes where there is sufficient definition of scope. Some suppliers may need to be nominated based on specific criteria critical to the success of the project (such as the existing operations contractor, designers with prior knowledge or specific expertise, etc).
- Stage 2 – identify preferred constructor contractor(s) through a competitive tender process, potentially utilising management fee / margins for price competitiveness together with other non-price attributes.
- Stage 3 – all partners to the alliance work to establish the scope, risk, programme and baseline price in a reconciliation phase, which can be compared against the outputs of an independent expert / advisor. This would be intended to provide outturn cost certainty at the end of this stage, which can be expected to take approximately 20 weeks from the end of Stage 2.
- Stage 4 – execute the project based on the finally agreed scope, risk apportionment, programme and price established in Stage 3.
- “Standardised” alliance agreements and documentation have been established by the New Zealand Transport Agency and other Australasian public works sector organisations, which could be directly applicable here. Aligning the approach to establishing and managing the alliance with already established processes would reduce administrative effort and cost. Alternatively, “standardised” contracts such as the NEC4 suite can facilitate alliancing or advanced collaborative models.

7.3 Capital Cost Estimate

7.3.1 Basis of Estimate

A capital cost estimate has been prepared for the proposed Wellington SMF in accordance with WWL's Cost Estimation Manual (Rev. 0, 2019). The following table provides a summary of how the estimate has been developed to align with the Manual.

Table 7-6: Basis of Capital Cost Estimate Summary

Cost Estimate Manual Section		Considerations for Procurement Strategy
3.1	Estimation Approach	» The approach taken is the **General Approach**, unless otherwise stated below.

3.2.1	Development of Base Estimate	The base estimate has been developed as follows:
		» Vendor pricing has been sought for all major plant and equipment wherever possible. Where this has not been possible (due to time constraints), multiple quotations and contract prices have been used from previous projects, generally within the last five years.
		    » For installation of vendor supplied plant, percentage allowances of the vendor plant cost have been made. These are based on an analysis of installation costs in similar projects undertaken by us in the last 10 years.
		    » For piping and ancillary costs (not part of main plant supply), percentage allowances of the vendor plant cost have been made. These are based on an analysis of installation costs in similar projects undertaken by us in the last 10 years, taking a system-by-system approach.
		    » Costs for structures have been developed by applying detailed designs for projects completed in the last 10 years of a similar nature to this, with concept level updates to reflect the specific structural design standards that apply to this project. For tanks, bottom-up estimate of costs has been developed. For building structures, an assessment of the $/m2 rates from previous similar projects has been applied, adding additional allowances to reflect the proposed structural design approach for this project.
		    » A bottom-up estimate of geotechnical treatment and civil works costs has been undertaken.
		    » A bottom-up estimate of electrical, instrumentation and controls costs has been made, as follows:
		» Costs for significant components, such as main switchboards, earthing systems and power supply upgrade costs, have been obtained from recent similar projects.

Cost Estimate Manual Section		Considerations for Procurement Strategy
		» A count of the likely number of local control panels and VSDs, and low and high rates from recent similar projects has been made. » A general allowance for instrumentation has been made based on experience from recent previous projects. » A % cost for cabling and installation has been made from an analysis of recent projects. » Costs for contractor margins, overheads and risk allowances have been applied as described further below. » Professional services costs have been applied as described further below.
3.2.2, 3.2.4, 6.2	Expected Estimate and Project Contingency	» The simple approach has been used to arrive at the expected estimate, which is based on applying a percentage project contingency (described further below). » At the completion of a project risk review, the advanced approach will be applied as an alternative subject to agreement with WWL.
3.2.3, 3.2.5, 6.2	95^{th} Percentile Estimate and Funding Risk Contingency	» The simple approach has been used to arrive at the 95^{th} percentile estimate presented below, which is based on applying a percentage funding risk contingency (described further below). At the completion of a project risk review, the advanced approach will be applied as an alternative.
4	Estimate Type	» The estimate presented in this report is a Level Two estimate, in accordance with Section 4.3 of the Cost Estimation Manual.
6.3	Simple Approach for Contingency	» As previously noted, the simple approach has been used at this stage for project and funding risk contingencies. At the completion of a project risk review, the advanced approach will be applied as an alternative. » Based on Section 2.3 of the Cost Estimation Manual, for the Level Two Estimate, the project contingency applied is 20% (percentages applied to average of low, mean and high values), and the funding risk contingency applied is 30% (percentages applied to average of low, mean and high values)
7.1	Use and Application of Historic Rates	» Refer above on development of Base Estimate
7.2	Consultancy and Council Costs	» Based on assessment of the project scale and complexity, the following percentage allowances of physical works cost have been applied for professional services: » Development – 3.0% » Consenting – 3.0%

Cost Estimate Manual Section		Considerations for Procurement Strategy
		» Detailed Design – 6.5% » Procurement – 0.5% » Construction – 5.0% » Comparisons have been made of these costs against other projects of similar scale and complexity, available industry guidelines and consultation with design discipline leads. The proposed percentages above are consistent with these comparisons.

7.3	Physical Works Costs	» Physical works costs were applied in accordance with Section 7.3 of the Cost Estimation Manual, and incorporating consideration of the complexity and nature of the project, including:
		» On-site overheads of 15% - this project is considered to be of a complexity that warrants on-site overheads at the upper range of those stipulated in the Cost Estimation Manual.
		» Off-site overheads of 12%
		» Environmental Management of 3%
		  » Contractor's Risk of 5% - the work is considered to be complex and require management of international vendors by the main contractor.
		  » Traffic management of 6%

	Other	» All estimates are presented in New Zealand Dollars, exclusive of GST. » The "Base Date" of the estimate as at the date of submission and no allowance has been made at this stage for escalation. » Escalation allowances will be assessed as part of a risk review of the project. » No allowances made for Global exchange rate fluctuations. Allowances for this will be assessed as part of a risk review of the project. » No allowances made for associated land acquisition fees. For land valuation information, refer to the reported figures from Align Ltd[14].

[14]*Wellington Water Sludge Project – Property Estimates and Process report. (*September 2020). Align Ltd.

7.3.2 Capital Cost Summary

Applying the basis of estimate described above, the following table presents the summary capital cost estimate for the proposed Wellington SMF, constructed as a DLD + TD under a single stage.

Table 7-7: Capital Cost Summary for DLD + TD and LD + TD option

Item No.	Description	DLD + TD	LD + TD
1.	Main Process Vendor Plant & Equipment	$35,737,000	$35,762,000
2.	Sub-total Preparation Works	$965,000	$734,000
3.	Sub-total Structures and Buildings	$24,245,000	$20,241,000
4.	Sub-total Civil Works	$8,598,000	$7,121,000
5.	Sub-total Electrical, Instrumentation and Controls	$4,232,000	$4,012,000
6.	Sub-total Contractor's Overheads and Margin	$34,040,000	$31,257,000
7.	Sub-total Professional Services	$17,251,000	$15,860,000
8.	**Baseline Estimate**	**$125,068,000**	**$114,987,000**
9.	Project Contingency	$22,610,987	$20,852,500
10.	**Expected Estimate**	**$147,678,987**	**$135,839,500**
11.	Funding Contingency	$40,021,449	$36,908,900
12.	**95th Percentile Estimate**	**$187,700,435**	**$172,748,400**

7.4 Consenting Strategy

A consenting strategy has been developed as a framework for pursuing the approvals required under the Resource Management Act 1991 (RMA) for the construction, operation and maintenance of the SMF.

7.4.1 Approvals from Wellington City Council

The recommended approach is to alter the existing Moa Point Drainage and Sewage Treatment Plant Designation (Designation 58) through a Notice of Requirement. The Notice of Requirement would alter the existing designation boundaries as well as some of the existing conditions to provide for the SMF. It is noted that the approach to utilising and altering Designation 58 is subject to agreement with Wellington City Council as the requiring authority.

Part of the site the SMF would occupy has been identified as being on the Hazardous Activities and Industries List (HAIL) meaning that it has the potential to be contaminated. It is recommended that a Preliminary Site Investigation (PSI) be undertaken to gain more information about the potential for contamination of the site. Depending on the results of the PSI, resource consent may be needed under the National Environmental Standard for Contaminants in Soil (NESCS).

7.4.2 Approvals from Greater Wellington Regional Council

It is anticipated that resource consent will be required from Greater Wellington Regional Council for the following activities:

- Discharge of contaminants to air from the operation of the SMF.
- Discharge of stormwater from the site; and
- Earthworks exceeding 3,000m^2 for the construction of the SMF.

It is considered that the overall status would be as a discretionary activity. If dewatering was required during construction, this should be able to process under an existing ‘global’ resource consent held by WWL for dewatering.

7.5 Stakeholder and Community Engagement Plan

A framework has been developed to guide stakeholder and community engagement activities for the project. Early engagement with affected community groups, commercial tenants and stakeholders will ensure that they have an awareness of the project, its purpose, the benefits of the project to the wider community and the opportunity to discuss future prospects beyond the establishment of the new SMF.

The community's understanding of the project constraints, including vulnerability of existing sludge management infrastructure and connections with the overall Southern Landfill consenting process is of key importance to the project.

The key stakeholders identified for this project are:

- Taranaki Whānui
- Ngati Toa
- WCC Waste Management Team
- WCC Consents
- GWRC Consents
- WIAL
- Cyclotek Industries
- Moa Point Community Reference group
- Miramar Golf Course
- Moa Point road groups and individuals

7.6 Risk Management

At the commencement of the project in 2019, a project risk workshop was held involving representatives of WWL, Connect Water and Veolia, from which a project risk register was established. This risk register has been reviewed to confirm key risks and identify new risks on a monthly basis in line with project governance reporting.

In the development of this concept design report, the latest version of the project risk register has been reviewed. Risks have or are being addressed in two ways:

- Where a risk is likely to occur and it is possible to appropriately mitigate, methods to mitigate these risks have been incorporated into the concept design.
- Where there is uncertainty about the likelihood or probability or treatment of a risk, or it is not practicable to ordinarily incorporate it into the concept design, a risk allowance is to be made and included as funding risk contingency.

7.7 Programme

A detailed programme for the Consenting, Detailed Design and Procurement activities are to be included in the next revision of the Project Management Plan (PMP).

Appendix A: Process Basis of Design Report

Wellington Water Consultancy Panel

Connect Water

Wellington Sludge Minimisation Facility

Process Basis of Design Report
May 2020

Wellington Water Consultancy Panel

Wellington Sludge Minimisation Facility

Process Basis of Design (Design Criteria) Report

May 2020

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1	29 May 2020	Keerthana Rajasekaran / Sarah Burgess	Nanne de Haan / Chris French	Malcolm Franklin

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Contents

1 Executive Summary

At present, sludge from Wellington City's two Wastewater Treatment Plants (WWTPs), Moa Point and Karori WWTPs, is dewatered and disposed of at the Southern Landfill. The current sludge handling and disposal method is causing significant constraints on current landfill operation and longer-term aspirations for waste minimisation. Therefore, Wellington City Council (WCC) are proposing to establish a new Sludge Minimisation Facility to de-couple the disposal of sludge from landfill disposal and ultimately enable the future diversion of biosolids for beneficial re-use. The objectives of the project are:

1. The volume of sludge sent to landfill is substantially reduced;
2. The resilience of sludge management in Wellington is secured, because sludge disposal is de-coupled from the landfill, and the proposed sludge minimisation solution allows for growth in sludge over the next 50 years;
3. The sludge management system is safe to construct, operate and maintain;
4. The whole of life cost (TOTEX) of sludge management is minimised across the wastewater network.

To achieve these objectives, the current "Develop" stage of the project is considering process and site options for the new Sludge Minimisation Facility. To undertake process sizing and inform site selection, this report established a process basis of design. The key findings from this Basis of Design are:

Table 1: Key Findings from Basis of Design

Design Basis Parameter	Summary
Design Horizon:	The design horizon of the plant, in terms of plant capacity, is proposed to be 50 years. Therefore, assuming that the plant is commissioned in 2023, the design horizon is year 2073. Components of the new Sludge Minimisation Facility will have different design lives. The typical design life of a mechanically-intensive sludge processing plant is 20 to 25 years. Therefore, a design horizon of 50 years represents two to two and a half "life cycles" of the main process train of the new facility.
Design population:	Wellington City Council have published 30-year population projections from years 2013 – 2043, which have been used as a baseline population projection for the proposed Sludge Minimisation Facility. These projections have then been tested by considering low, high and very high projections around the baseline. It is proposed that the Sludge Minimisation Facility be sized to cater for a "high population growth" scenario, representing 20% growth above the baseline growth rate from WCC figures. This allows for some head room above baseline population growth and is thought to align with urban growth limitations in the Wellington City catchments. If population growth were to follow the "very high" scenario (which would create significant urban growth challenges), the capacity of the plant would be reduced to 33 years. However, this is still beyond the first lifecycle of a process/mechanical plant and would allow the capacity of the plant to be adjusted during a major upgrade in 20-25 years' time. Under the high scenario, the estimated population of the catchments serviced by Moa Point and Karori WWTPs is 248,548 persons. In the absence of specific trade waste growth predictions, it has been assumed that the trade waste contribution per head of population will stay the same as the population increases.
Sludge Flows:	An analysis of historical sludge flows over the last five years has been undertaken and then applied directly to the population projections. The historical sludge flow analysis has identified that sludge flows are reducing and it is uncertain whether these trends will continue. Therefore, to accommodate future sludge flow increases caused by changes in the

Design Basis Parameter	Summary
	WWTP operation, 2015 sludge flows have been used, which are higher than the most recent available dataset for 2019. Applying the “high” population projection, and assuming no significant change in the industrial / domestic mix of waste in the WWTP influent or significant changes to the WWWTP configurations, the estimated peak week sludge production in year 2073 is 147 Tonnes Dry Solids (DS) / week, or 17,544 m^3/week (as ~1% DS raw sludge). A peaking factor of 1.25 between average and peak weekly flows has been applied, based on analysis of rolling average weekly historical flows. A weekly sludge production figure has been used to accommodate daily variations in sludge production, which are expected to be accommodated by buffer storage.
Operating regime:	The above sludge flows assume continuous (24/7) operation of the Sludge Minimisation Facility without maintenance shutdowns. The actual operating regime of the plant will be dependent on the technology and should be considered when evaluating process options. The projected sludge flows above do not account for additional capacity required for maintenance and operational interruptions and will be taken into account when sizing specific process options. However, it assumed that the plant is to be able to run without personnel and with limited supervision.
Biosolids End Use Criteria:	The biosolids produced from the new Sludge Minimisation Facility will be subject to landfill disposal criteria (in the shorter term) and current and emerging biosolids guidelines for future re-use applications. For landfill disposal, the key criteria are that the biosolids are a minimum of 20% DS and are of a volume that enables the biosolids to be disposed of at 1 part biosolids to 4 parts other solid waste. This is currently achieved (albeit barely and with considerable constraints), and the new Sludge Minimisation Facility is expected to substantially improve this. In addition, odour management is a key driver for landfill disposal, so stabilising volatile organics which would otherwise generate odour is a key criterion for the new facility.In New Zealand, biosolids are graded for both “Stabilisation” (A or B) and “Contamination” (a or b) levels. The combination of these two grades (Aa, Ab, and so on) dictate what type of reuse pathways may be viable, subject to consenting. In order to allow future de-coupling of Wellington’s sludge from discharge to Southern Landfill, a pragmatic approach would be to treat the sludge to at least a B stabilisation grade[1]. This would represent a reduction in water content and odour-causing compounds, making it more acceptable to the landfill in the short-term, and produce a biosolid which a land discharge consent could be obtained for in the future. It may be more cost effective to treat to a class A stabilisation grade, once handling and transportation costs are taken into account, but this will need to be determined as part of the options development and assessment process. There is very little information available on the contaminant concentrations in the Wellington sludges and so the likely contaminant grade of any biosolid produced cannot be assessed at this time. Sludge characterisation sampling is currently being undertaken by Veolia which will allow determination of the sludge’s suitability for land application in particular. It is unlikely that the sludge will meet the current ‘a’ contaminant grade as municipal sludges are typically too high in copper and zinc to meet those concentration limits. It is worth noting that the current guidelines are under revision, with the future guidelines being more permissive with respect to heavy metal concentrations. However, the timeframe for adopting the new guidelines is uncertain. As such the current guidelines are considered to be the most relevant.

[1] The B stabilisation grade represents the lowest acceptable reductions in pathogens and vector attraction under the Guidelines. Refer to Table 11 in the text for more detail.

2 Introduction

2.1 Background Information

The wider Wellington metropolitan region's wastewater is currently managed through the operation of four Wastewater Treatment Plants (WWTPs), with disposal of the collected sludge into three landfills. All sludge from Wellington City's Moa Point and Western (Karori) WWTPs is currently dewatered at the sludge dewatering facility (SDF) south of the Southern Landfill, known as Carey's Gully SDF, and then disposed of in the Southern Landfill.

Wellington City Council (WCC) requires a fundamental change in the management of the sludge produced at its wastewater treatment plants. The change needs to enable the management of the sludge to be 'de-coupled' from the existing disposal to the Southern Landfill and enable WCC to pursue other options for disposing of, or otherwise utilising the sludge. The Southern Landfill is located in an urban context, with a sensitive and mobilised neighbouring community. WCC does not consider that landfilling at the site will remain viable in the longer term.

To achieve this, WCC wish to establish a new Sludge Minimisation Facility. The project is to be delivered in several stages, including Develop (Stage 1), Consenting (Stage 2), Detailed Design (Stage 3), Procurement (Stage 4) and Construction (Stage 5). The current Stage 1 – Develop – involves the identification and evaluation of options for the sludge minimisation process, and where it is to be located. Upon selection of a site and process, concept development for the preferred option will be undertaken.

2.2 Purpose of This Report

The purpose of this report is to present the key design criteria to enable the identification and selection of preferred site and process options. The key criteria that need to be considered when developing the options (and therefore covered in this report) are:

- Project objectives – to provide direction to the process and site selection.
- Design life – so that process (and site) sizing takes into account the design horizon of the plant.
- Population and sludge production projections – which are critical to plant sizing.
- Biosolids disposal criteria.

During concept design development for the preferred process and site options, this Basis of Design will be further developed to include all design disciplines, noting that they are dependent on the proposed site and process.

3 Project Objectives

Based on the strategic context provided in the project brief, the following project objectives have been established to provide direction to the selection and development of a preferred option for the new Sludge Minimisation Facility:

Table 2: Project Objectives

Objective	How will we know we have achieved the objective?	How Does this Impact Optioneering?
1. The volume of sludge sent to landfill is substantially reduced, so that: » **Operational constraints on the landfill from biosolids disposal are removed (short term); and** » **Wellington City Council can meaningfully pursue its solid waste minimisation objectives / aspirations (longer term).**	» Operational constraints have been identified at the landfill, which are caused by the volume of sludge relative to solid waste available for mixing. Through consultation with the landfill operators, we will confirm that the proposed volume reduction is substantial and of the right form to take away these constraints. » The volume of sludge to landfill is minimized to the extent that it does not provide a significant constraint on the Council's proposed solid waste minimization initiatives.	» Process options will be selected by initially applying a "fatal flaw" analysis which includes consideration of the degree to which sludge minimisation is achieved. » A wider range of criteria will then be assessed during a MCA that aligns to this objective.
2. The resilience of sludge management in Wellington is secured because: » **Sludge disposal is de-coupled from the landfill operation by removing the current landfill operational constraints imposed by biosolids disposal, and enabling future beneficial re-use;** » **Foreseeable growth in sludge production over the next 50 years is accounted for; and** » **System reliability is acceptable to Wellington Water based on the design, operating conditions and maintenance regime.**	» Social, environmental and cultural outcomes from future beneficial re-use are clearly defined. The technology selection can then be proven to have achieved these outcomes in previous projects. » The processing and disposal of sludge aligns to Tangata Whenua values. » Sludge growth projection are confirmed, and performance tests confirm that the plant can achieve this capacity (or has space to do so). » System reliability is tested through FMEA analysis.	» The design criteria needs to include consideration of current and future biosolids disposal criteria for beneficial re-use. Consider process options that allow for a range of disposal options. » Consider site and process options that enhance operational resilience. » Engage with iwi to establish Maori values and apply these to the selection of the process and site options (via a fatal flaw analysis and the MCA)
3. The sludge management system is safe to construct, operate and maintain.	» Tested through Safety in Design reviews to confirm that all parties are satisfied with the hazard controls proposed for construction and operation.	» When considering process options and sites, identify key health and safety exposure risks, and identify mitigation options. Where options present significant health and safety

Objective	How will we know we have achieved the objective?	How Does this Impact Optioneering?
	» Measurement of injuries and near miss reporting through the life cycle of the project and early operations period.	exposure risks that cannot be mitigated, they should be discounted.
4. The whole of life cost (TOTEX) of sludge management is minimised across the wastewater network.	» Key Wellington Water / WCC stakeholders understand and agree that the TOTEX of the solution has been minimised based on the detailed whole of life cost analysis presented, with robust comparison against alternatives.	» This will be considered during the MCA assessment.

4 Design Horizon and Population Projections

4.1 Design Horizon

Through an assessment of the design and actual life of assets from other sludge processing facilities and projects for process/mechanical plant operating under similar conditions, an indicative (target) design life for various types of plant and equipment has been established. This has been aligned to the population projection assessment presented later in this section.

The service life of individual components of a sludge processing facility may vary. The facility includes mechanical, electrical and control, building, and civil works, and associated services and ancillaries.

Expected service lives for specific asset categories are shown in Table 3 below. It should be noted that civil and building works will have a design life exceeding 20 years.

Table 3: Plant Service Life Schedule (Minimum Requirements)

Plant Category	Service life (Years)
Civil and Building works	60 +
Structures for mechanical plant	20
Biofilter media (if used)	5 – 10
Mechanical – main process train key components	20 – 30
Mechanical - pumps, compressors, fans, vessels, heat exchangers	20
Electrical - equipment power and instrument cabling	40
Electrical - motors and actuators	25
Electrical - motor starters, variable frequency drives, instruments	15
Electrical - process controllers	10

For the purposes of assessing the capacity of process plant, a design horizon of 50 years has been selected. This aligns to available population projections and identified limitations in growth projections for Wellington City, as described below. This equates to approximately two to two and a half life cycles of main process/mechanical plant and provides the flexibility to re-assess plant capacity at the end of the first plant lifecycle.

Therefore, on the basis that the plant is to be commissioned in 2023, the design horizon for process sizing is year 2073, with an interim horizon of 2048.

4.2 Design Population

To inform an analysis of sludge production rates (presented in Section 4), an assessment of population growth in the catchments serviced by the Moa Point and Karori WWTPs has been undertaken. This assumes that sludge production will increase linearly with population growth, which would require that there is no significant change to the mix of industrial / trade waste and domestic-borne wastewater in the WWTP influent to either plant, and that no significant change to the liquid treatment process are proposed. While detailed analysis of influent make-up has not been undertaken, we understand that there are no changes to industry within the catchment that would have a significant impact as far as can be practicably seen.

Population projections have been sourced from available published data from Wellington City Council for the period 2013 to 2043[2]. These estimates include Wellington's Northern suburb population whose wastewater is processed at Porirua WWTP. Therefore, the population estimates for the Northern suburbs of Wellington were retrieved from the Porirua Wastewater Network model and excluded from the WCC projections, as shown in Table 4.

Table 4: Baseline Population Adjustment.

Year	Wellington City Baseline Population Estimates	Wellington Northern Suburbs Population Estimates	Baseline Population Estimate for Moa Point and Karori WWTP Catchments
2013	197,500	24,700	172,800
2018	211,142	27,400	183,742
2023	221,421	30,100	191,321
2028	229,303	32,800	196,503
2033	234,286	35,500	198,786
2038	240,915	38,200	202,715
2043	248,953	40,900	208,053
2048	257,052	43,600	212,915
2053	265,151	46,300	217,777
2058	273,250	49,000	222,640
2063	281,349	51,700	227,502
2068	289,448	54,400	232,364
2073	297,547	57,100	237,226

From the baseline population estimates, low, high and extremely high projections have then been developed to test the sensitivity of process sizing to changes in population growth. The rationale for the low, high and extremely high projections is as follows:

» **Low Projection** – This projection assumes growth occurs at 20% below anticipated growth rate from period to period. This was an arbitrary factor chosen by Connect Water as 20% less growth than anticipated would cause a significant drop in population compared to the baseline population estimates.

» **High Projection** – This projection assumes growth occurs at 20% above anticipated growth rate. This was an arbitrary factor chosen by Connect Water as 20% more growth than anticipated would cause a significant increase in population compared to baseline population estimates.

» **Extremely High Projection** – This projection assumes growth occurs at 55% above the anticipated baseline growth rate. Previous estimates from Wellington Water (and others) show that population is expected to grow by 50,000 to 80,000 over the next 30 years[3]. The baseline data provided shows an increase of 50,000 people in 25 years. In order for the population to reach an additional 80,000, a growth rate of 55% would be required above the baseline expected growth rate.

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[2] Wellington City Council Population Forecast, prepared by .id, November 2019. Refer https://forecast.idnz.co.nz/wellington/population-households-dwellings

[3] Wellington City Council. Wellington Urban Growth Plan. 2015, https://wellington.govt.nz/~/media/your-council/plans-policies-and-bylaws/plans-and-policies/a-to-z/wgtn-urban-growth/wgtn-urban-growth-plan2015.pdf. Accessed 9 Apr 2020.

To adjust the population estimates to the proposed design horizon of 50 years, each scenario estimate was linearly extrapolated from 2043 to 2073s. This resulted in an increase of 972, 770, 1178 and 1553 people per year for baseline, low, high and extremely high scenarios respectively. Assuming sludge production is proportional to population growth, the per capita production rate was used at a reference year to estimate both the DS sludge and volumetric raw sludge production. Figure 1 and

Table 5 and provide a summary of the population analysis.

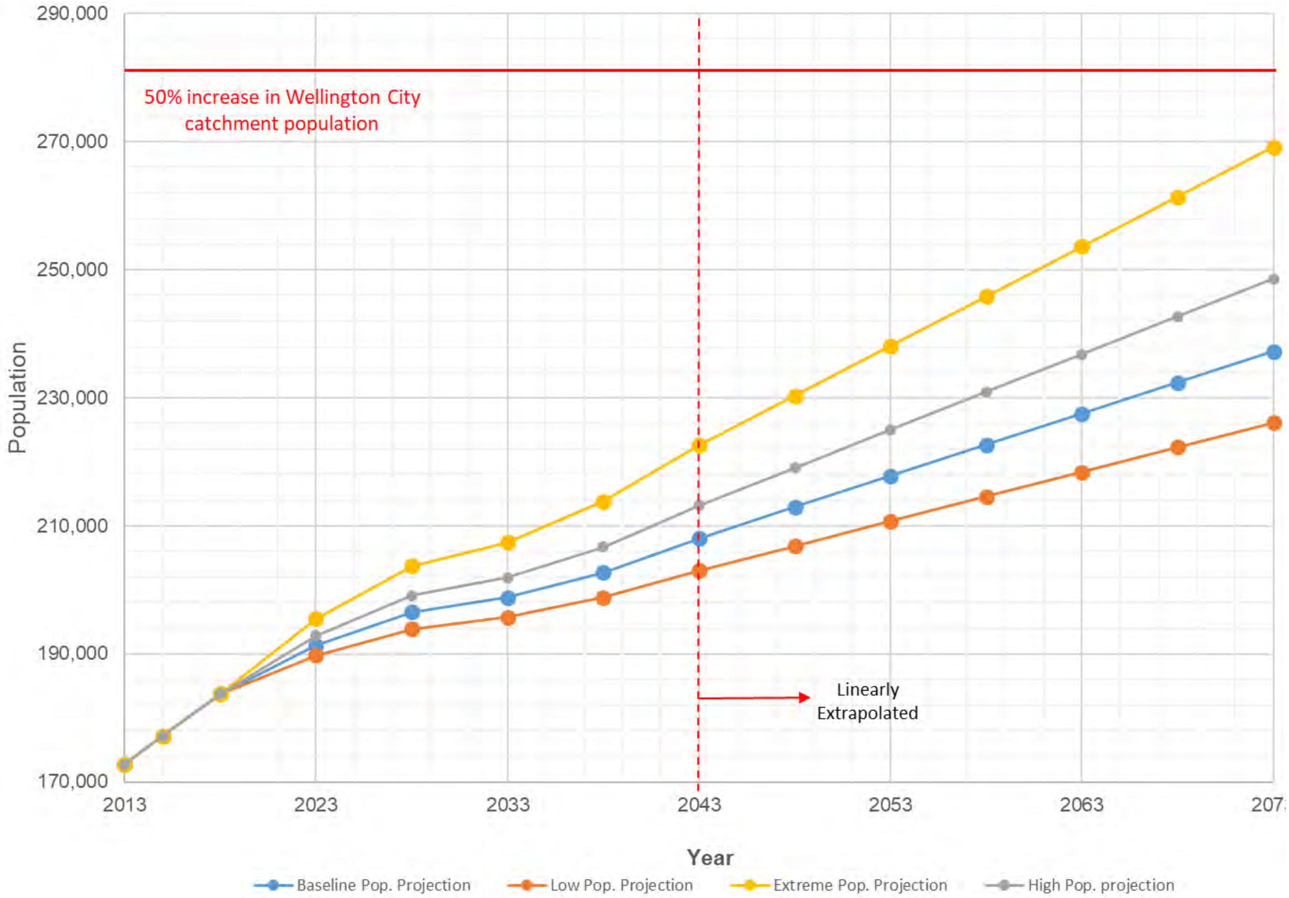

Figure 1: Projected Catchment Population for Moa Point and Karori WWTP Catchments, 2013 – 2073.

Table 5: Estimated Sludge Minimisation Facility Catchment Population 2015 - 2043

Year	2015*[1]	2018	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
Baseline Pop. Projection	177,177	183,742	191,321	196,503	198,786	202,715	208,053	212,915	217,777	222,640	227,502	232,364	237,226
Low Pop. Projection	177,177	183,742	189,805	193,918	195,720	198,815	203,003	206,856	210,708	214,560	218,412	222,265	226,117
High Pop. Projection	177,177	183,742	192,837	199,104	201,880	206,669	213,199	219,090	224,982	230,873	236,765	242,656	248,548
Extremely High Pop. projection	177,177	183,742	195,526	203,760	207,441	213,816	222,570	230,335	238,101	245,866	253,632	261,398	269,163

Notes:

1. 2015 population was linearly interpolated from Figure 1 for the basis of this analysis.

5 Plant Capacity

5.1 Sludge Volume and Solids Production

5.1.1 Background Information

This section presents an analysis of sludge production projections for the period 2023 – 2073 by considering historical sludge production trends and applying the population projection analysis from Section 3. In undertaking the analysis, several factors relating to sludge production from the Wellington city WWTPs need to be considered:

- The sludge coming from Karori WWTP is a small portion of the total sludge production, historically amounting to 4.1% of the total sludge production from the Wellington city WWTPs. We are not aware of any plans to undertake significant capacity upgrades, relative to the Moa Point WWTP, which would change this proportion. Therefore, it is assumed that growth in the Karori catchment will be proportional to the total growth figure. Allowing for minor change, we have applied a 4.5% increase to the Moa Point WWTP sludge production (for which a more detailed data set is available) to arrive at total sludge production data for the purposes of Sludge Minimisation Facility sizing.
- Sludge from Karori WWTP is currently delivered to Southern Landfill as a dewatered cake. The design of the new Sludge Minimisation Facility will need to allow for this to be blended back into the more dilute Moa Pt sludge (e.g. for digestion) or introduced at an appropriate stage of the process (e.g. prior to thermal drying).
- Moa Point WWTP sludge is produced as a ~1% dry solids (DS) concentrated slurry of mixed primary and secondary (waste activated) sludge, however the percentage DS in the slurry varies considerably. The hydraulic loading design for the proposed new Sludge Minimisation Facility will need to take this into account at detailed design and may change if sludge thickening or blending processes are used in the new plant. For the purposes of concept design, it is more meaningful to express the sludge production basis in terms of tonnes dry solids per unit of time.
- Sludge production / transfer varies daily through the week. For example, due to operation and maintenance constraints, more sludge is transferred to the existing Carey's Gully during the week than during the weekend. To account for this and potentially differing operating regimes between the process options, for the purposes of the concept design, sludge production figures have been expressed on a weekly basis. Once the preferred process technology is known, the operating regime can be revisited. For the historical sludge analysis presented in this section, a weekly rolling average has been used to manage "noise" in the data set.
- Moa Point WWTP sludge production is measured at two points:
  - **Point 1:** The 1% slurry called "**Transfer Sludge**" is grab sampled on a periodic basis. Between 2015 and 2020, 733 grab samples were collected and analysed for Total Suspended Solids. There is considerable variability in the data series (the standard deviation is 15% of the average). Flow rate is measured and totalised on a daily basis.
  - **Point 2:** The ~28% DS "**Wet Cake**" produced at the existing Carey's Gully Sludge Dewatering Plant goes over the weighbridge of the Southern Landfill. The wet cake is sampled more often for TSS than the Transfer Sludge – it has been sampled and analysed 1236 times over the same period. It can be regarded as a more o composite sample because the wet cake is the result of significant back mixing of sludge before it is dewatered, so the sample is more homogenous. The variability in the data series is lower, with the standard deviation is 9.5% of the average.

When using the "Wet Cake" data source, consideration must be given to:

- Centrifuge solids capture rate – an aspect of the current sludge dewatering plant is that between the 1% Transfer Sludge and the Wet Cake sampling points, 5% of mass is "lost" to centrate. This reflects the so-called capture rate of the centrifuges which averages 95%.

  This centrate gets biologically treated at a moving bed bioreactor (MBBR) type WWTP at the Carey's Gully SDP, known as the "Black Boxes". In treating the solids-bearing centrate, the MBBR process produces sludge itself which is not accurately measured. This MBBR sludge is injected into the main sludge feed line into the SDP and blends in with the Moa Point Transfer Sludge. An MBBR process typically generates much less sludge (expressed as solids) than what it is fed as TSS. We can therefore assume that the correction for capture rate ("lost mass" cannot be fully negated by this unknown contribution of MBBR sludge.

» Dehydration – the wet cake sometimes sits in the well-ventilated SDP building for several days before it is transported to the landfill. It is suspected that the wet cake loses some moisture during this period. The mass balance between Transfer Sludge and wet cake shows a discrepancy that cannot be explained through capture rate alone. Refer to Table 6 below.

5.1.2 Historical Sludge Production

For the purpose of this analysis a "year" is defined as the beginning of March to end of February to allow for a 5-year data evaluation, while also including the most recent available data.

The sludge produced from Moa Point WWTP is transferred to the Carey's Gully SDP, where it is then centrifuged at a certain target capture rate. As the Total Suspended Solids (TSS) of sludge in Point 1 (Transfer Sludge) is not measured every day, values have been interpolated for the missing days. The dry solids (DS) calculated from Point 2 was compared to the DS calculated from Point 1 to evaluate whether a consistent ratio between the two occurs. Table 6 provides this comparison.

Table 6: Comparison of DS sludge calculated from Point 1 and Point 2

	Point 2		Point 1		
Year	Weigh Bridge DS (Tonnes)	Capture rate	Centrifuge feed DS (Tonnes)	Transferred DS (Tonnes)	Ratio
2015	3883	0.96	4050	4149	0.98
2016	3642	0.95	3831	4311	0.89
2017	3653	0.96	3810	4127	0.92
2018	3897	0.96	4070	4505	0.90
2019	3639	0.95	3839	4355	0.88
Average Capture Rate		**0.95**		**Average Ratio**	**0.91**

As shown in Table 6, the ratio is seen to fluctuate significantly over the past five years. We attribute this to the TSS at Point 1 being measured using grab samples, where there is potential for operators to apply judgement and undertake additional sampling if they are not satisfied with the initial sample (and other such operational factors). Therefore, the data set produced from Point 2 was used to determine current DS sludge production. By picking a safe peak factor we can negate any underestimation that is made due to evaporation of moisture between wet cake production and the weighbridge.

To accommodate for the fact that dry solids are also present in the centrate after the centrifuge process (as previously noted), the DS sludge measured from the weighbridge was divided by the average capture rate of 95%. The results of this analysis are shown in Table 7.

Table 7: Historical Dry Solids Production from Carey's Gully Sludge Dewatering Plant.

DS sludge rolling analysis (Tonnes/week)					
	Weigh Bridge DS Data		DS with applied Capture Rate		
Year	Average Weekly Production	Peak Weekly Production	Average Weekly Production	Peak Weekly Production	Peak factor
2015	76.26	90.26	80.28	95.01	1.18
2016	71.93	89.40	75.72	94.11	1.24
2017	71.25	85.33	75.00	89.82	1.20
2018	76.24	89.74	80.25	94.47	1.18
2019	70.92	85.27	74.65	89.76	1.20
Average Peak Factor:					**1.20**

The volumetric raw sludge data has been obtained from Point 1 as this is a reliable data set and is the best representation of the volumes that will feed into the new Sludge Minimisation Facility. Table 8 presents the historical average weekly production, peak weekly production and the resulting peak factor for volumetric raw sludge production.

Table 8: Historical Volumetric Raw Sludge Production from Moa Point WWTP.

Volumetric Raw Sludge Rolling Analysis (m3/week)			
Year	Average Weekly Production	Peak Weekly Production	Peaking Factor[1]
2015	9988	11581	1.16
2016	9905	11333	1.14
2017	8380	10232	1.22
2018	8276	9321	1.13
2019	7663	8723	1.14
		Average Peak Factor	**1.16**

Notes:

1. Peaking Factor has been developed based on an analysis of average and peak weekly sludge production as follows:

» The Average Weekly Production (AWP) for current production was determined from measured data by taking the mean of a seven day rolling average of available data. The projected AWP was then evaluated using population projections provided by Wellington City Council's urban growth team with an adjustment using Porirua WWTP catchment estimates.

» The Peak Weekly Production (PWP) is represented by the 95th percentile production of DS sludge and volumetric raw sludge. This assumes that any peaks above this can be accommodated by buffer storage rather than providing capacity in the process train itself.

» The peak factor is expressed as the ratio of PWP divided by AWP. This peak factor, in conjunction with the future population projections, has been used to determine the projected PWP of the plant.

The peaking factors presented in Table 7 for the last five years of production vary between 1.14 and 1.22. An analysis has also been undertaken of peaking factor in the Transfer Sludge flow data, which results in slightly lower peaks. In order to cater for reasonable peak production as well as a safety margin because of mass balance discrepancies it is proposed that a peaking factor of 1.25 is applied, such that:

» Peak Weekly Production = 1.25 x Average Weekly Production.

5.1.3 Sludge Production Basis for Projections

Initially the intention was to linearly extrapolate the historical sludge production to determine future sludge production. However, as seen in Figure 2, the sludge production is decreasing over the years, possibly due to process optimisation both at Moa Point WWTP and Carey's Gully Sludge Dewatering Plant. Further investigation would be required to confirm this.

The projected population of Wellington City presented in Figure 1 shows all population scenarios increasing over time, which would typically correlate to an increase in sludge production. As the source of the decrease has not been confirmed the likelihood of this continuing cannot be predicted. Extrapolating in line with this trend would risk undersizing the new Sludge Minimisation Facility. Therefore, the trend produced by the projected population was used to forecast sludge production.

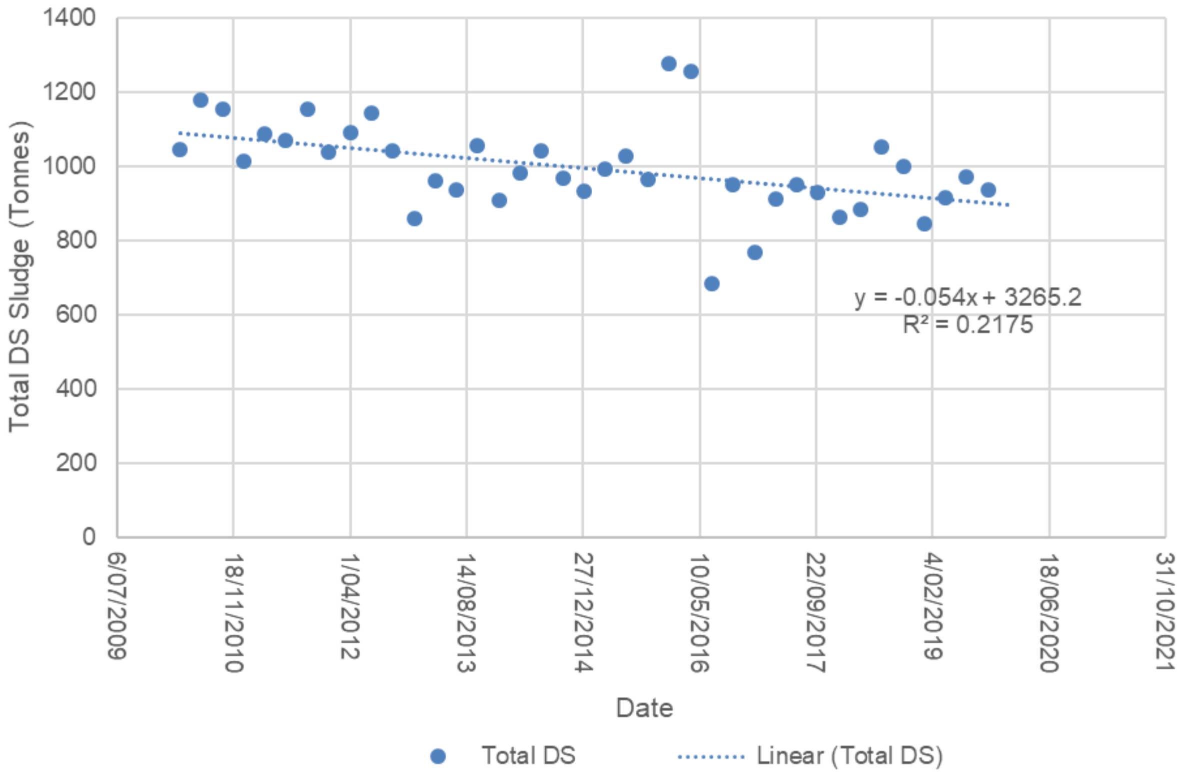

Figure 2: Moa Point WWTP Sludge DS Production, 2009 – 2020.

Since sludge production has decreased over the years, the reference point was taken as 2015 as opposed to 2019, as this is the earliest year that a full, reliable dataset is available. Prior years were ignored. The population for 2015 was estimated by linearly interpolating the baseline population from 2013 to 2018, resulting in a population of 177,177.

To account for sludge produced at Karori WWTP a 4.5% increase was applied to the DS sludge produced at Moa point[4]. The same increase cannot be applied to the volumetric raw sludge as the new Sludge Minimisation Facility will receive dewatered sludge from Karori WWTP. Currently the sludge produced at Karori WWTP is dewatered to 22% DS and amounts to ~200 tonnes DS per annum[5]. Therefore, an increase of 17.5 m^3/week volumetric raw sludge can be applied to the Moa Point WWTP calculations to account for volumetric raw sludge produced at Karori WWTP. Accordingly, the basis of forecast sludge production is summarised in Table 9.

Table 9: Sludge Production Basis

Parameter	Value
Year	2015
Population	177,177
Total Volumetric Raw Sludge AWP (m^3/week)	10,005
Volumetric Raw Sludge AWP (m^3/week) per capita	0.056
Total DS Sludge AWP (Tonnes/week)	84
Total DS Sludge AWP (Tonnes/week) per capita	0.00047
Peak Factor	1.25

5.1.4 Sludge Growth Rate and Plant Capacity Recommendation

Assuming sludge production is proportional to population, the forecast sludge production was determined using the sludge basis and the population growth rates described above. The results for average weekly production and peak weekly production for both dry solids sludge and volumetric raw sludge for each population growth scenario are provided in Figure 3 and Figure 4 respectively.

As shown in the figures, the target capacity for the proposed new Sludge Minimisation Facility has been set as the year 2073 projected sludge production rate for the high population growth scenario. Based on the assessment of sludge growth projections, it has been assessed that this will provide a reasonable level of capacity above the baseline projection. Should the very high population scenario occur, the plant is expected to reach capacity in 2057, 16 years ahead of the 50-year design horizon. However, recent urban growth studies have highlighted that, under different urban growth scenarios, land use limitations will likely not enable this level of growth to occur. Furthermore, if it did, the capacity of the plant would be reached well outside the first lifecycle of the main process plant and would enable a re-assessment of capacity to be undertaken at that time and accounted for in any upgrades.

[4] de Haan, Nanne. *Wellington Sludge Investigation Report*. Veolia Water Service (ANZ), 2018, p. 8.

[5] Tonkin & Taylor Ltd, 2015. *Wellington Regional Biosolids Strategy*. Tonkin & Taylor, p.7.

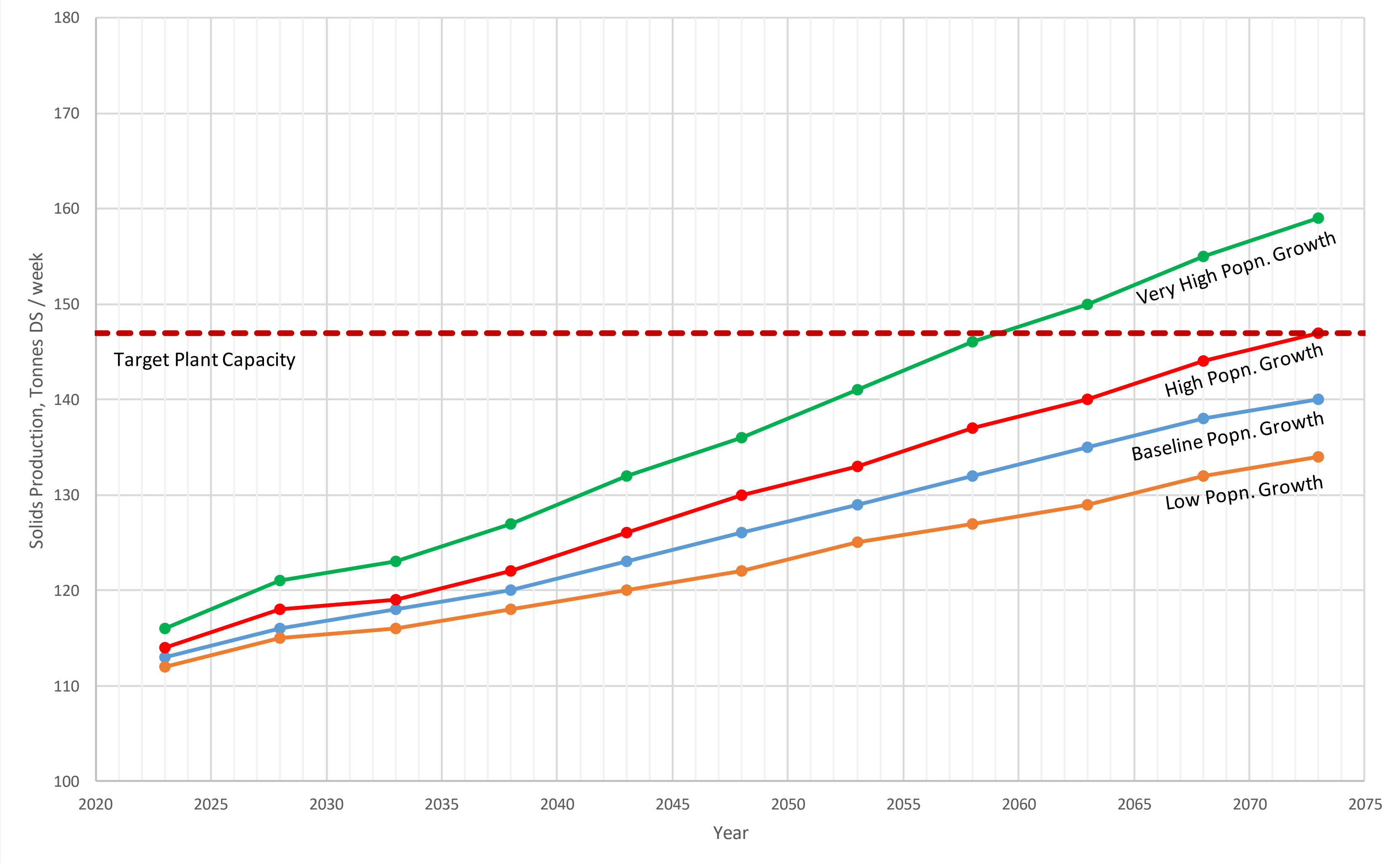

Figure 3: Wellington City Sludge Production Projections, Peak Week Dry Solids, 2023 – 2073.

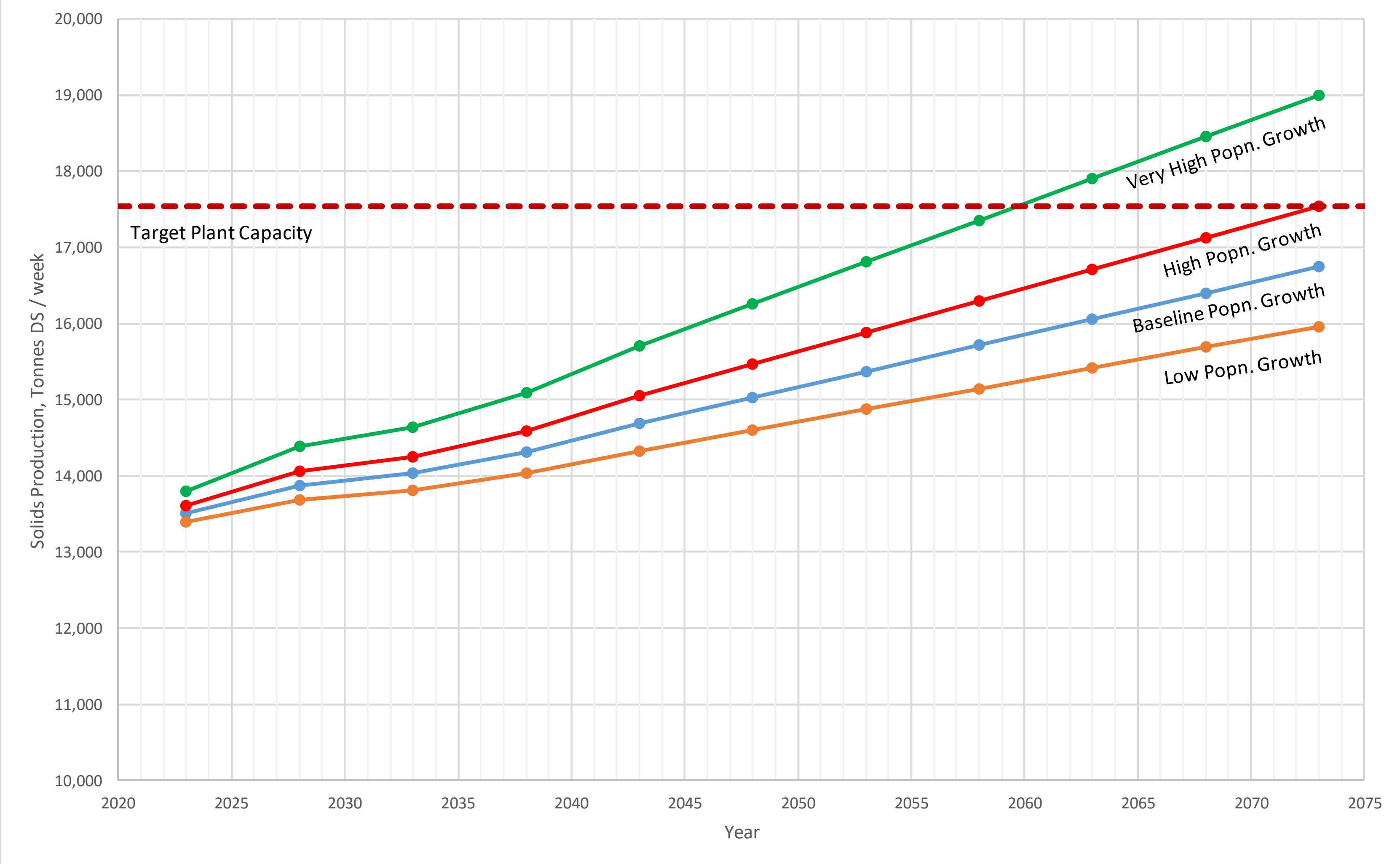

Figure 4: Wellington City Sludge Production Projections, Peak Week Raw Sludge, 2023 – 2073.

On the basis of this assessment the proposed plant capacity for the new Sludge Minimisation Facility is provided below.

Table 10: Sludge Production Basis

Parameter	Value
Year	2073
Population Served	248,548
Population Projection Scenario Applied	High (20% above WCC baseline population projections)
Plant Volumetric Raw Sludge Capacity (at 1% DS, m^3/week)	17,544[1]
Plant Dry Solids Capacity (Tonnes/week)	150[1]
Assumed Peak Factor	1.25

Notes:

1. Assumes continuous operation and excludes capacity for maintenance outages. Refer to Section 5.2 for further details.

5.2 Operating Regime

The operating regime of the proposed Sludge Minimisation Facility will be very dependent on the technology employed. Many biological and complex thermal processes require continuous operation to maintain stable operation with periodic maintenance periods. During engagement with plant vendors for process sizing during this Develop stage, additional plant capacity and storage requirements will need to be taken into account over and above the capacity recommended in Section 5.1.4.

For the purposes of concept control systems design, it is assumed that the plant will operate unmanned with limited supervision, where feasible. Specific operational considerations, and operational complexity, are to be taken into account in the multi-criteria assessment of options.

6 Biosolids End Use Criteria

This section discusses the sludge specification requirements for both landfill acceptance and for potential future sludge discharge pathways, which need to be considered to meet the core objectives of the approach. It summarises the potential pathways available and the relevant classification and regulatory frameworks that influence the requirements for sludge production and disposal.

6.1 Sludge Discharge Options

6.1.1 Sludge Management in New Zealand

There is currently no standard approach to management of WWTP sludge in New Zealand. Geographic location, site space, sludge quality, and environmental, cultural and economic considerations are all factors which influence the available options for sludge treatment and disposal. Typically, the starting point is to identify the most feasible local discharge route and develop the treatment process to meet the criteria required for this use, based on the considerations listed above. The most commonly used sludge discharge routes in New Zealand are summarised below:

- **Landfill disposal:** Assumes a suitable landfill location is available. Most common discharge pathway in New Zealand. There is usually no resource consent application required for the WWTP operator. High greenhouse gas profile associated with transportation, and contrary to NZ waste strategy objectives.
- **Mine or landfill rehabilitation:** Improves infertile and degraded soils in certain mine and landfill sites by providing beneficial nutrients. This will require identification of a suitable location, a discharge consent and transportation to site.
- **Agriculture, cropping and horticulture:** Provides nutrients to soils, low transportation cost assuming a short distance from site. This can have a negative public perception, and requires a discharge consent, depending on biosolids grade.
- **Forestry:** Provides nutrients to soils, less negative public perception, but requires a discharge consent and transportation to site, depending on biosolids grade.
- **Vermiculture:** Utilisation of worms to convert biodegradable material into soil conditioner. This does not require a consent application, and positive public perception. Limited number of processing facilities in NZ, and so carries a market risk.
- **Combustion:** Direct combustion of biosolids to generate heat for plant processes, such as biosolids drying. This will result in the emission of fine ash particulate matter, carbon monoxide, nitrogen oxides, sulphur dioxide and other air pollutants.

A summary of biosolids end uses in New Zealand is shown in Figure 5 further below. The end use of biosolids for some other local authorities in New Zealand is noted below:

- Hutt Valley: Solids are dried in the thermal dryer and sent to Silverstream landfill. Previously had been used as a soil conditioner on farms in the Tangimoana area in Manawatu. The biosolids were supplied at no cost and the user paid for the transport. There were strict quality control requirements and the biosolids were required to be stockpiled for two weeks until the results of the chemical analysis were available.
- New Plymouth: Solids are dried in a thermal dryer and used to produce a fertiliser called Bioboost®. Biosolids fertiliser is expensive to produce and must compete with other cheaper compost products. The composting and landscaping supplies market is a well-established and there are a number of manufacturers of compost in the lower North Island. New Plymouth District Council has also had to obtain discharge consents in three regions in order to allow the product to be applied to land by the end users.
- Kapiti Coast: WAS from the Paraparaumu WWTP is dried in an indirect drier to 75% DS. Currently biosolids are disposed of to the Otaihanga Landfill. The dryer heat is supplied by a wood fuelled boiler. KCDC propose to evaluate emerging technologies which will provide resources such as chemicals, fertilisers and electricity.

- Christchurch City Council – WAS and primary sludge is digested then dried in an indirect drier to ~90% DS. Dried biosolids are used for mine rehabilitation.
- Selwyn District: Solar dried sludge from the Pines WWTP in Rolleston is also used for land rehabilitation at Stockton Mine.
- Watercare: Sludge from Mangere WWTP is digested, then dewatered and used for quarry rehabilitation on Puketutu Island
- Hamilton City: Sludge from Pukete WWTP is digested then dewatered and vermi-composted.
- Dunedin City: Digested sludge from Green Island WWTP is incinerated.

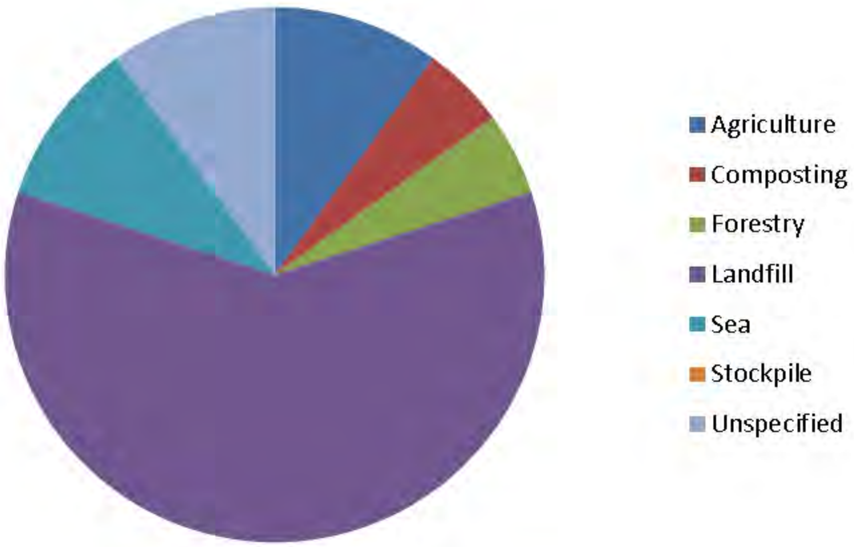

Figure 5: Biosolids End-Use in New Zealand (CH2M Hill 2015)

6.1.2 Wellington Sludge Management

For the proposed Wellington Sludge Minimisation Project, the drive to de-couple wastewater sludge management from the landfill operation has been influenced by other factors, and so the sludge management process will be selected without a preferred disposal route selected. In the short-term, it has been agreed that the sludge from the new facility will continue to be discharged to landfill while other disposal pathways are identified.

This means that the treated sludge specification will need to be set at a level which is either suitable for a range of options or can be upgraded in the future to meet any specific requirements. To allow short-term and longer-term discharge routes, the relevant criteria for the treated sludge specification are:

- Southern Landfill's sludge acceptance criteria
- Land application guidelines

These are discussed further below.

6.2 Discharge Criteria

6.2.1 Landfills

6.2.1.1 **Southern Landfill**

Southern Landfill is a Class A[6] classified landfill, which is owned and operated by Wellington City Council. Under MfE's Landfill Waste Criteria[7], as a Class A landfill Southern Landfill can accept municipal waste and non-liquid, non-municipal wastes that are not classified as hazardous. Sludge from urban wastewater treatment is classified as non-hazardous by the NZ Waste List[8] (waste code 19 08 05), and hence Southern Landfill can accept the waste without detailed quality specifications. However Southern Landfill's operational staff have noted that there are other parameters which need to be controlled for the sludge to continue to be accepted at the Landfill, including:

- **Total Sludge Volume, and Dry Solids Content.** Sludge from the Carey's Gully dewatering facility is currently sent to the landfill at approximately 25% dry solids. At this concentration the sludge must be blended with general waste in a volumetric ratio of at least 4 parts general waste to one-part sludge for waste cohesion and compaction. This 4:1 blending ratio limit's Council's ability to implement waste minimisation and/or diversion. Increasing the dry solids concentration of the sludge would address both these issues as the blending ratio could be reduced, and the total volume of sludge to be blended would also drop.
- **Odour.** Currently the landfill 'buries' the sludge in the base of the day's cell as an odour management precaution. This also influences the operation of the dewatering plant as the landfill stops accepting sludge at midday. Stabilising volatile organics which generate odour would allow both operations more flexibility.

6.2.1.2 Other Landfills

The current stage of the Southern landfill is expected to be full by 2025. The next stage of expansion is under development, subject to receiving resource consent. Though it is considered an unlikely scenario, if the landfill does not receive consent for the planned expansion WCC may need to consider other short-term disposal routes for the sludge.

If the sludge goes to another Class A landfill, the acceptance criteria are likely to be similar to that at Southern Landfill, but the cost of transportation (likely to be at least 36 km) will be a further driver to reduce the mass of sludge.

If the sludge is sent to a Class B landfill, more stringent acceptance criteria may also be required to prevent contaminants leaching into soils or groundwater.

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[6] Centre for Advanced Engineering, Landfill Guidelines (2000)

[7] https://www.mfe.govt.nz/publications/waste/module-2-%E2%80%93-hazardous-waste-guidelines-landfill-waste-acceptance-criteria-and-5 accessed 13/03/20

[8] https://www.mfe.govt.nz/waste/guidance-and-resources/waste-list, accessed 13/03/20

6.2.2 Land Discharge Criteria

6.2.2.1 Biosolids Guidelines

Overview

Best practice for safe disposal of sludge onto land in New Zealand is currently set out in the *NZWWA/MfE Guidelines for the Safe Application of Biosolids to Land in New Zealand*, published in August 2003 (the Guidelines). The Guidelines apply international and national scientific evidence through standardised practices to allow this disposal route to be managed in a safe and sustainable manner. The Guidelines also provide guidance to regional authorities on suitable activity statuses for applications of biosolids to land, although not all authorities have adopted them.

While no specific disposal pathway has been identified yet, from a practical perspective it is likely that beneficial use would occur on land in either the Greater Wellington or Manawatu-Whanganui (Horizons) Regions, as transporting sludge further north is unlikely to be feasible. An initial review of Greater Wellington and Horizons Regional council rules show that:

- **GWRC's** Proposed Natural Resources plan9 includes conditions for discharging biosolids to land. Under Rule R77 application of Aa biosolids to land is a permitted activity and under Rule R78 application of Ab, Ba or Bb biosolids to land is a restricted discretionary activity. This plan is still in the Appeal process, and so is not operative as of the time of writing.
- **Horizons Regional Council's** One Plan includes conditions for discharging unrestricted (grade Aa) and restricted use biosolids are outlined in Rule 14-7 and Rule 14-8 respectively[10.]
- The rules in both plans are consistent with the current Biosolids Guidelines.

Therefore, compliance with the Guidelines will be required for any land application of the treated biosolids.

A new document (*Guidelines for Beneficial Use of Organic Materials on Productive Land*), developed by four key Waste Sectors, intends to provide an update to the existing guidelines once it is published. However, it will not replace the current Guidelines until it has been adopted by Regional Councils as the basis for the relevant discharge rules. This document was issued as draft for public consultation in December 2017 and the final version is expected in 2021.

The sludge specifications and intended applications for both guidelines are summarised in this section.

Current Guidelines

The Guidelines for the Safe Application of Biosolids to Land in New Zealand (NZWWA, 2003) specifies a basis for grading biosolids, the levels of treatment required to achieve the specified grades and management procedures for applying the biosolids for different land uses. The biosolids are graded against two factors, the level of stabilisation achieved (Grade A or B) and the level of chemical contaminants (Grade a or b). The stabilisation and contaminant grades are combined to give four possible grades of biosolids, Aa, Ab, Ba and Bb. Grade Aa products can be applied to land as a permitted activity with no requirement for a resource consent. All other biosolids grades require a resource consent to be applied to land (see Figure 6)

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[9] *Chapter 5 Rules, Proposed Natural Resources Plan for the Wellington Region (31.07.2015)* (GWRC, 2015)

[10] *Chapter 14, One Plan Part II* (Horizons Regional Council, 2014)

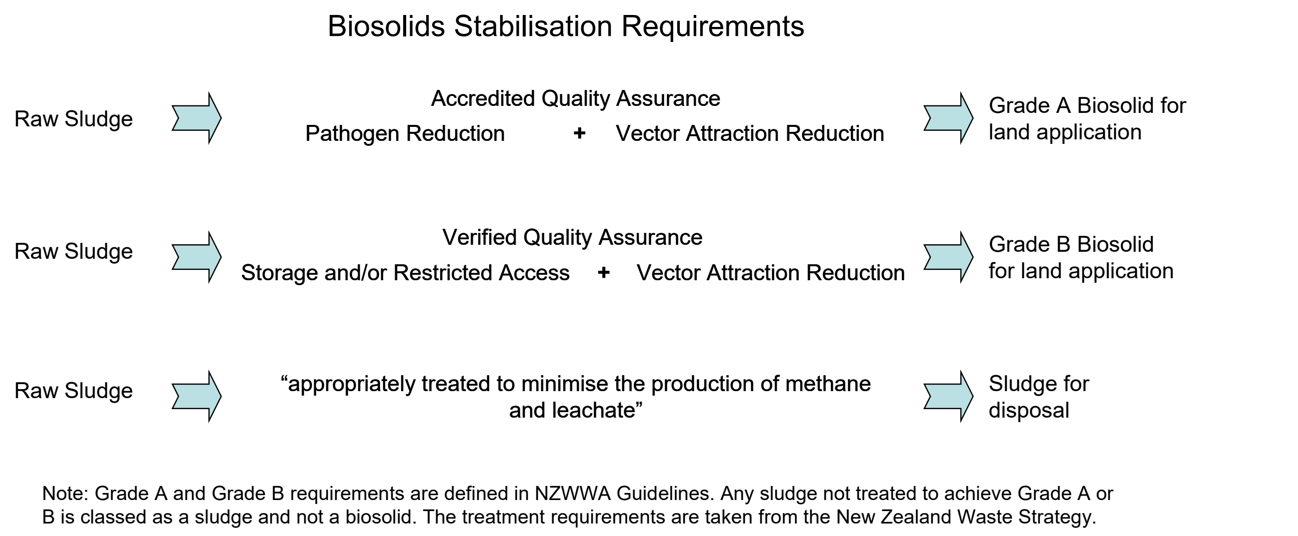

Figure 6: Treatment Requirements for Different Stabilisation Grades of Biosolids.

The stabilisation grade is defined by a combination of pathogen reduction and vector attraction reduction (VAR). These requirements are summarised in Table 11.

Table 11: NZWWA/MfE Guidelines – Biosolids Stabilisation Requirements

	Acceptable pathogen reduction processes	Acceptable vector attraction reduction methods	Product
Grade A	Accredited quality assurance ***Plus*** One pathogen reduction process from the 3 options below: **1. Time temperature process** a) ≥7% DS Within the relationship $t = \frac{131700000}{10^{0.14T}}$ (t=days, T=°C) T≥50°C and t≥15 seconds b) <7% DS Within the relationship $t = \frac{50070000}{10^{0.14T}}$	Accredited quality assurance ***Plus*** At least one vector attraction reduction/ odour method from the list below: **1.** Mass of volatile solids in biosolids shall be reduced by a minimum of 38%; or **2.** Biosolids ≥90% DS if heat dried at T>80°C; or **3.** T≥40°C for ≥14 days and T_{ave} ≥45°C; or **4.** SOUR @ 20°C≤ 1.5g/m^3 for liquid sludges from aerobic processes; or **5.** pH ≥ 12 @ 25°C for at least 2 hours and pH≥11.5 for 22 more hours; or **6.** Soil incorporation	Accredited quality assurance ***Plus both:*** **1. Verification sampling** showing that: - *E. Coli* < 100 MPN/g - *Campylobacter* <1/25g - *Salmonella* < 1/25g - Enteric viruses <1 PFU/4g - Helminth ova < 1/4g And **2. Routine sampling** showing that: *E. Coli* < 100 MPN/g

	Acceptable pathogen reduction processes	Acceptable vector attraction reduction methods	Product
	(t=days, T=°C) T≥50°C and t≥30 minutes c) Composting - In-vessel: T≥55°C for ≥3 days, or - Windrow: T≥55°C for ≥15 days with a minimum of 5 turnings during this period **2. High pH – high temperature process** pH>12 (measured at 25°C) for ≥72 hours and maintain T>52°C for 12 consecutive hours within the 72 hours, all from the same chemical application, and drying to >50% DS afterwards. **3. Other processes** Demonstration by agreed comprehensive process and product monitoring that the Grade A pathogen levels can be consistently met.		
Grade B	Verified quality assurance ***Plus*** Storage/exclusion period, depending on end use	Verified quality assurance ***Plus*** One of the vector reduction attraction methods from Grade A.	Not applicable

To apply a Grade B biosolid to land, management processes need to be put in place which are specific to the land use and which may make it impractical as a solution in some cases. These are discussed in more detail below.

Contaminant grades are assigned based on concentration of metals and organochlorine compounds in the biosolids. If the concentrations of *all* the contaminants in the biosolids are at, or below the specified limits, it is classified as grade 'a', otherwise it is classed as grade 'b'. These contaminant limits are tabulated below (Table 12). Note that grade 'a' biosolid concentrations are equivalent to the soil limit concentration.

Sludge treatment does not typically provide any reduction in the contaminant concentration of the sludge, with the exception of composting, which 'dilutes' the concentrations through blending with other substances to meet grade 'a' requirements. The alternative is managing the composition of influent which enters the WWTP (i.e. limiting industrial wastewater discharges), as 70-90% of metal contaminants from influent end up in sludge.

Table 12: NZWWA/MfE Guidelines - Biosolids Contaminant Requirements[11]

	Grade a maximum concentration (mg/kg dry weight)	Grade b maximum concentration (mg/kg dry weight)
Metals		
Arsenic	20	30
Cadmium	1	10
Chromium	600	1500
Copper	100	1250
Lead	300	300
Mercury	1	7.5
Nickel	60	135
Zinc	300	1500
Organics		
DDT/DDD/DDE	0.5	0.5
Aldrin	0.02	0.2
Dieldrin	0.02	0.2
Chlordane	0.02	0.2
Heptachlor & Heptachlor epoxide	0.02	0.2
Hexachlorobenzene (HCB)	0.02	0.2
Hexachlorocyclohexane (Lindane)	0.02	0.2
Benzene hexachoride (BHC)	0.02	0.2
Total polychlorinated biphenyls (PCBs)	0.2	0.2
Total dioxin TEQ	0.00003	0.00005

[11] Reproduced from "Guidelines for the safe application of biosolids to land New Zealand" *(MfE/NZWWA, August 2003)*

Draft WaterNZ Guidelines

The *Guidelines for Beneficial Use of Organic Materials on Productive Land* are the updated version of the existing NZWWA/MfE Biosolids Guidelines. The scope of this document has been extended to include all wastes of animal origin, whether human or otherwise, as they contain similar levels of pathogens, trace elements and organic contaminants, meaning risks should be managed in a similar manner. When finalised, it is expected that this document will replace the

A fundamental premise of these new guidelines is that a wide range of organic materials can be beneficially recycled to land, provided that they undergo sufficient treatment, appropriate land management controls are in place, and the agronomic nitrogen requirements of the land are not being exceeded. Organic materials can be use beneficially as a soil replacement or for land rehabilitation.

The grading convention of biosolids for stabilisation and contaminants is modified, so contaminant grades are given a '1' or '2' for compliance and non-compliance respectively. The 'A' and 'B' grading for stabilisation requirements remains the same.

The acceptable pathogen and vector attraction reduction processes remain the same as the 2003 Biosolids Guidelines (see Table 11). The pathogen requirements under verification sampling and routine sampling also remain unchanged.

For contaminant requirements, metal concentration limits are set at the current Guidelines 'b' limit, and new limits have been set for emerging organic contaminants (see Table 13**Error! Reference source not found.**).

Table 13: WaterNZ Guidelines – Contaminant Requirements for Grade 1 Biosolids[12]

Parameter	Concentration limit (mg/kg dry weight)
Metals:	
See Error! Reference source not found. 'b'	
Emerging Organic Contaminants (EOCs):	
Nonyl phenol and ethoxylates (NP/NPE)	50
Phthalate (DEHP)	100
Linear alkydbenzene sulphonates (LAS)	2600
Musks – Tonalide	15
Musks – Galaxolid	50

6.2.2.2 Applications

Grade Aa/A1 Biosolids

Grade Aa (or A1) biosolids are considered to be unrestricted use biosolids. This means they are of sufficiently high quality that they can be safely handled by the public and applied to land without risk of significant adverse effects, and so their use is recommended as a permitted activity. These biosolids must carry a registered Biosolids Quality Mark (BQM) to provide independent confirmation that they meet grade

[12] Reproduced from "Guidelines for Beneficial Use of Organic Materials on Productive Land" *(WaterNZ, December 2017)*

Aa requirements. The only limits placed on the use of Grade Aa/A1 biosolids are from regional plan rules, if these do not allow discharge as a permitted activity.

Other Grades

Grade Ab, Ba and Bb biosolids discharges are restricted use, and will require a resource consent to be discharged to land. In practice this means that appropriate discharge rates and methods will need to be established which do not present a risk to public health or the environment. This may involve a soil characterisation study, identification of groundwater, surface water or other 'sensitive' areas, social considerations, restrictions on nitrogen loading rates, and monitoring requirements.

Grade B biosolids (Ba, Bb) potentially contain pathogens at levels which pose a risk to human health, and so require special controls to manage this risk, depending on the end use (Table 14 -). These controls combine vector attraction reduction (VAR) and management protocols to manage public health risk.

Table 14 - NZWWA/MfE Guidelines - Recommended Controls for Grade B Biosolids, depending on end use[13]

Land use	VAR requirement	Recommended controls
Salad crops, fruit, other crops for human consumption that may be eaten unpeeled or uncooked	1. Mass of volatile solids in biosolids shall be reduced by a minimum of 38%; or 2. SOUR @ 20°C≤ 1.5g/m3 for liquid sludges from aerobic processes; or 3. pH ≥ 12 @ 25°C for at least 2 hours and pH≥11.5 for 22 more hours;	May be applied immediately ***Plus*** Soil incorporation. ***Plus*** A further waiting period of at least 1 year before crops are sown (the land may be used for other purposes in the meantime).
	Storage/ exclusion period	Store or lagoon for at least 1 year prior to application. ***Plus*** Soil incorporation. ***Plus*** A further waiting period of at least 1 year before crops are sown (the land may be used for other purposes in the meantime).
Public amenities, sport fields, public parks, golf courses, playgrounds, land reclamation	1. Mass of volatile solids in biosolids shall be reduced by a minimum of 38%; or 2. SOUR @ 20°C≤ 1.5g/m^3 for liquid sludges from aerobic processes; or 3. pH ≥ 12 @ 25°C for at least 2 hours and pH≥11.5 for 22 more hours;	Store or lagoon for at least 6 months prior to application. ***Plus*** Soil incorporation. ***Plus*** Restriction on public access for period of time necessary to establish a full vegetation cover on the land.
	Storage/ exclusion period	Store or lagoon for at least 1 year prior to application. ***Plus*** Soil incorporation. ***Plus*** Restriction on public access for period of time necessary to establish a full vegetation cover on the land.

[13] Reproduced from "Guidelines for the safe application of biosolids to land New Zealand" *(MfE/NZWWA, August 2003)*

Land use	VAR requirement	Recommended controls
Fodder crops and pasture, orchards where dropped fruit is not harvested, turf farming, industrial or non-edible crops, crops that will be peeled or cooked before eating	1. Mass of volatile solids in biosolids shall be reduced by a minimum of 38%; or 2. SOUR @ 20°C≤ 1.5g/m^3 for liquid sludges from aerobic processes; or 3. pH ≥ 12 @ 25°C for at least 2 hours and pH≥11.5 for 22 more hours;	May be applied immediately. **Plus** Soil incorporation. **Plus** Fruit and turf should not be harvested or pastures grazed for at least 6 months after applications. **Plus** Crops that will be peeled or cooked should not be harvested for at least 6 months after application.
	Storage/ exclusion period	Store or lagoon for at least 1 year prior to application ***Plus*** Soil incorporation ***Plus*** Fruit and turf should not be harvested, or pastures grazed for at least 6 months after applications. ***Plus:*** Crops that will be peeled or cooked should not be harvested for at least 6 months after application.
Forest, trees or bush scrubland	1. Mass of volatile solids in biosolids shall be reduced by a minimum of 38%; or 2. SOUR @ 20°C≤ 1.5g/m3 for liquid sludges from aerobic processes; or 3. pH ≥ 12 @ 25°C for at least 2 hours and pH≥11.5 for 22 more hours;	May be applied immediately. ***Plus*** Public access restricted for 6 months. ***Plus*** Buffer zones should be fenced and signposted.
	Storage/ exclusion period	Store or lagoon for at least 1 year prior to application. ***Plus*** Public access restricted for 6 months. ***Plus*** Buffer zones should be fenced and signposted.

Biosolids with a 'b' grade for contaminants should be characterised for the contaminant content (metals and organic chemicals) to validate that they do not contain abnormal contaminant concentrations. This will inform the application rate, based on an understanding of the background soil concentrations and the soil concentration limit.

As nitrogen is relatively mobile in soils, the potential for leaching of nitrogen from biosolids (of all grades) into groundwater is an issue which must be taken into considering for land application. Ideally, the N content in the biosolids and in the receiving soil should be assessed to establish a nitrogen mass balance and determine an application rate. The general approach to this issue is to ensure that the agronomic nitrogen needs of crops is being met. As agronomic rates can vary widely depending on site conditions, a default value of 200 kg total N/ha/year is often adopted for New Zealand pastures.

Under the new Draft Guidelines, the default value for nitrogen loading rates for continual application of biosolids to productive land shall not exceed an average of 200 kg N/ha/year over a maximum of two years, based on evidence that the organic nitrogen present in the product is eventually mineralised. For rebuilding of degraded soil or refurbishment of contaminated land, the one-off biosolids application volume should not result in a nitrogen concentration exceeding 150 kg mineral N/ha. With the exception of the nitrogen loading rates, the conditions and recommended controls for land application of unrestricted or unrestricted use organic materials remains unchanged from the 2003 Biosolids Guidelines.

6.3 Conclusions

In order to allow future de-coupling of Wellington's sludge from discharge to Southern Landfill, a pragmatic approach would be to treat the sludge to at least a B stabilisation grade. This would represent a reduction in water content and odour-causing compounds, making it more acceptable to the landfill in the short-term, and produce a biosolid which a land discharge consent could be obtained for in the future. It may be more cost effective to treat to a class A stabilisation grade, once handling and transportation costs are taken into account, but this will need to be determined as part of the options development and assessment process.

There is very little information available on the contaminant concentrations in the Wellington sludges and so the likely contaminant grade of any biosolid produced cannot be assessed at this time. Sludge characterisation sampling is currently being undertaken by Veolia which will allow determination of the sludge's suitability for land application in particular. It is unlikely that the sludge will meet the current 'a' contaminant grade as municipal sludges are typically too high in copper and zinc to meet those concentration limits. However, it is more likely that the sludge will meet future contaminant limits which are likely to be more permissive.

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Appendix B: Sludge Treatment Process Technologies Overview

CONNECT WATER

Memorandum

To: Wellington Water Limited

From: Connect Water Limited

Date: 23 September 2020

Subject: Sludge Process Technologies Overview

1. Purpose

The purpose of this memo is to present the process technologies available for sludge treatment. An overview of these technologies has been incorporated in the *Sludge Minimisation Process Options Assessment Report* issued by Connect Water in June 2020.

2. Concentration Technologies

2.1. Overview

Concentration technologies reduce the amount of moisture from sludge, decreasing the total mass. This includes thickening and dewatering processes that will produce sludge in the range of 2 – 6% dry solids (thickening) and 18 – 28% dry solids (dewatering). The benefit of these technologies is the reduction in total sludge volume, which can decrease unit sizes of other equipment in the downstream sludge processing line or decrease the mass of sludge transported. Therefore, most of the technologies in this category are used for the optimisation of a sludge processing plant, rather than as standalone options.

Sludge which undergoes only a concentration process (with the exception of thermal drying) is difficult to re-use in New Zealand due to the need to manage exposure to the harmful pathogens still present, and thus often ends up in landfill. The following sections describe each of the concentration technologies including some advantages and disadvantages.

2.2. Thickening

2.2.1. Gravity Thickening

Gravity thickeners come in two forms; static thickeners and dynamic thickeners. Static thickeners are similar to sedimentation tanks albeit with a much steeper floor grading. They are usually applied to the excess sludge from the activated sludge process. The sludge is directed to the centre of the tank, where solids settle according to their respective weight forming a concentrated sludge layer at the bottom of the tank. The thickened sludge is removed from the bottom and liquid is removed over a weir at the top of the tank. The solids layer is maintained by controlled removal which may be continuous at a low rate. The tank is equipped with a slow-moving rake which consolidates the sludge for discharge. This method typically produces a sludge with a solids content of 2-3%.

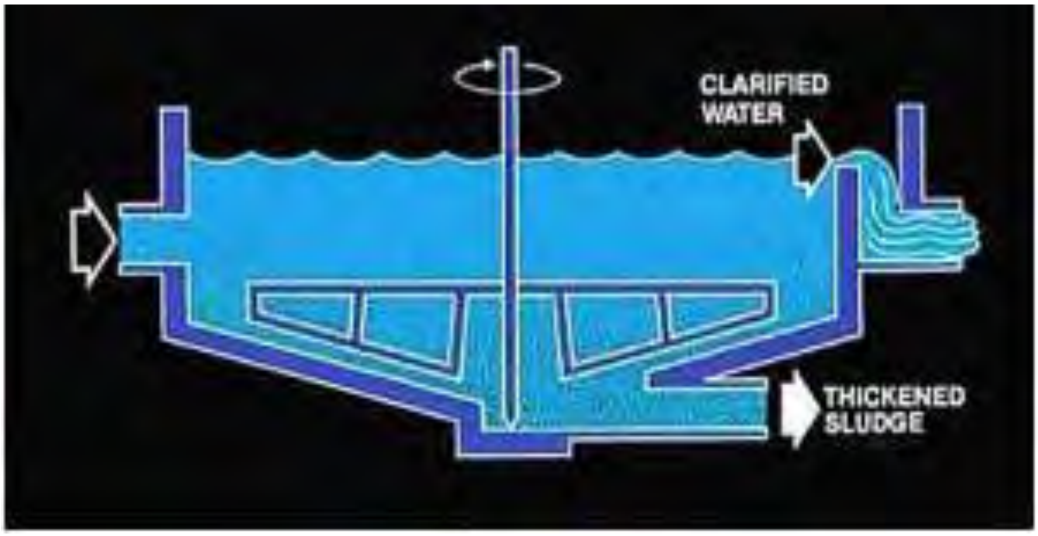


Figure 1: Schematic of a Static Gravity Thickener

2.2.2. Dynamic Thickening

Dynamic thickeners incorporate mechanical means that aid gravity to do its work. Examples are technologies such as dissolved air flotation and gravity belt thickeners.

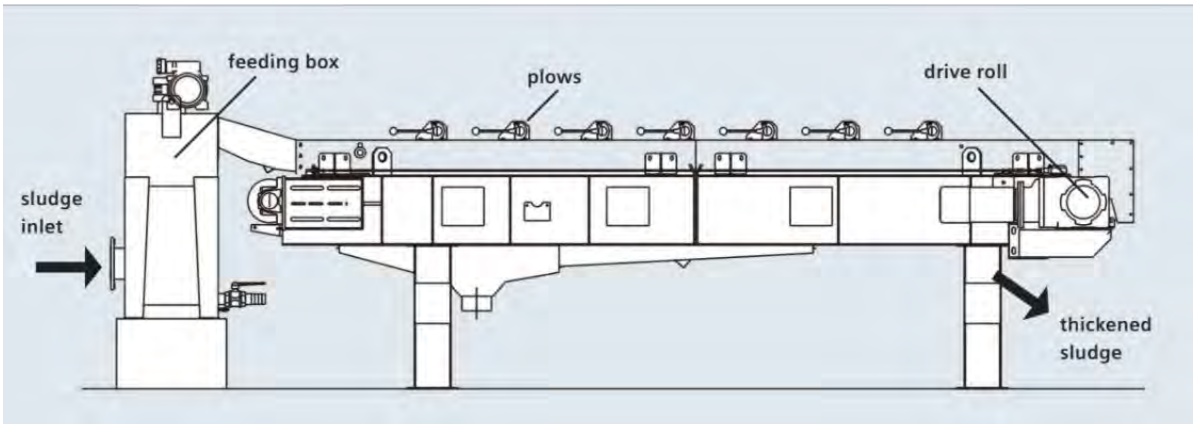


Figure 2 Schematic of a Gravity Belt Thickener

In gravity belt thickening, sludge which has been mixed with a coagulant is applied to a travelling woven belt. Water falls through the gaps in the belt and is collected and returned to treatment, and solids particles are retained on the belt and collected for further treatment. This technology can produce a sludge concentration of between 3% and 7% dry solids, depending on the upstream technologies and coagulant use.

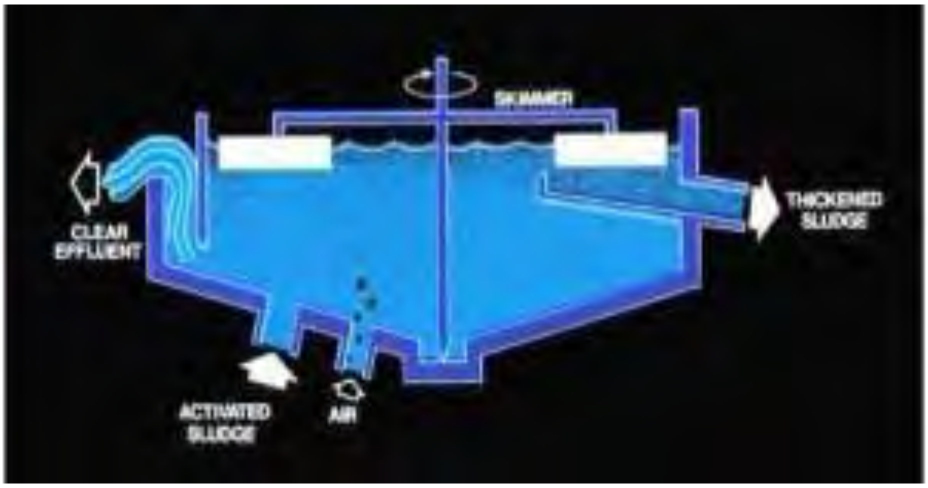


Figure 3: Schematic of a Dissolved Air Flotation Apparatus

Dissolved Air Flotation (DAF) is a gravity separation technology that uses the difference in specific density between air and water to establish a separation. The principle of DAF, as shown in Figure 3, is to inject minute air particles into the system in order to attach to suspended solids, causing the aggregate to have a lower specific gravity than the water. This will enable the solids to rise creating a blanket of thickened sludge which can be skimmed off. DAF is used mostly for secondary sludge. Thickened sludge off a DAF is typically around 3%. Performance of the technology can be improved with the use of chemicals. Note that DAF is not generally suitable for sludges containing primary sludge.

Another example of dynamic thickening is drum thickening, where the sludge is passed through a rotating drum cylinder made of fine mesh, which captures solids and allows water to pass through the mesh. Different zones of the drum can have different size mesh media to augment the capture efficiency as the sludge moves along the length of the cylinder. Polymer is added to the sludge to enhance thickening.

2.3. Dewatering

2.3.1. Belt Filter Press

Belt filter presses use both physical pressure and gravity to drain water from the sludge, resulting in a thicker final product than a gravity-only process. Sludge is typically thickened prior to the belt press, where the influent is pressed between two belts and run through a series of rollers to encourage water to drain away. Typically for organic sludge significant amounts of coagulant are required for optimal performance, though this can vary depending on the type of biological system the sludge has come from, and what upstream sludge treatment technologies are used. Belt presses typically produce a dewatered sludge of between 18 – 25% dry solids.

2.3.2. Centrifugation

Centrifuges are a high-speed technology that uses force from rapid rotation of a cylindrical bowl to separate solids from the wastewater within sludge. Centrifuges spin at very high rates, typically between 1,200 and 2,800 rpm. There are several different types of centrifuges used to dewater and thicken sludge with the solid bowl centrifuge being the most popular. Centrifuging organic sludge typically produces a dewatered product of between 16% - 30% solids.

Figure 4 shows an example of a solid bowl centrifuge used in the wastewater industry.

Figure 4: Example of Solid Bowl Centrifuge.

2.3.3. Electrostatic Belt Filter Press

Electrostatic dewatering is a technology that applies a continuous electric current to a layer of partially dewatered cake through a cathode and anode to increase both the rate and extent of dewatering. These steps increase the rate of filtration at the cathode and decrease blinding of the cloth. Pressure is also required to maintain conductivity. This method of dewatering digested sludge is claimed to produce a cake of 35-39% solids and does not require polymer addition.

2.3.3.1. Heated Filter Press

A regular filter press uses a bank of serial chambers that are lined with filtration cloth. Sludge is pumped in under high pressure. Water is pressed through the cloth while solids stay behind. Once all chambers are full indicated by a threshold pressure, the chambers are opened one by one and the cake drops out into a skip or onto a conveyor. Dryness is typically 30-35% for organic sludge.

Heated filter presses use a combination of hot water and vacuum to both press as well as boil the water out of the sludge. Hot water is circulated through a manifold and cavities in specially designed filter plates. The water pressurises the sludge as to force water out of it and through the filter cloth. When vacuum is used on the filtrate side of the cloth the boiling point of the interstitial water is lowered so the sludge starts to boil, and water vapour is extracted. Dryness over 60% can be achieved.

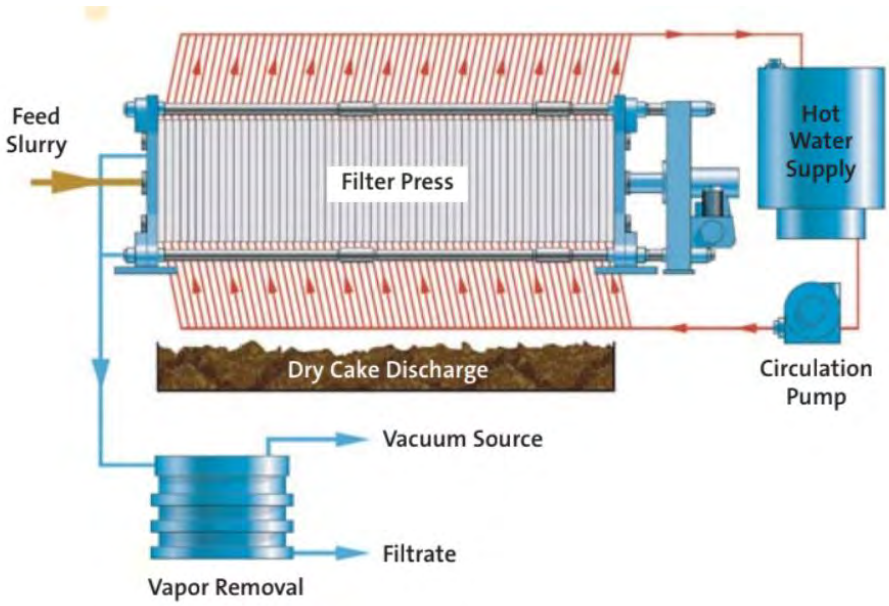


Figure 5: Schematic of a Heated Filter Press

2.3.3.2. Screw Presses

Screw presses utilise a slow-moving drum constructed of fine mesh, through which sludge is passed. Polymer is introduced to the sludge prior to entering the drum, and the sludge is “pressurised” inside the drum by an auger. The pressure inside the drum is usually controlled by a back-pressure plate on the outlet end of the screw press. Screw presses are typically able to produced dewatered sludges in the range of 16 – 22% dry solids, but this is highly dependent on the total volatile solids concentration of the sludge, which can have large bearing on dewaterability.

2.4. Drying

2.4.1.1. Solar drying

A solar dryer uses evaporation from solar radiation to decrease the water content of sludge. Evaporation is enhanced by using a greenhouse-like structure which captures solar energy and increases the ambient air temperature over the Biosolids. A moving rake-type system or mole is used to mix and transport the Biosolids along the length of the solar dryer. The solar drying outcome is highly dependent on the local climate and the quality and moisture content of the feed sludge. Dryness between 30 and 80% have been reported.

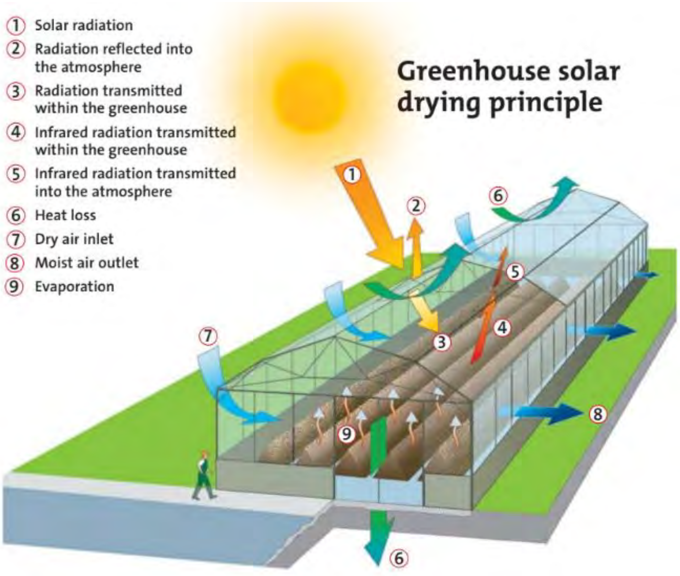


Figure 6: Schematic of a Solar Dryer

2.4.1.2. Thermal Drying

Thermal drying of sludge involves indirectly or directly heating sludge to evaporate moisture. The gaseous water can then diffuse out of the sludge, leaving the solids. The heat travels through the sludge by convection, conduction and radiation. A large number of sub-technologies exist within the category of thermal drying. The dried product may look like pellets or irregular particles depending on the technology selected.

3. Stabilisation Technologies

3.1. Overview

Stabilisation technologies involve the use of microorganisms to digest sludge. Stabilisation is performed to reduce the harmful pathogens present in sludge as well as reducing sludge odours. In New Zealand stabilisation is required for any application of biosolids to land for beneficial use.

Aerobic and anaerobic digestion are the most prominent sludge stabilisation technologies in the wastewater industry. Anaerobic digestion can be further improved by pre-treatment technologies that break up sludge on a cellular level prior to digestion, making the technology more efficient. These pre-treatment technologies will be detailed in Section 4 where hydrolysis technologies are discussed.

3.2. Mesophilic Anaerobic Digestion

Mesophilic anaerobic digestion (MAD) is a common sludge stabilisation technology that involves operating anaerobic digesters at temperatures ranging from 35 °C to 38 °C with a retention time of at least 15 days (with 2% to 4% solids concentration). This conventional type of anaerobic digestion provides an environment in the tank that maintains optimum conditions for microorganisms which convert the organic material into a cell mass and release gaseous product (including methane) as a byproduct. This gas can be utilised as an energy resource and is usually termed ‘Biogas’. Biogas is typically used as fuel source for on-site boilers or cogen units. The waste heat from boilers and cogen units is used to maintain the optimum digester temperature.

Thermophilic anaerobic digestion is a variety on the more common mesophilic pathway. The residence time is shorter, but OPEX is higher due to the higher operating temperature (55°C to 57°C) and extra chemical consumption on the subsequent dewatering step. The two technologies can also be used in series in a process called temperature-phased anaerobic digestion (TPAD) for greater solids destruction and hence gas production. TPAD is most commonly used to augment existing digestion processes when footprint is a constraint or when pathogen reduction is a requirement.

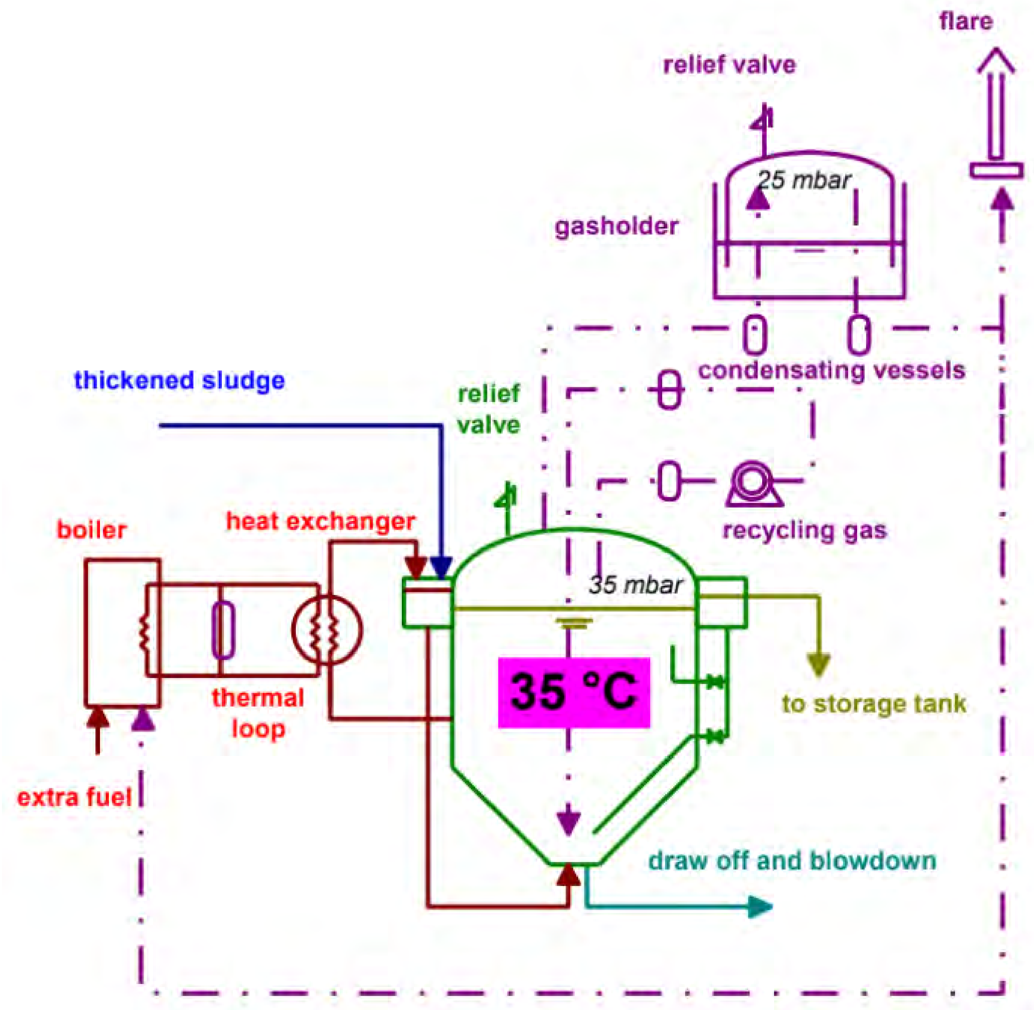


Figure 7: Schematic of a Mesophilic Anaerobic Digester

3.3. Aerobic Digestion

Aerobic digestion is another common method of stabilisation. It involves digestion in completely mixed tanks under aerobic conditions at ambient temperatures for a period of 20 to 45 days (with 1.5%–2% solids concentration). These conditions are optimal for microorganisms which convert organic material into carbon-dioxide. Aerobic conditions are maintained through diffusing either air or high purity oxygen into the digester. Autothermal thermophilic aerobic digestion (ATAD) is a variation on aerobic digestion where the feed sludge is pre-thickened to provide a feed greater than 4% dry solids, and the reactors are insulated to conserve the heat produced from the biological degradation of the organic solids. The aim of these modifications is to maintain thermophilic conditions in the insulated reactors (temperatures in the range of 45 °C - 70 °C) using the heat generated by the biological activity. No supplemental heat is provided (other than the aeration and mixing devices located inside the vessels). Sludge retention time in the digesters is 6-8 days shorter than for the earlier mentioned technologies. ATAD's are used where the digestate is used for fertilisation because retention of nitrogen in the solids is good.

Figure 8: ATAD facility in Nelson, New Zealand

3.4. Composting

Composting is a biological technology that uses naturally occurring microorganisms to convert biodegradable organic matter into a humus-like product, which can be used for agriculture. The composting process destroys pathogens, converts nitrogen from unstable ammonia to stable, organic forms of nitrogen. This technology is controlled by environmental parameters such as moisture content, pH, temperature and aeration. Composting requires a bulking agent to be added to the sludge which enlarges the volume by a factor of 2 – 3 times. Composting can occur in either open fields or in a controlled environment with air-conditioned vessels.

Figure 9: Example of a Traditional Composting Bund

Vermicomposting is a variation on the composting technology which involves digestion and mineralization of organic material. In contrast to composting, it depends on the action of earthworms, and microorganisms. During vermicomposting, the important nutrients such as calcium, nitrogen and phosphorus present in the feed material are converted into forms that are much more soluble and available to plants.

Due to the larger footprint and bulk material handling requirements for both composting and vermicomposting, controlling fugitive odours emissions can be difficult. Consequently, most composting/vermicomposting facilities are positioned away from sensitive receptors.

4. Hydrolysis Technologies

4.1. Overview

The efficiency of anaerobic digestion can be improved by performing sludge hydrolysis prior to anaerobic digestion. This is valid more for secondary sludge (or waste activated sludge) than for Primary Sludge. The reason is the fact that hydrolysis predominantly works on cell material of which there is much in WAS, but not so much in primary sludge. In the case of Wellington's WWTPs the sludges are mixed (Moa Point) or exclusively secondary (Karori). Unless the two Moa Point sludges could be collected and transported separately to the sludge facility there is no possibility to optimise any hydrolysis capacity by utilising it for a side-stream only.

Hydrolysis technologies break-down complex particulate matter into dissolved compounds with low molecular weight. Breakdown of these particulates are usually the rate-limiting step in anaerobic digestion. Hydrolysis pre-treatment improves the sludge dewaterability, improves the yield of biogas during digestion and enables a higher feed concentration into the anaerobic digestion process and a shorter residence time thereby reducing reactor size. Thermal hydrolysis also kills pathogens by sterilisation. Apart from thermal there are three other mechanisms of hydrolysing sludge; also, mechanical, ultrasonic and biological hydrolysis are discussed below.

4.2. Thermal Hydrolysis

Thermal hydrolysis process (THP) is the most common method used in the wastewater industry. It uses high temperature (up to 165 °C) and high pressure (up to 11 bar) to break down cellular structures in the biomass, resulting in a sterilised and more readily digestible sludge.

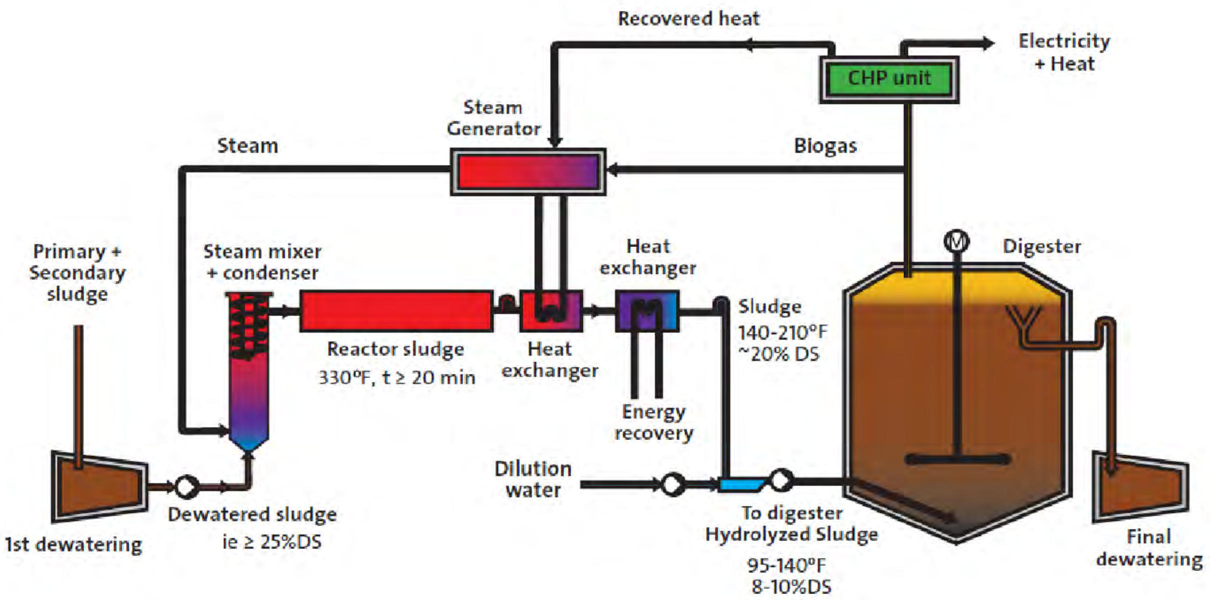


Figure 10: Schematic of a Continuous Thermal Hydrolysis Process

4.3. Mechanical Hydrolysis

Mechanical hydrolysis involves the use of mechanical force to cause cell lysis in sludge. The mechanical forces can be applied in many forms such as, pressure change, shearing or cavitation. It involves significant energy input.

4.4. Ultrasonic Hydrolysis

Ultrasonic hydrolysis uses the application of ultrasonic waves to cause cavitation at a micro scale. This results in high shear forces which break cell walls and release the cellular material, making the sludge more readily digestible. It is demanding on energy and can only be applied on dilute sludge. It has the shortest retention time of all hydrolysis technologies.

4.5. Biological Hydrolysis

Biological hydrolysis of sludge involves the addition of hydrolytic enzymes to sludge prior to anaerobic digestion. These enzymes catalyse the reactions that break down organic molecules like proteins and polysaccharides in the sludge. They also lyse pathogenic cells making them more digestible.

5. Thermal Conversion Technologies

5.1. Overview

Thermal conversion technologies can be performed on sludge once it has been sufficiently dried to reduce its water content and increase the calorific value. As a result, the required dryness for a self-sustaining conversion is dependent on the volatile concentration of the sludge as shown in Figure 11. With a high volatile concentration of sludge, a low dryness level is required to carry out a conversion process.

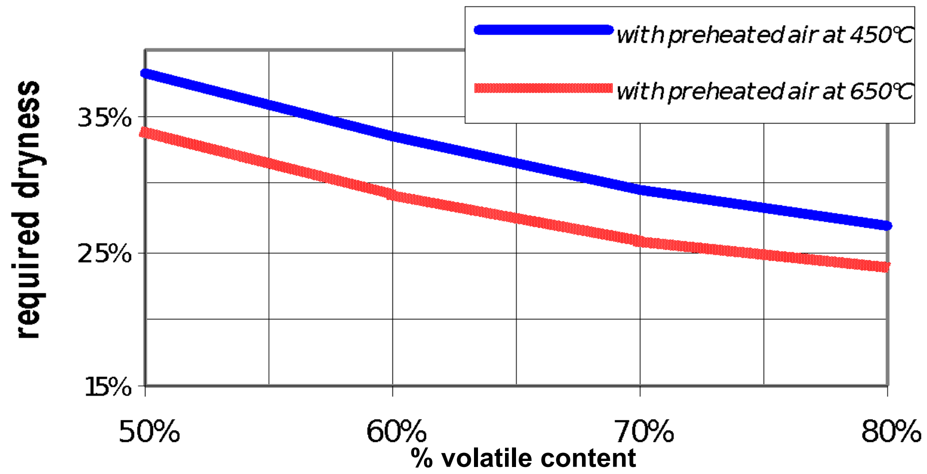


Figure 11: Dryness Requirements for Incineration

Thermal conversion technologies involve exposing sludge to high temperatures in order to chemically convert their structure. In most cases at least one resource is recovered. There will always also be a (waste) product but at a greatly reduced total mass compared to the original sludge. Organic solids in the sludge are either converted into liquids or gases, reducing or almost eliminating the amount of organic material. The high temperatures also kill all micro-organisms in the sludge by sterilising it. There are various technologies in this category, including:

1. Incineration
2. Gasification
3. Pyrolysis
4. Wet air oxidation (WAO)
5. Hydrothermal Liquefaction.

5.2. Incineration

Incineration is the process of combusting sludge in the presence of oxygen. Incineration destroys harmful pathogens and significantly reduces the total mass and volume of the sludge. The high temperature causes the molecules in the sludge to react with oxygen. The products of incineration are ash and waste gases known as flue gas.

The flue gasses created in incineration processes can include compounds which are harmful to either human health or the environment and typically require treatment before discharge to the environment. Treatment typically consists of several steps that involve filtration and chemical dosing. An example of a flue gas treatment set-up is presented in Figure 12.

Figure 12: Typical Dry Treatment for Flue Gas

As shown in Figure 12, the sludge will need to be dewatered prior to incineration otherwise a significant amount of external fuel would need to be brought in to evaporate water. The Wellington sludge promises to have a good volatile content which indicates that direct incineration after centrifugation should be possible.

5.3. Gasification

Gasification involves the conversion of organic material into smaller gaseous molecules using high temperatures and a small amount of oxygen being introduced into the system. Gasification mineralises the sludge. The main product of gasification is syngas, which is composed of carbon dioxide (CO2), carbon monoxide (CO), hydrogen (H2), methane (CH4), and nitrogen (N2). A small amount of dry residue similar to ash is also produced. The residue does not hold value.

Sludge will need to be dried prior to gasification.

5.4. Pyrolysis

Pyrolysis is a conversion technology that decomposes sludge by heating it in the absence of oxygen. The technology converts sludge into a high carbon solid called biochar, a mixture of gases known as syngas and a mixture of liquids known as bio-oil. Pyrolysis typically occurs at temperatures higher than 400 °C.

Sludge will need to be dried prior to pyrolysis.

5.5. Wet Air Oxidation

Wet air oxidation (WAO) is the oxidation of sludge in the liquid phase. A feed concentration of 4-8% dry solids is required which means that the sludge must be thickened prior. Often a MAD step precedes the technology to reduce the amount of feed sludge and thereby the capital investment. Either air or oxygen is used to oxidise the organic molecules in sludge and convert them into a clean gaseous effluent consisting of carbon dioxide, water and nitrogen. There is an ammonia rich water stream coming off the process as well as a mineral solid stream which is reusable as construction material. The process occurs under conditions of 54 bar (in case of pure oxygen) and 250 °C.

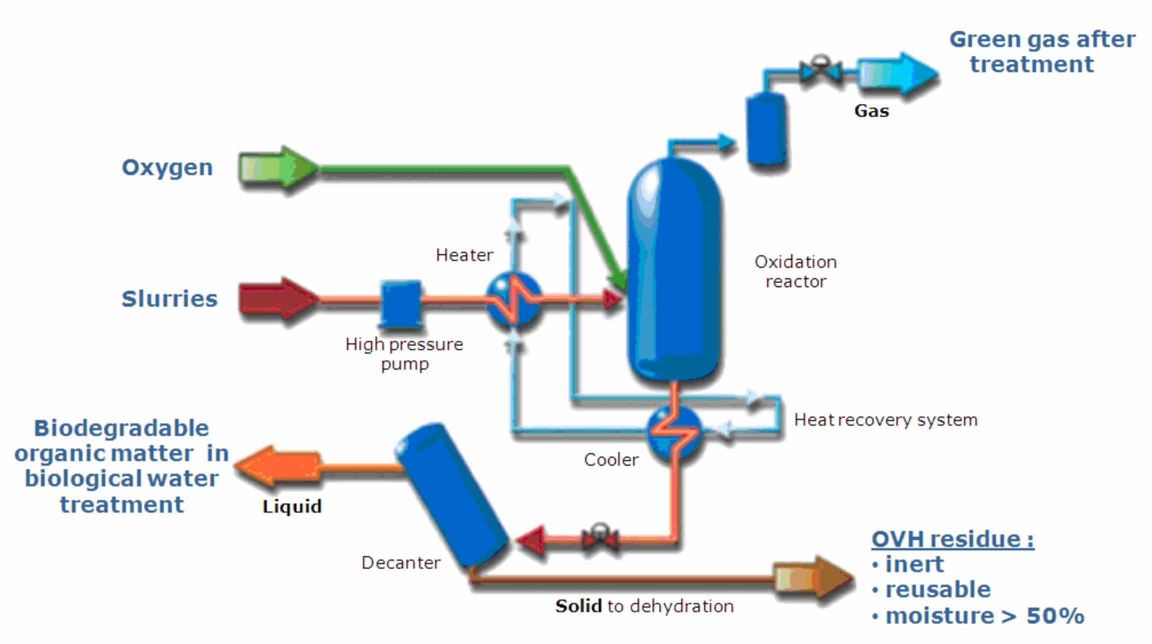


Figure 13: Schematic of the Wet Air Oxidation Process

5.6. Hydrothermal Liquefaction

This technology involves transferring the sludge to a high temperature high pressure reactor which separates the sludge into an organic biocrude phase, aqueous phase and a small number of solids (biochar) and gases. The biocrude is cooled then undergoes biocrude upgrading and the aqueous phase undergoes catalytic hydrothermal gasification. This is a novel technology which entails multiple steps to achieve production of crude oil.

Appendix C: Process Options Short List Summary

Sensitivity: General

CONNECT WATER

Memorandum

To: Wellington Water Limited

From: Connect Water Limited

Date: 23 September 2020

Subject: Process Options Short List Summary

1. Purpose

The purpose of this memo is to provide a summary of the shortlisted process options taken forward for the multi-criteria assessment (MCA) workshop on 2 July 2020. An overview of these process options has been incorporated in the *Sludge Minimisation Process Options Assessment Report* issued by Connect Water in June 2020.

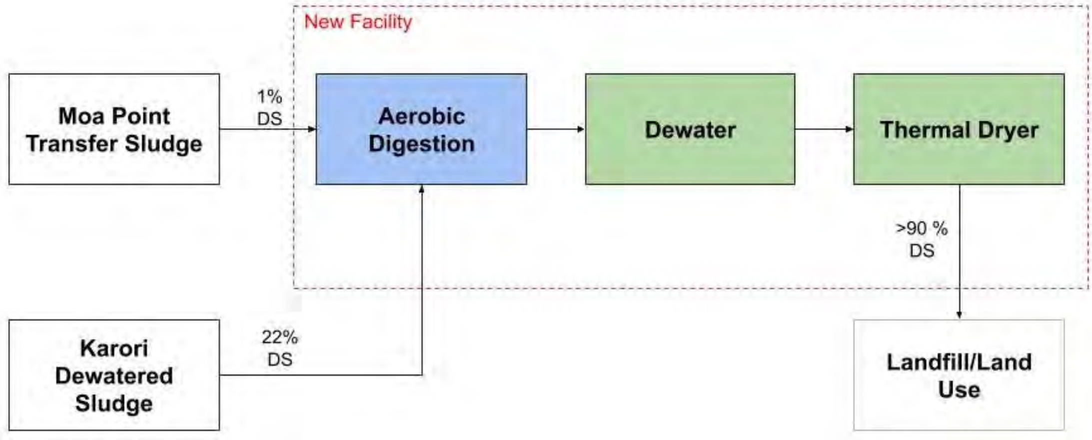
2. Process Options Short List Summary

The following options were taken forward to the MCA workshop:

- Option 7 - Autothermal Aerobic digestion (ATAD) + TD
- Option 8 – Mesophilic Anaerobic Digestion (MAD) + Composting
- Option 10 - Thermal Hydrolysis Process (THP) + MAD + Thermal Dryer (TD), also known as Lysis-Digestion + Thermal Drying (LD + TD)
- Option 12 – Digestion – Lysis – Digestion (DLD) + TD
- Option 17 – MAD + TD
- Option 18 – TD only
- Option 19 – TD + Gasification.
- Option 23 – Wet Air Oxidation (WAO) + upstream MAD
- Option 25 – Incineration (TD optional)

3. Option 7 – ATAD + TD

Moa Point and Karori sludges are mixed and fed to an (autothermal) aerobic digestion facility. After stabilisation the sludge is dewatered and dried in a thermal dryer. The dried product can be applied to land or landfilled.

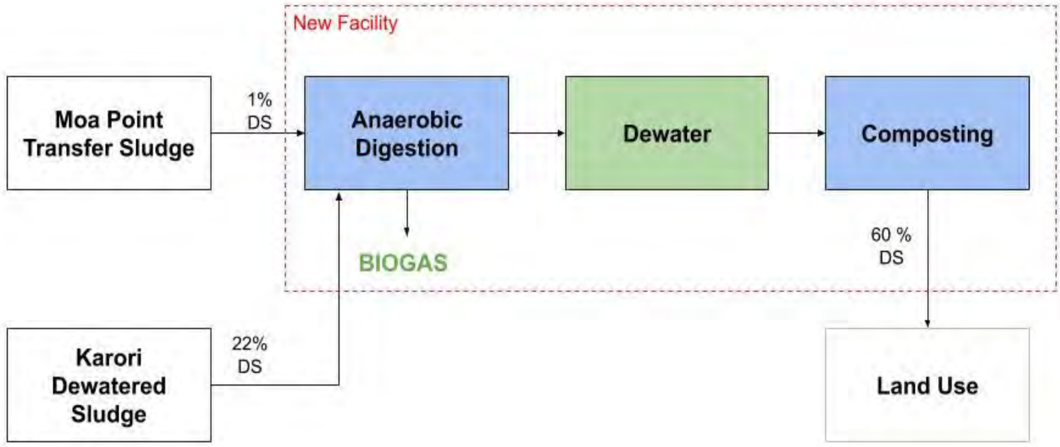


Evaluation Criteria	Option 7 - (Autothermal) Aerobic Digestion + TD	
	Evaluation	**Rating**
Maturity of Technology	ATAD is currently used in Bell Island Nelson for a population of 133,000 people. It is not succeeded by Thermal Drying in Nelson's case, but there is no reason it could not work if it was. Each process individually is established and used in multiple plants globally.	
Dry solid content of End Product	A stand-alone aerobic digestion system with centrifuge can reduce dry solids content to approximately 26%. With a thermal dryer this process can obtain a dry solids content greater than 90%.	
Total plant footprint	A process of aerobic digestion followed by a TD is comparable in footprint to that of anaerobic digestion which is 2,500 m^2	
Recommended Action	Retain for further evaluation	

4. Option 8 – MAD + Composting

Moa Point sludge is thickened. Karori sludge is mixed in and the blend is fed to an anaerobic digestion facility. After stabilisation the sludge is dewatered and composted. The product must be applied to land.

Biogas can be used for heating and/or electricity production.

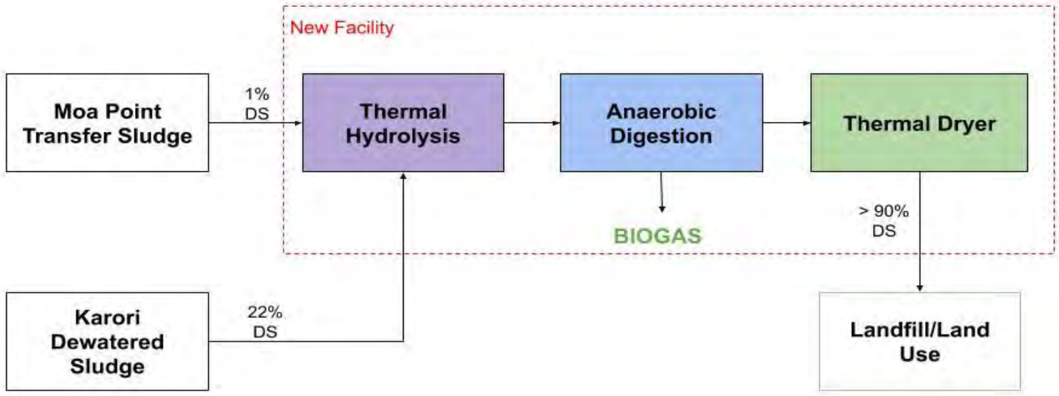


Evaluation Criteria	Option 8 - MAD + Composting	
	Evaluation	**Rating**
Maturity of Technology	This method is used in Palmerston North WWTP, New Zealand which serves a population of 100,000 people.	
Dry solid content of End Product	A dry solids content of approximately 60% is achievable provided a dry bulking agent is used. It has to be noted that the dryness is achieved by adding a dry bulking agent, so the total mass of the end product increases significantly.	
Total plant footprint	In-vessel composting can significantly reduce footprint requirements. An in-vessel composting system typically has a residence time of 16 - 20 days. This would require a similar footprint as MAD shown in Option 6, resulting in a total area of 5,000 m^2 for both the MAD and composting units.	
Recommended Action	Retain for further evaluation	

5. Option 10 – THP + MAD + TD aka LD + TD

Moa Point sludge is thickened. Karori sludge is mixed in and the blend is fed to a THP followed by anaerobic digestion. After stabilisation the sludge is dewatered and thermally dried. Biogas can be used to satisfy the heat requirements of the hydrolysis process and / or the dryer.

Biosolids can be applied to land or be landfilled.

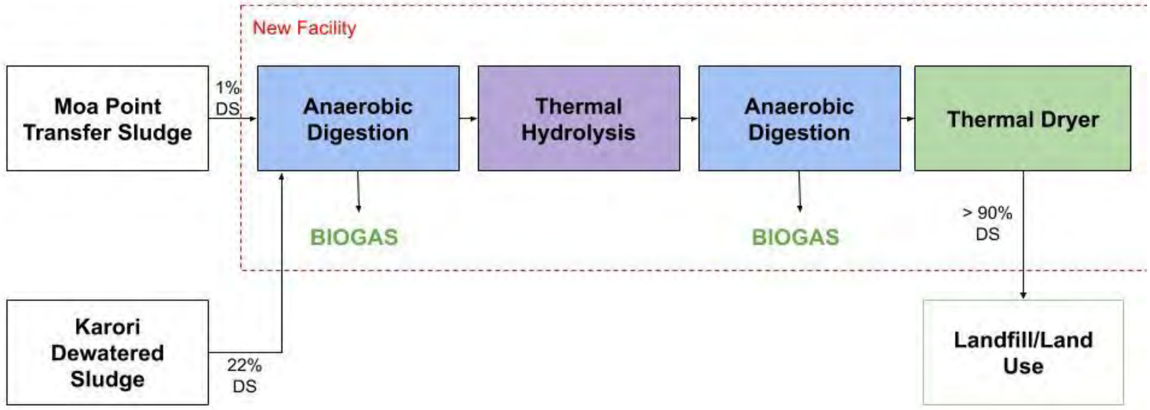


Evaluation Criteria	Option 10 – THP + MAD +TD	
	Evaluation	Rating
Maturity of Technology	This process is well established and is currently being constructed in NZ at the Rosedale WWTP serving 235,000 people. It is also used widely in many other regions including but not limited to: • Ljubljana, Slovenia (2018/2019): 572,000 PE • Yeosu, Korea (2018): 140,000 PE • Oberstown, Ireland (2017/2018): 360,000 PE • Versailles, France (2015): 330,000 PE • Marquette-Lez- Lille, France (2015) - 620,000 PE • Hamar Norway: 90,000 PE	
Dry solid content of End Product	This process configuration can obtain a dry solids content greater than 90%.	
Total plant footprint	Based on Marquette-Lez- Lille France WWTP it was determined that 0.0024m^2/people equivalent is required for a THP unit and 0.0058m^2 / people equivalent is required for a thermal dryer unit. For the envisaged future population of 250,000 in Wellington this would require 600m^2 for a THP unit and 1500m^2 for a TD unit. With a MAD unit of 2,500m^2 the total area required is 4,600m^2	
Recommended Action	Retain for further evaluation	

6. Option 12 – DLD + TD

Moa Point sludge is thickened. Karori sludge is mixed in and the blend is fed to a process consisting of two anaerobic digestion steps with thermal hydrolysis in between. After stabilisation the sludge is dewatered and thermally dried. Biogas can be used to satisfy the heat requirements of the hydrolysis process and / or the dryer.

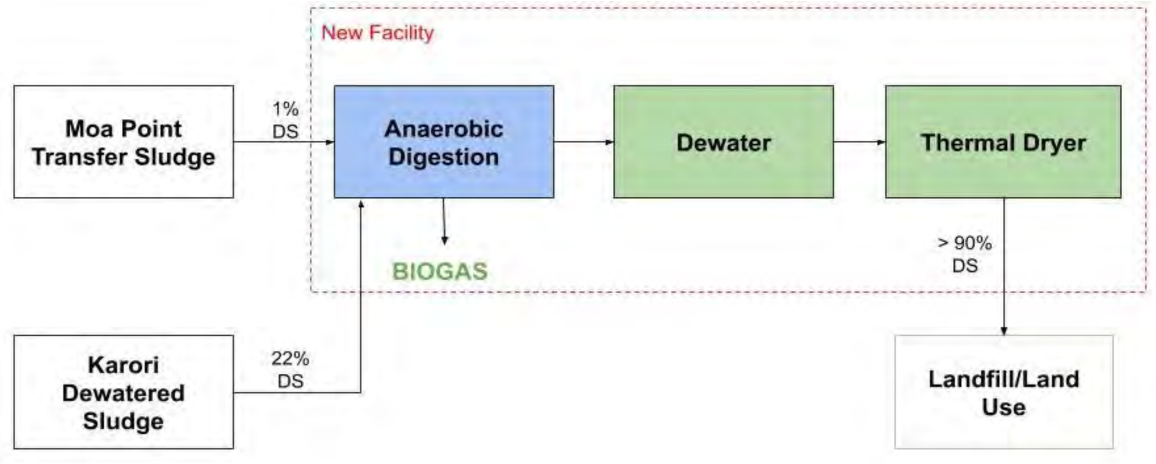
Biosolids can be applied to land or be landfilled.



Evaluation Criteria	Option 12 - DLD + TD	
	Evaluation	**Rating**
Maturity of Technology	DLD has not been implemented in New Zealand. It is used globally in the following locations: • Billund Denmark – 130,000PE • Marquette-Lez-Lille, France, 2015: 620,000 PE • Hillerod Denmark 80,000PE	
Dry solid content of End Product	This process configuration can obtain a dry solids content greater than 90%.	
Total plant footprint	Based on unit sizes calculated in Option 10, the overall area required for this process will be under 7,100 m^2 because the second digestion step occupies less space than the first.	
Recommended Action	Retain for further evaluation	

7. Option 17 – MAD + TD

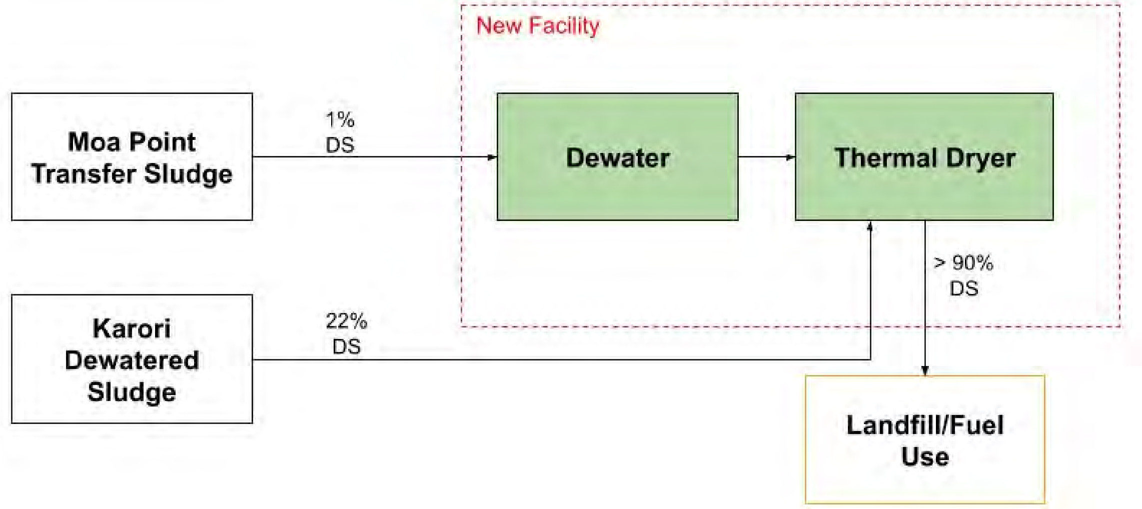
Moa Point sludge is thickened. Karori sludge is mixed in and the blend is fed to an anaerobic digestion step. After stabilisation the sludge is dewatered and thermally dried. Biogas can be used to satisfy the heat requirements of the dryer. Biosolids can be applied to land or be landfilled.



Evaluation Criteria	Option 17 - MAD + TD	
	Evaluation	Rating
Maturity of Technology	This configuration is currently being used at the Christchurch WWTP in NZ. sites globally also use this process including the following: • Hatton-Dundee -230,000PE (the thermal dryer is fired using biogas generated from MAD) • Prado – Reunion Island – 175,000PE (the thermal dryer is fired using biogas generated from MAD) • Evry, France – 250,000 PE	
Dry solid content of End Product	Greater than 90% dry solids content is achievable.	
Total plant footprint	Based on previous calculations for an MAD reactor and TD the required area to process the envisaged Wellington population sludge is approximately 4,000m^2.	
Recommended Action	Retain for further evaluation	

8. Option 18 – TD only

Moa Point sludge is dewatered and combined with Karori sludge. The blend is fed to a thermal dryer. The biosolids are a low-grade fuel but can be landfilled.

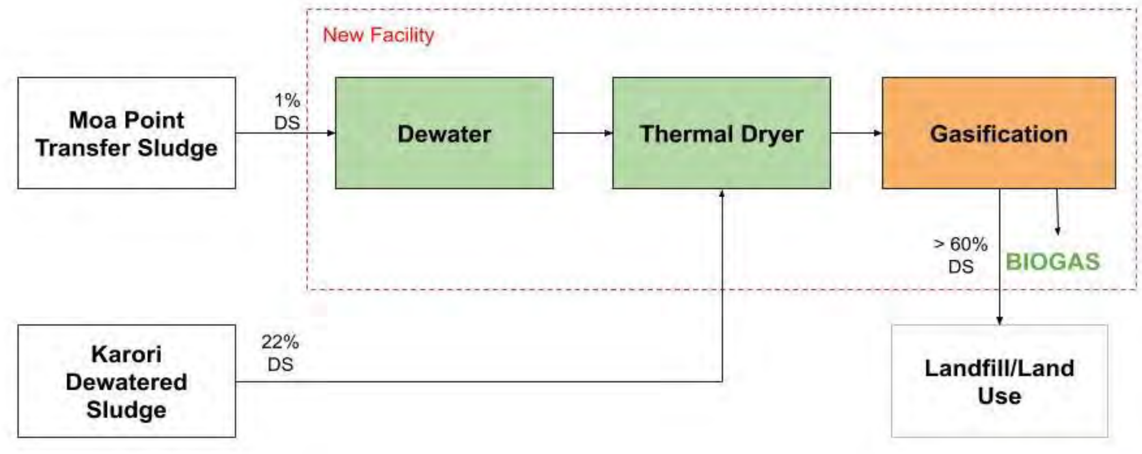


Evaluation Criteria	Option 18 - Thermal Dryer	
	Evaluation	**Rating**
Maturity of Technology	This sludge processing technique is currently used in NZ at Hutt Valley, New Plymouth, Christchurch and Whanganui WWTPs. It is an established process applied globally in multiple plants including but not limited to the following: • Marquette lez Lille, France (2015) - 620 000 PE • Alderwood, USA (2013) - 100 000 PE • Pomorzany, Poland (2011) - 420 000 PE • Draguignan, France (2006) - 70 000 PE • Ballarat North, Australia (2008)	
Dry solid content of End Product	Greater than 90% dry solids content is achievable.	
Total plant footprint	The area required for a thermal dryer is 1500m^2, as shown in Option 10.	
Recommended Action	Retain for further evaluation	

9. Option 19 – TD + Gasification

Moa Point sludge is dewatered and combined with Karori sludge in a thermal dryer. The dried solids are gasified. Syngas can be used to partially satisfy the thermal dryer energy needs.

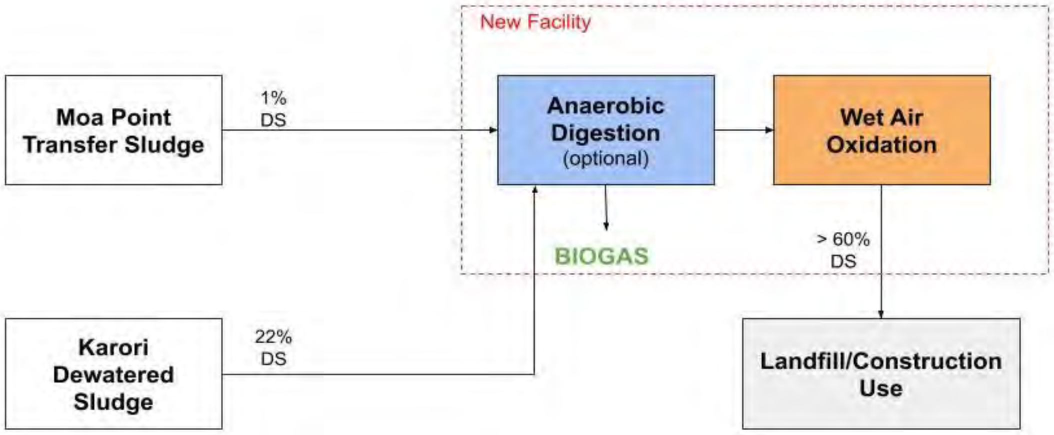
The biosolids can applied to land or be landfilled.



Evaluation Criteria	Option 19 - TD + Gasification	
	Evaluation	**Rating**
Maturity of Technology	Gasification of sludge has not been implemented in NZ. It is used globally in the following WWTPs: • Balingen WWTP, Germany (2001) – 125,000PE • Mannheim WWTP, Germany (2010) -725,000PE • Koblenz WWTP, Germany (commissioning) • Loganholme WWTP, Australia (construction phase) – 300,000PE	
Dry solid content of End Product	Biochar is produced therefore greater than 60% dry solids content is achieved.	
Total plant footprint	Based on the gasification unit in Mannheim WWTP it was determined that 0.0007m^2/ people equivalent is required. For the envisaged future population of 250,000 in Wellington this would require 200m^2. With the addition of a TD the footprint would be approximately 1,700 m^2.	
Recommended Action	Retain for further evaluation	

10. Option 23 – WAO + upstream MAD

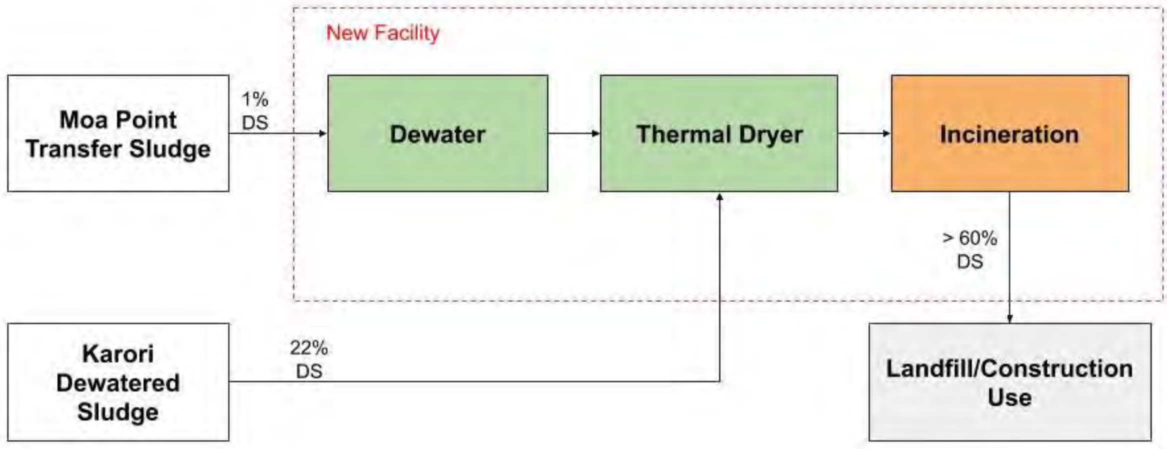
Moa Point sludge is dewatered and combined with Karori sludge in an anaerobic digester. The stabilised solids are fed to a WAO unit. The biosolids can be landfilled or used as construction material. Biogas can contribute to the WAO energy need.



Evaluation Criteria	Option 23 - WAO + upstream MAD	
	Evaluation	Rating
Maturity of Technology	A pilot plant was tested in Rotorua and Palmerston North however neither was carried through to full scale. Hence there are no current wastewater treatment facilities using this process in NZ. However, WAO is used extensively worldwide including in the following WWTPs amongst others: • Trucazzanno, Italy (2004) – 300,000 PE • Aix-en- Provence, France (2011) – 150,000 PE • Epernay, France (2006) – 175,000 PE • Rennes Beaurade, France (2012) – 360,000PE	
Dry solid content of End Product	Technosand produced, therefore greater than 60% dry solids content is achieved.	
Total plant footprint	Based on the WAO unit in Rennes Beaurade (MAD in process line) it was determined that 0.006 m²/ people equivalent is required. For the envisaged future population of 250,000 in Wellington this would require an area of 1500m².	
Recommended Action	Retain for further evaluation	

11. Option 25 - Incineration (TD optional)

Moa Point sludge is dewatered. Karori sludge is mixed in and the blend is fed to an incinerator. Potentially a thermal drying step is required for partial drying of the sludge blend. Residual ash can be partially used for construction purposes but must otherwise be landfilled.



Evaluation Criteria	Option 25 - Incineration (TD optional)	
	Evaluation	Rating
Maturity of Technology	Incineration is an established technology currently used in Dunedin's Tahuna WWTP, NZ – 80,000PE. It is also used extensively worldwide including but not limited to the following locations: • Noisy le Grand – Marne Aval, France -300,000 PE • Toulouse Ginestous France -950,000 PE • La Cartuja WWTP, Spain – 1.2 million PE	
Dry solid content of End Product	Ash is produced therefore, greater than 60% dry solids content is achieved.	
Total plant footprint	Based on the incineration unit in Tahuna WWTP it was determined that 0.02m2/ people equivalent is required. This would result in an area of 5,000m^2 for a 250,000 people population. As shown in Option 10 a TD would require 1,500 m^2 for the envisaged Wellington population. Therefore, the total footprint of this process is approximately 6,500m^2.	
Recommended Action	Retain for further evaluation	

Appendix D: MCA Workshop Minutes

Wellington Water

MINUTES

SUBJECT **Multi-criteria Assessment (MCA) Evaluation Workshop**

DATE Thursday, 2nd July 2020

WHERE Seaview Meeting Room, Wellington Water Office

ATTENDEES
Anna Hector (AH) – Wellington Water
Chris French (CF) – Connect Water
Dan Ormond (DO) – Latitude
Ezekiel Hudspith (EH) – Dentons Kensington Swan
Greg Lord (GL) – Connect Water
Joemar Cacnio (JC) – Wellington Water
Kara Puketapu-Dentice (KD)– Taranaki Whānui
Keerthana Rajasekaran (KR) – Veolia
Leah Agustin (LA) – Connect Water
Maiora Puketapu-Dentice (MD) – Wellington Water
Mel Wykes (MW) – Connect Water
Mike Medonca (MM) – Wellington City Council
Nanne de Haan (NdH) – Veolia
Phil Garrity (PG) – Wellington Water
Sarah Burgess (SB) – Connect Water
Sharli-jo Solomon (SS) – Ngati Toa
Steve Hutchison (SH) – Wellington Water
Turi Hippolite (TH) – Ngati Toa
Tristan Reynard (TR) - Wellington Water
Zac Jordan (ZJ) – Wellington City Council

APOLOGIES Nicky McIndoe (NM) – Dentons Kensington Swan

Item no.	Description	Comment / Query	In-workshop Response / Action	Post-workshop Actions
1	**Introduction and Purpose of Workshop**	NA	NA	NA
2	**Evaluation Criteria**	**Feedback on evaluation criteria and weightings presented:**		
		Sludge Minimisation and *Biosolids Re-use* should be evaluated as two separate criteria as opposed to encompassed within the *Function* criterion [MM]	*Sludge Minimisation* and *Biosolids Re-use* have individual sub-criterion weightings and will therefore be assessed separately (baseline weighting 12% and 9%, respectively). [CF / EH]	NA

		Should we specify Southern Landfill in the Interpretation of Sludge Minimisation sub-criterion? i.e. amend as "*The degree to which the solution reduces the mass of sludge going to **Southern** landfill*" [SH]	It is fine to leave as per the original interpretation. [MM]	NA
			The main concern is regarding the mobility of the sludge. We want to reduce the amount of sludge being transported in general [ZJ]	NA
		Request for additional sensitivity analysis to be done with a 30-40% cost weighting, as baseline weighting for cost criterion looks to be quite low [SH]	Noted that [CF]	Connect Water to undertake sensitivity analysis with higher cost criterion weighting and circulate results to MCA participants
		What is the basis of the *Whole-of-life cost* sub-criterion? [MM]	*Whole-of-life cost* sub-criterion interpretation was determined by estimating high-level capital costs and operational costs for a design horizon of 50 years [CF]	NA
		Sensitivity analysis suggestion in relation to *Environment* criterion amendment (assessing alignment with Part II of RMA) [EH]	NA	EH and CF to discuss additional sensitivity analysis and circulate results to MCA participants
3	**Options Analysis**	**Feedback on process technology options presented:**		
		Gasification can also produce ash instead of biochar depending on process [SB]	Noted. In this case, the volume of sludge has the potential to be further reduced, similar to incineration process [NdH]	NA
		Have electric thermal dryers been considered in this analysis? [ZJ]	No, we have assumed natural gas fuel source for the *Carbon Emissions* and *Whole of lie cost* analysis [SB]	Connect Water to undertake assessment using other fuel source (electric, natural gas, wood chips)
		Feedback on site options presented:		
		"Area 2" adjacent to the Moa Point WWTP and Miramar golf course has been earmarked for the future expansion of the Moa Point WWTP [AH]	Noted by all	NA
		Feedback on basis of ranking shortlist options against "Sludge Minimisation" sub-criterion:		

		If Southern Landfill is not a disposal option, which of the process options offers a product that is easier to transport? [ZJ]	Similar level in terms of ease of transport [NdH]	NA
		Is this sub-criterion necessary for the MCA workshop, or has this already been assessed through the fatal flaw analysis? [SH]	The technical fatal flaw assessment filtered out process options which did not meet the requirement of achieving 60% DS content, which indicates significant volume reduction (water content reduction). However, ranking options to compare sludge volume reduction would still be necessary [CF]	NA
		Are there any biohazardous outputs from any of the processes?	None, except for a small percentage from the incineration process [NdH]	NA
		Suggestion to increase score of Thermal Dryer option from **3 to 6**, as this process option still fulfils the sludge volume reduction objective set out in brief, albeit less effective than other process options	Agreed by all	NA
		Feedback on basis of ranking shortlist options against "Biosolids Re-use" sub-criterion:		
		Reuse potential could be high if you have very small amounts of product, e.g. can mix outputs with asphalt to produce concrete [CF]	Important to note that we will not be able to stop intaking sludge feedstock despite market fluctuations [SB]	NA
			Market is shrinking (composting, agriculture re-use) [MM]	NA
		Can we reframe the basis of ranking as ease of finding a market? [EH / NdH]	Uncomfortable with this suggestion as finding a market for biosolids re-use is not something that WCC will want to actively chase. It is suggested to view sludge minimisation as equivalent to Landfill gate fee [MM / ZJ]	NA
		Suggestion to reduce the score of Incineration process option from **10 to 8**. Despite achieving 0% VS (degradable content), there is no re-use opportunity for the end product.	Agreed by all	NA
		Feedback on basis of ranking shortlist options against "Mana Whenua Values" sub-criterion:		
		Why is there a big difference between scoring of the Moa Point and Carey's Gulley sites? Moa Point site (and truck transport route from Western WWTP) is also along coastline –	Moa Point areas has already been established as a site for WWTP processes, whereas the Owhiro Bay area is utilised by the community (mahinga kai sites along stream). It is also important	NA

		would this also have a significant impact from a culture perspective? [AH]	to consider recent 2020 Mt Albert pipeline failures and raw sludge trucking operation [MD / KD / TH / SS]	
			Establishing the facility at Moa Point avoids the need of the sludge transfer pipeline from Moa Point to Carey's Gulley, thus avoiding the risk of pipeline failure and discharge to waterways. [ZJ]	NA
			Failure can still occur with truck transport of processed sludge from Moa Point to Southern Landfill for disposal. Processed sludge (60-90%DS) is not immediately pathogenic if truck spillage were to occur from Moa Point to Carey's Gulley / Southern Landfill site, and this would be a very small amount in comparison to raw 1%DS sludge. [NdH]	NA
		Suggestion to **increase all Carey's Gulley process options score by 1 point**, i.e establish 2-point difference between equivalent Moa Point and Carey's Gulley process options	Agreed by all	NA
		Feedback on basis of ranking shortlist options against "Operational and Technological Complexity" sub-criterion:		
		Moa Point interested parties are now decreasing; home ownership at Moa Point is decreasing. Number of complaints from Moa Point community have significantly reduced, whereas Southern Landfill complaints have remained constant. Does this have an effect on the overall scoring against this sub-criterion? [AH]	The odour issues and associated community complaints would be assessed against the *Community Impacts* sub-criterion rather than the *Operational and Technological Complexity* sub-criterion [DO]	NA
		Do the rankings incorporate analysis of complexity with inclusion of Moa Point to Southern Landfill transfer pipeline? [SH]	Yes [CF]	NA
		Feedback on basis of ranking shortlist options against "Carbon Emissions" sub-criterion:		
		Does this sub criterion include emissions from disposal of any residual waste? [MM]	Yes, this assessment includes the disposal of biosolid product, electricity use, fossil fuel use, combustion of biogas and transportation emissions [CF / SB]	NA

		Did you consider electrical thermal dryer? [ZJ]	Electrical power source for thermal drying option was not considered in the scoring. The fuel source used for the basis of scoring for most process options is natural gas. For gasification, the fuel source is diesel for start-up based on reference site / project. [SB / GL]	Connect Water to undertake additional sensitivity analysis to incorporate alternative power / fuel source for thermal drying option.
		Feedback on basis of ranking shortlist options against "Ecological Effects" sub-criterion:		
		Noted GHG (basis of Thermal Drying down scoring) has already been considered in Carbon Emissions sub-criterion [EH]	Agreed by all to increase the scoring of the Thermal Dryer option from **6 to 8**.	NA
		Feedback on basis of ranking shortlist options against "Community Impacts" sub-criterion:		
		Should Landscape and visual impacts be incorporated under *Community Impacts or Consenting and Planning sub*-criterion? There are noted concerns with removal of bluff and the associated effects on the coastal environment, from an RMA coastal policy perspective. [EH]	Agreed by all to incorporate this into *Consenting and Planning* sub-criterion	Connect Water to liaise with Kensington Swan to undertake high-level landscape and visual assessment for Moa Point and Carey's Gulley site options. CF to circulate revised MCA scoring to participants for feedback.
		Noted that composting option still remains in assessment list – should this have been fatally flawed earlier? [MM]	We have kept it in the options list but have placed a big penalty in scoring due to current perceptions and previous challenges with consenting the composting facility. [CF]	NA
		Carey's Gulley community is incredibly mobilised and well-coordinated, whereas the Moa Point area is increasingly being bought out by WIAL and is transitioning into a more commercial space. What is the justification for having a 2-point difference between the Moa Point and Carey's Gulley sites? [ZJ]	We need to be careful when we get into discussion about the (subjective) anticipated level of community mobilisation surrounding Moa Point and Carey's Gulley [EH]	NA
			From a local community perspective, Carey's Gulley option(s) may receive more community agitation, but there may be a wider community concern at Moa Point. Carey's Gulley would be in an isolated, residential valley whereas Moa Point is adjacent to international airport and golf course. [DO]	NA
			Noted that Carey's Gulley community extends all the way into Island Bay. It is a wide community to consider [ZJ]	NA

			Agreed by all that the 2-point difference between site location remains. Noted that sub-criterion weighting is minimal (3%)	NA
		Feedback on basis of ranking shortlist options against "Consenting and Planning" sub-criterion:		
		Specific regulations note that incineration processes are prohibited unless incineration is part of a high waste to energy plant. This may be a fatal flaw. [ZJ]	Noted. NES for Air Quality has specific restriction around high temperature incineration [SB]	NA
		Discharge to air permit requires no discernible odour from plant operation at or beyond the boundary – is this incorporated in the scoring? How have we captured the management of this risk? This needs to be factored in, especially with the Moa Point site [AH]	This has been factored in the *Ecological Effects* and *Operational and Technological Complexity* sub-criterion ranking. [NdH / SB]	NA
		Feedback on basis of ranking shortlist options against "Whole of life cost" sub-criterion:		
		What is the approximate range of TOTEX? [MM]	The analysis for 50-year design horizon shows an NPV range of between $140-$485 million. The Carey's Gulley options take into account the rebuild and maintenance of the pipeline. [CF]	NA
		Important to note that current dewatering system (SDP) will have an effect on overall existing network. Moa Point will be a better option for network due to close proximity of WWTP from where centrate is discharged for treatment. [PG]	Noted.	NA
		Feedback on basis of ranking shortlist options against "Staging to meet budget" sub-criterion:		
		NA	NA	NA
		Summary of MCA results (Refer to Attachment 3 for scoring pre and post-MCA workshop) *Top option: Digestion-Lysis Digestion + Thermal Dryer Option at Moa Point*		
		Noted clear preference with Moa Point site [DO]	This avoids the re-debate the nuances with regards to community agitation between Moa Point and Carey's Gulley residents [ZJ]	NA

		Have there been any discussions regarding the relocation of the existing Cyclotek facility? [EH]	There have been discussions with WIAL (landlord) and they have a lease with a renewal which will take it beyond Stage 1 of development, but not subsequent stages. [CF]	Connect Water to assess staging and organise a follow up discussion with WIAL to provide an update on the preferred option and discuss way forward.
		TOTEX needs to incorporate stranded asset at Carey's Gulley. Residual depreciation to be taken into account. [MM]	Noted. Facility will need to be replaced within the 50-year design horizon [CF]	Connect Water to further refine NPV analysis to incorporate residual depreciation of Carey's Gulley assets.
4	Next Steps	NA	NA	• Wrap up post-workshop actions noted above by end July 2020 • Connect Water and Veolia to develop Concept Design report for preferred option • Connect Water to present preferred option and cost to WCC

KEY:

Wellington Water (WWL) representative

Wellington City Council (WCC) representative

Veolia representative

Ngati Toa / Taranaki Whānui representative

Connect Water / Latitude representative

Dentons Kensington Swan representative

Appendix E: Concept Design Drawings

WELLINGTON SLUDGE MINIMISATION FACILITY

Imagery sourced from the LINZ Data Service and licensed by Wellington City Council for re-use under the Creative Commons Attribution 4.0 International licence

LOCATION PLAN
1 : 2500

DRAWING LIST

DRG. No.	DRAWING NAME
GENERAL	
ZA-K0001	COVER SHEET
ZA-K1301	DLD + TD - 3D VIEWS
ZA-K2301	DLD + TD - LEVEL 00 SITE LAYOUT PLAN
ZA-K2311	DLD + TD - LEVEL 01 SITE LAYOUT PLAN
ZA-K2401	LD + TD - LEVEL 00 SITE LAYOUT PLAN
ZA-K2411	LD + TD - LEVEL 01 SITE LAYOUT PLAN
CIVIL	
CA-K1001	DLD + TD EXISTING AND NEW SERVICES LAYOUT
CA-K1011	DLD + TD SITE CROSS SECTIONS
STRUCTURAL	
SE-K2301	MAIN PROCESS BUILDING - GA PLANS - SHEET 1
SE-K2311	MAIN PROCESS BUILDING - GA PLANS - SHEET 2
SE-K2321	MAIN PROCESS BUILDING - GA PLANS - SHEET 3
SE-K2331	MAIN PROCESS BUILDING - GA PLANS - SHEET 4
SE-K2351	MAIN PROCESS BUILDING - GA SECTIONS - SHEET 1
SE-K2352	MAIN PROCESS BUILDING - GA SECTIONS - SHEET 2
SE-K2401	DIGESTER PLANT ROOM BUILDING - GA PLANS
SE-K2451	DIGESTER PLANT ROOM BUILDING - GA SECTIONS
MECHANICAL	
MA-K1001	DLD + TD MAIN PROCESS BUILDING GENERAL ARRANGEMENT SHEET 1
MA-K1002	DLD + TD MAIN PROCESS BUILDING GENERAL ARRANGEMENT SHEET 2
PROCESS	
PA-K1001	DLD + TD PROCESS FLOW DIAGRAM SHEET 1
PA-K1002	DLD + TD PROCESS FLOW DIAGRAM SHEET 2
PA-K1003	DLD + TD PROCESS FLOW DIAGRAM SHEET 3
PA-K2001	LD + TD PROCESS FLOW DIAGRAM SHEET 1
PA-K2002	LD + TD PROCESS FLOW DIAGRAM SHEET 2
PA-K2003	LD + TD PROCESS FLOW DIAGRAM SHEET 3
ELECTRICAL	
BE-K1001	DLD + TD EXISTING AND NEW SERVICES LAYOUT

A1 REPRODUCTION SCALE 0mm 20 40 60 80 100

A3 REPRODUCTION SCALE 0mm 10 20 30 40 50

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
B	FOR CONCEPT REPORT	AW	CSF	CAFF	06.11.20
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator
Connect Water
c/- Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000

CONNECT WATER

Original Scale (A1) 1 : 2500
Reduced Scale (A3)

Design		
Drawn	AW	22.09.20
Dsg Verifier		
Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: COVER SHEET

Discipline: GENERAL

Drawing No.: 6511521-1916-ZA-K0001

Rev.: B

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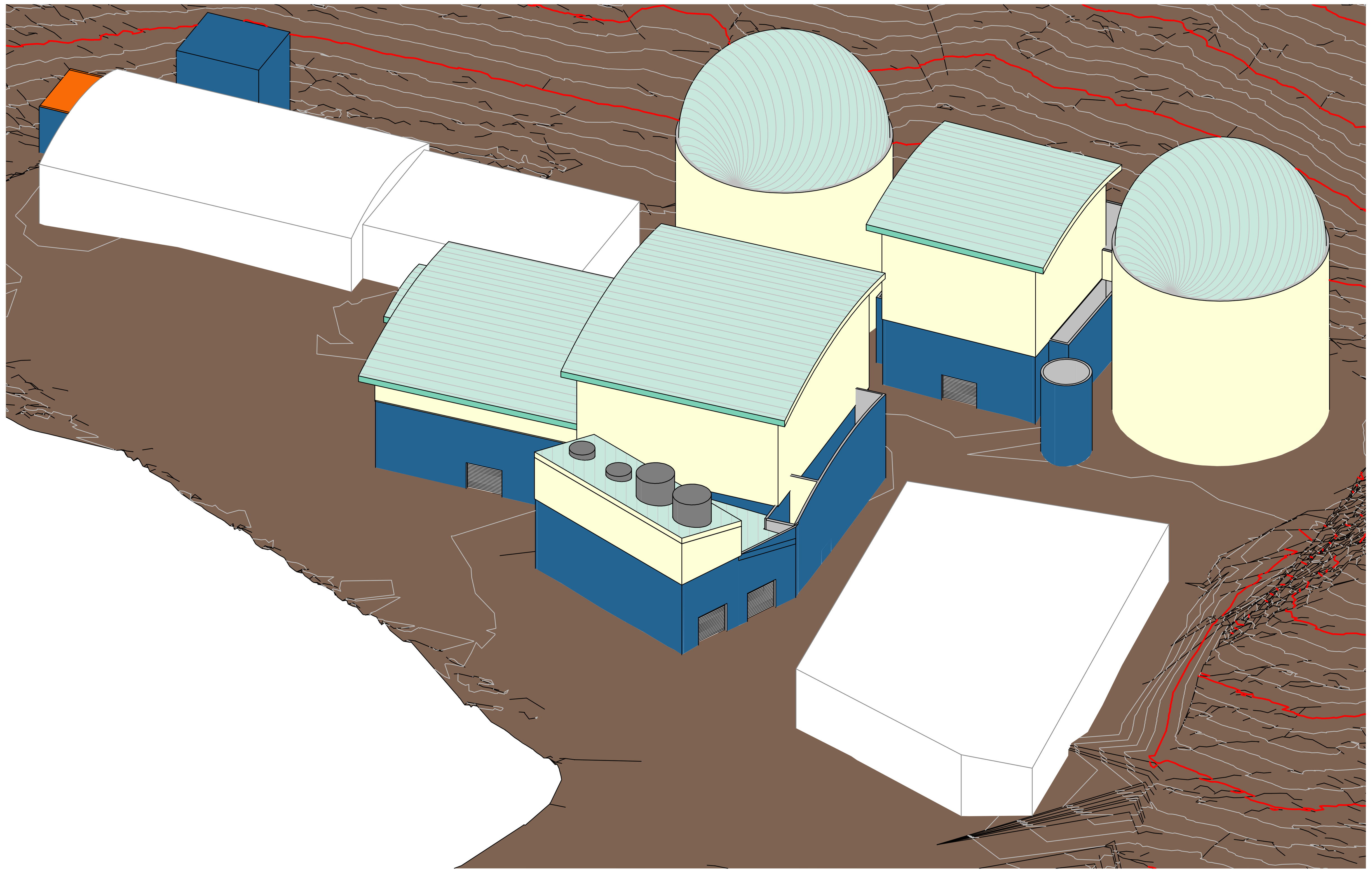
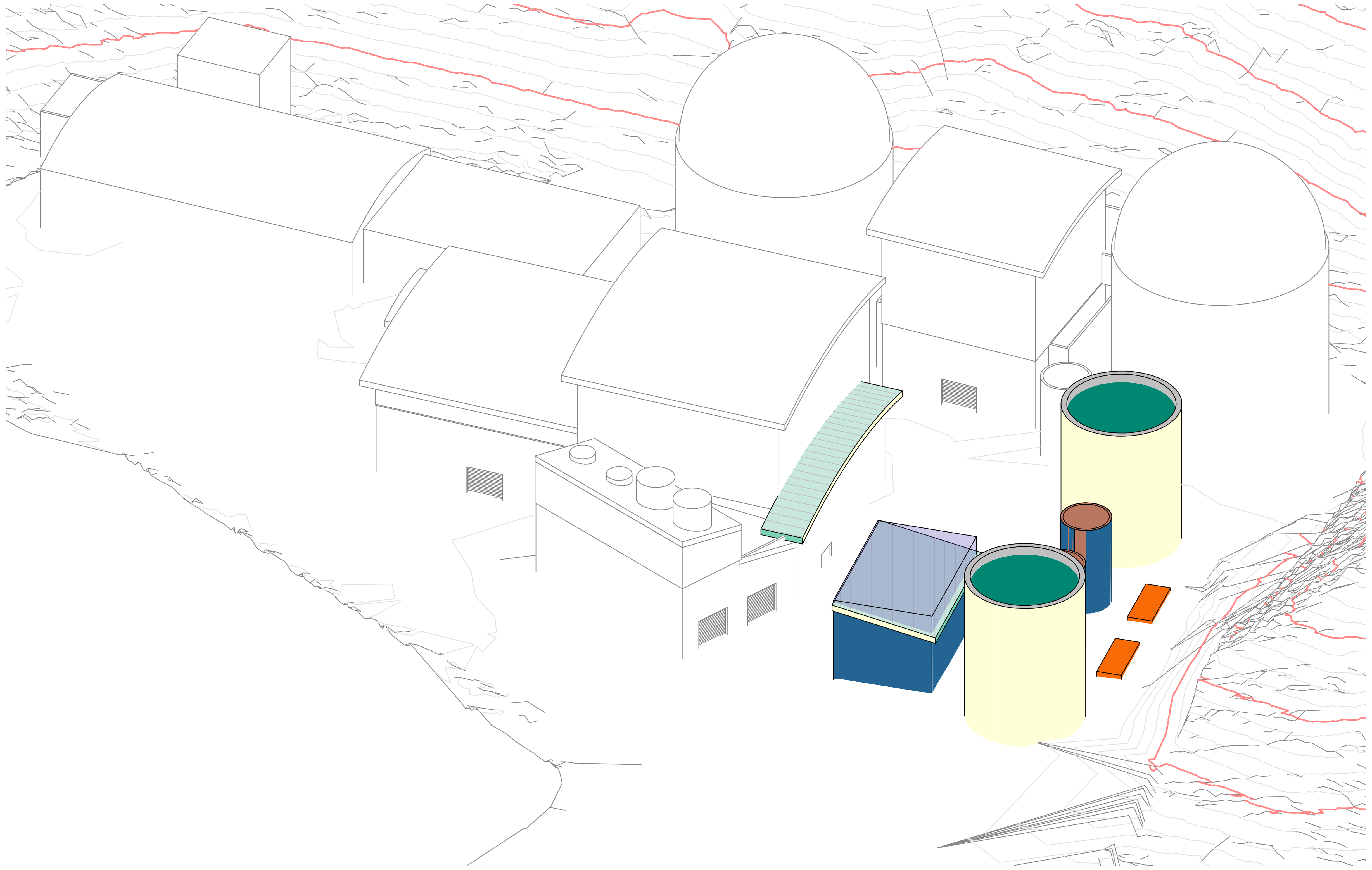
Drawing Plotted: 22/09/2020 12:46:06 PM



A 3D VIEW - DLD-TD - STAGE 1

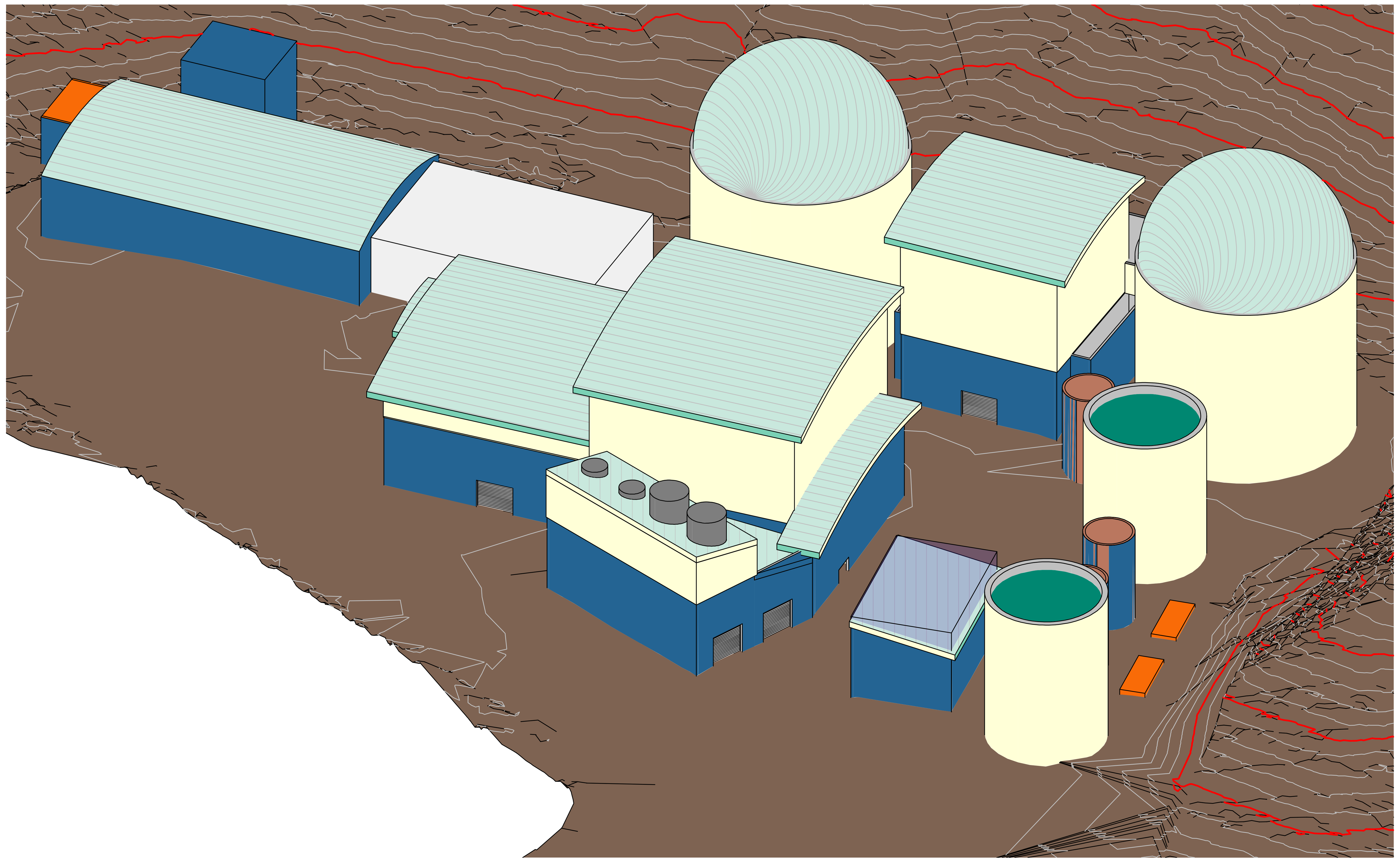


B 3D VIEW - DLD-TD - STAGE 2

NOTES:

1.0 GENERAL

1.1 FOR PROJECT AND GENERAL NOTES REFER TO SE-0XXX SERIES OF DRAWINGS



C 3D VIEW - DLD-TD - COMPLETED

A1 REPRODUCTION SCALE 0mm 20 40 60 80 100

A3 REPRODUCTION SCALE 0mm 10 20 30 40 50

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No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator
Connect Water
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Original Scale (A1) 1 : 1 Reduced Scale (A3)	Design		
	Drawn	CSF	22.09.20
	Dsg Verifier		
	Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DLD+TD - STAGE 1 & 2 3D VIEWS

Discipline: GENERAL

Drawing No.: 6511521-1916-ZA-K1301

Rev.: A

Document No. BIM 360://6511521-1916 SMURF/6511521-1916-SE-2020.rvt

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NOTES:

1.0 GENERAL

1.1 FOR PROJECT AND GENERAL NOTES REFER TO SE-0XXX SERIES OF DRAWINGS

A1 REPRODUCTION SCALE: 0mm, 20, 40, 60, 80, 100

A3 REPRODUCTION SCALE: 0mm, 10, 20, 30, 40, 50

SITE LAYOUT - DLD+TD LEVEL 00

1 : 200

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No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

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CONNECT WATER

Original Scale (A1)	Design	RPH / CAFF	22.09.20
As indicated	Drawn	CSF	22.09.20
Reduced Scale (A3)	Dsg Verifier		
	Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DLD+TD - LEVEL 00 SITE LAYOUT PLAN

Discipline: GENERAL

Drawing No.: 6511521-1916-ZA-K2301

Rev.: A

Document No. BIM 360://6511521-1916 SMURF/6511521-1916-SE-2020.rvt

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NOTES:

1.0 GENERAL

1.1 FOR PROJECT AND GENERAL NOTES REFER TO SE-0XXX SERIES OF DRAWINGS

SITE LAYOUT - DLD+TD LEVEL 01

1 : 200

A1 REPRODUCTION SCALE: 0mm, 20, 40, 60, 80, 100

A3 REPRODUCTION SCALE: 0mm, 10, 20, 30, 40, 50

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator: **Connect Water**
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Original Scale (A1): As indicated
Reduced Scale (A3)

Design	RPH / CAFF	22.09.20
Drawn	CSF	22.09.20
Dsg Verifier		
Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DLD+TD - LEVEL 01 SITE LAYOUT PLAN

Discipline: GENERAL

Drawing No. 6511521-1916-ZA-K2311

Rev. A

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NOTES:

1.0 GENERAL

1.1 FOR PROJECT AND GENERAL NOTES REFER TO SE-0XXX SERIES OF DRAWINGS

A1 REPRODUCTION SCALE 0mm 20 40 60 80 100 / 40 50

A3 REPRODUCTION SCALE 0mm 10 20 30

SITE LAYOUT - LD+TD LEVEL 00

1 : 200

FOR INFORMATION
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No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

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Original Scale (A1): As indicated
Reduced Scale (A3):

Design	RPH / CAFF	22.09.20
Drawn	CSF	22.09.20
Dsg Verifier		
Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: LD+TD - LEVEL 00 SITE LAYOUT PLAN

Discipline: GENERAL

Drawing No.: 6511521-1916-ZA-K2401

Rev.: A

Document No. BIM 360://6511521-1916 SMURF/6511521-1916-SE-2020.rvt

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NOTES:

1.0 GENERAL

1.1 FOR PROJECT AND GENERAL NOTES REFER TO SE-0XXX SERIES OF DRAWINGS

SITE LAYOUT - LD+TD LEVEL 01

1 : 200

A1 REPRODUCTION SCALE: 0mm, 20, 40, 60, 80, 100

A3 REPRODUCTION SCALE: 0mm, 10, 20, 30, 40, 50

FOR INFORMATION
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No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

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Wellington 6144
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Original Scale (A1) As indicated Reduced Scale (A3)	Design	RPH / CAFF	22.09.20
	Drawn	CSF	22.09.20
	Dsg Verifier		
	Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: LD+TD - LEVEL 01 SITE LAYOUT PLAN

Discipline: GENERAL

Drawing No. 6511521-1916-ZA-K2411

Rev. A

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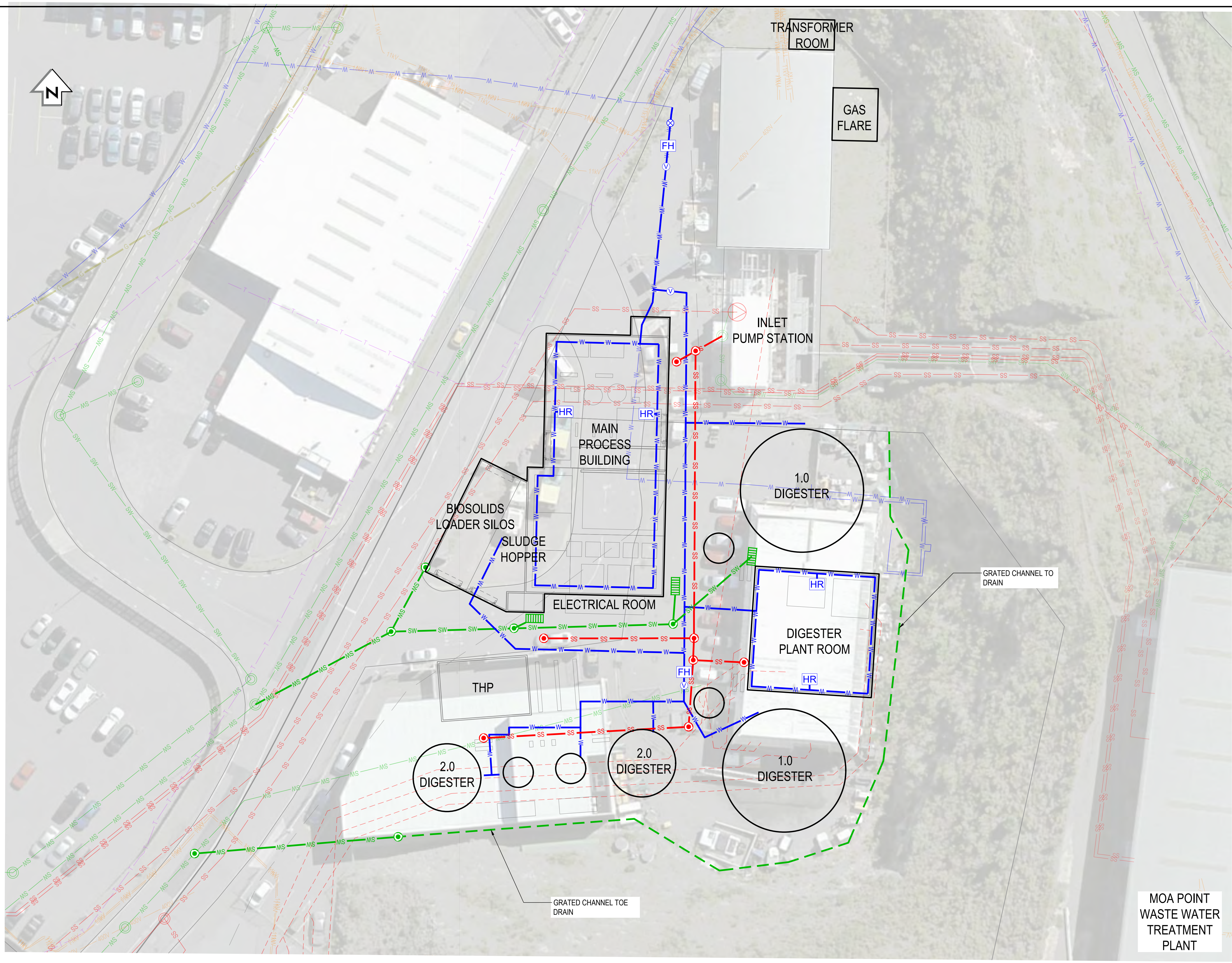


A1 REPRODUCTION SCALE: 0mm, 20, 40, 60, 80, 100

A3 REPRODUCTION SCALE: 0mm, 10, 20, 30, 40, 50

WW SERVICES LEGEND

- EXISTING WATER MAIN
- NEW WATER MAIN
- EXISTING STORMWATER
- NEW STORMWATER
- EXISTING WASTEWATER
- NEW WASTEWATER
- PRIVATE WATER
- PRIVATE STORMWATER
- PRIVATE WASTEWATER
- PARCEL BOUNDARY
- PUMP
- EXISTING SS/SW MANHOLE
- NEW SS/SW MANHOLE
- FIRE HOSE REEL — HR
- SUMP
- WATER METER
- GATE VALVE — V
- HYDRANT — FH

UTILITIES LEGEND

- GAS - POWERCO
- 400V U/G POWER
- 11kV U/G POWER
- 33kV U/G POWER
- TELECOMMS / CHORUS

ORIGINAL DRAWING IN COLOUR

FOR INFORMATION
NOT FOR CONSTRUCTION

SERVICES LAYOUT

1:250

No.	Revision	By	Chk	Appd	Date
A	FOR INFORMATION	RBP	RPH		15.09.20

Drawing Originator: Connect Water, c/- WSP Opus International Consultants Ltd, PO box 12 003 Thorndon, Wellington 6144, T 64 4 471 7000

CONNECT WATER

Original Scale (A1): AS SHOWN
Reduced Scale (A3): 1/2 SHOWN

Design	L. CHAKATSVA	15.09.20
Drawn	R. PRAJAPATI	15.09.20
Dsg Verifier		
Dwg Check		

Approved For Construction*
Date
* Refer to Revision 1 for Original Signature

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DLD + TD EXISTING AND NEW SERVICES LAYOUT

Discipline: CIVIL ENGINEERING

Drawing No.: 6511521-1916-CA-K1001 | Rev.: A

Plotted By: Rahul Prajapati

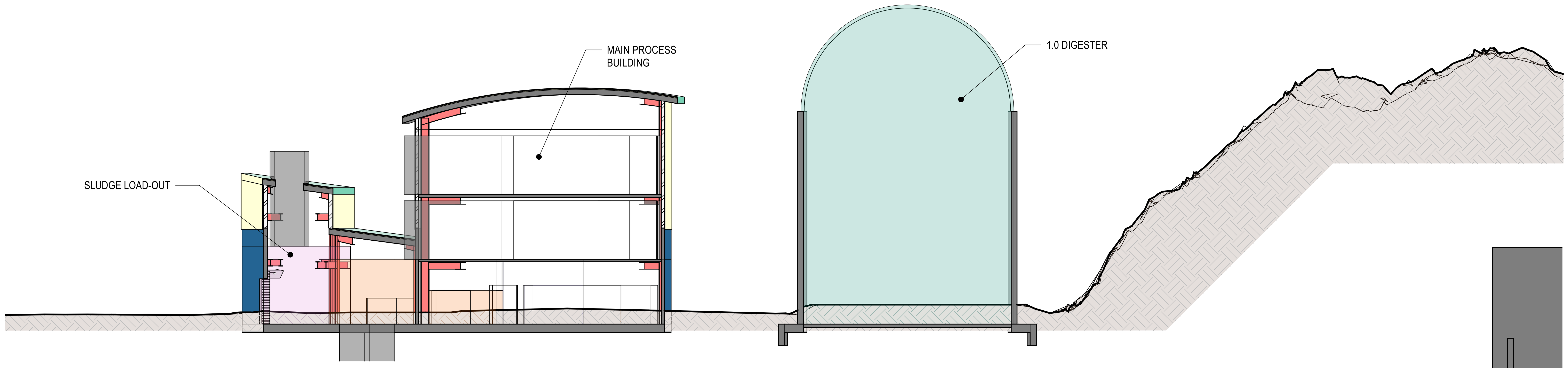
DO NOT SCALE - IF IN DOUBT ASK

Drawing Plotted: 22 Sep 2020 8:56 am

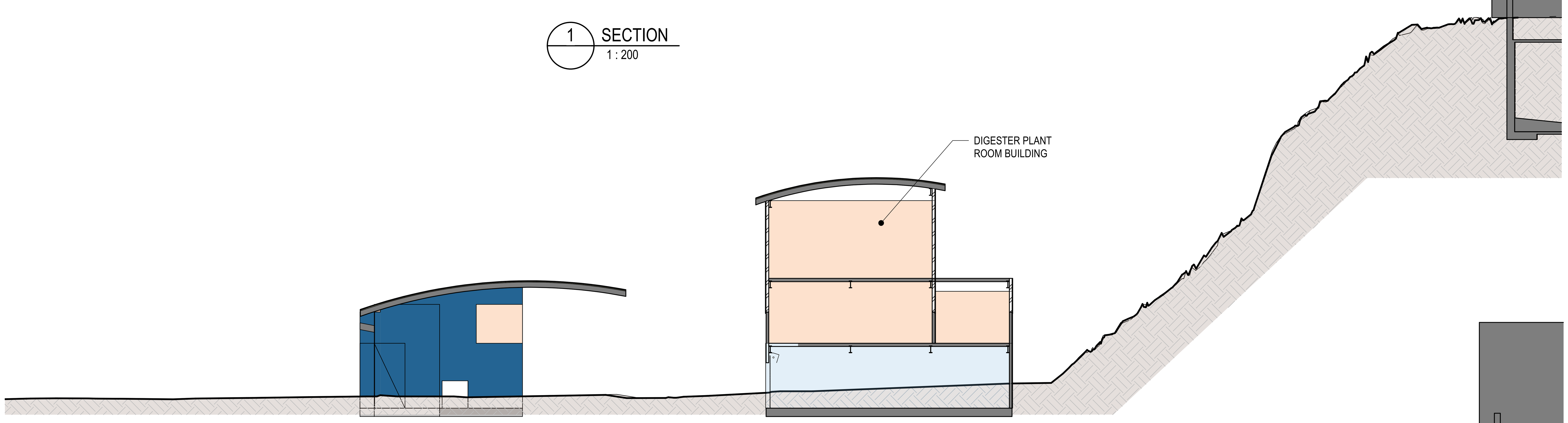
Document Path: P:\651\6511521\CAD_1916 - SMURF

Document No. 6511521-1916-CA-K1001.DWG

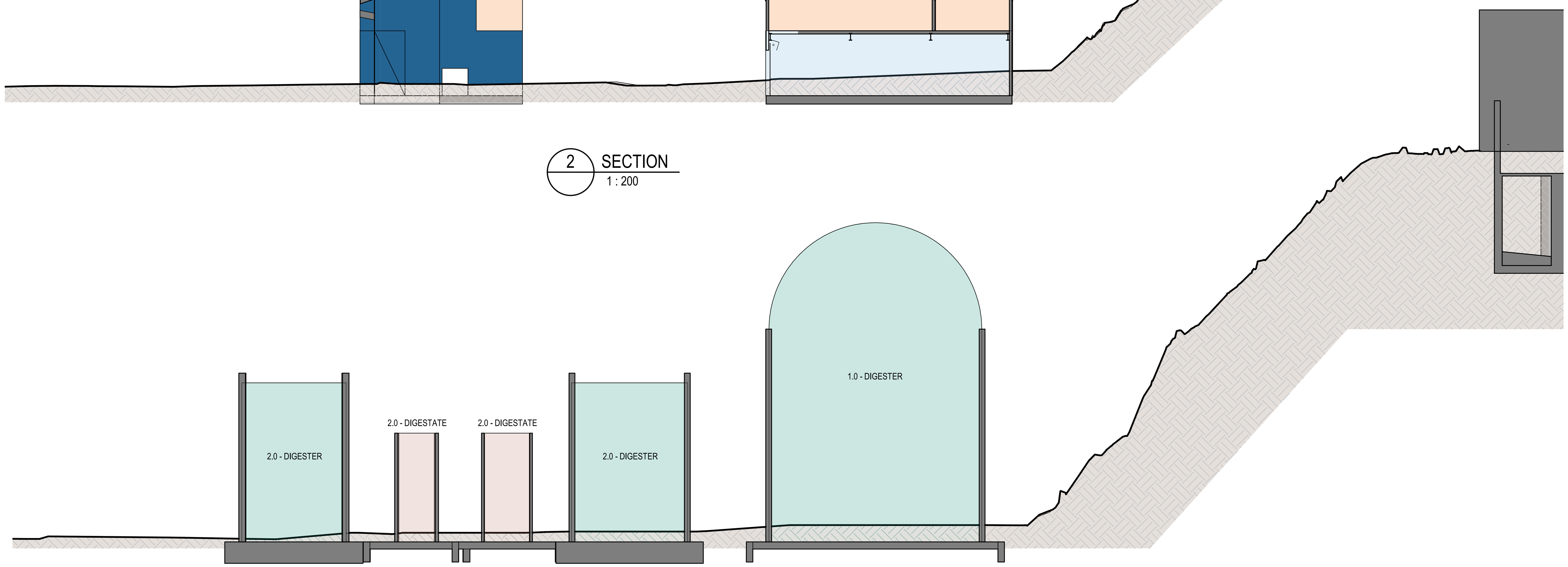
Drawing Plotted: 22/09/2020 12:44:45 PM



1 SECTION
1 : 200



2 SECTION
1 : 200



3 SECTION
1 : 200

A1 REPRODUCTION SCALE: 0mm, 20, 40, 60, 80, 100

A3 REPRODUCTION SCALE: 0mm, 10, 20, 30, 40, 50

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator
Connect Water
c/- Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000
CONNECT WATER

Original Scale (A1) 1 : 200
Reduced Scale (A3)

Design		
Drawn	CSF	22.09.20
Dsg Verifier		
Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DLD+TD - SITE CROSS SECTIONS

Discipline: CIVIL

Drawing No. 6511521-1916-CE-K1011

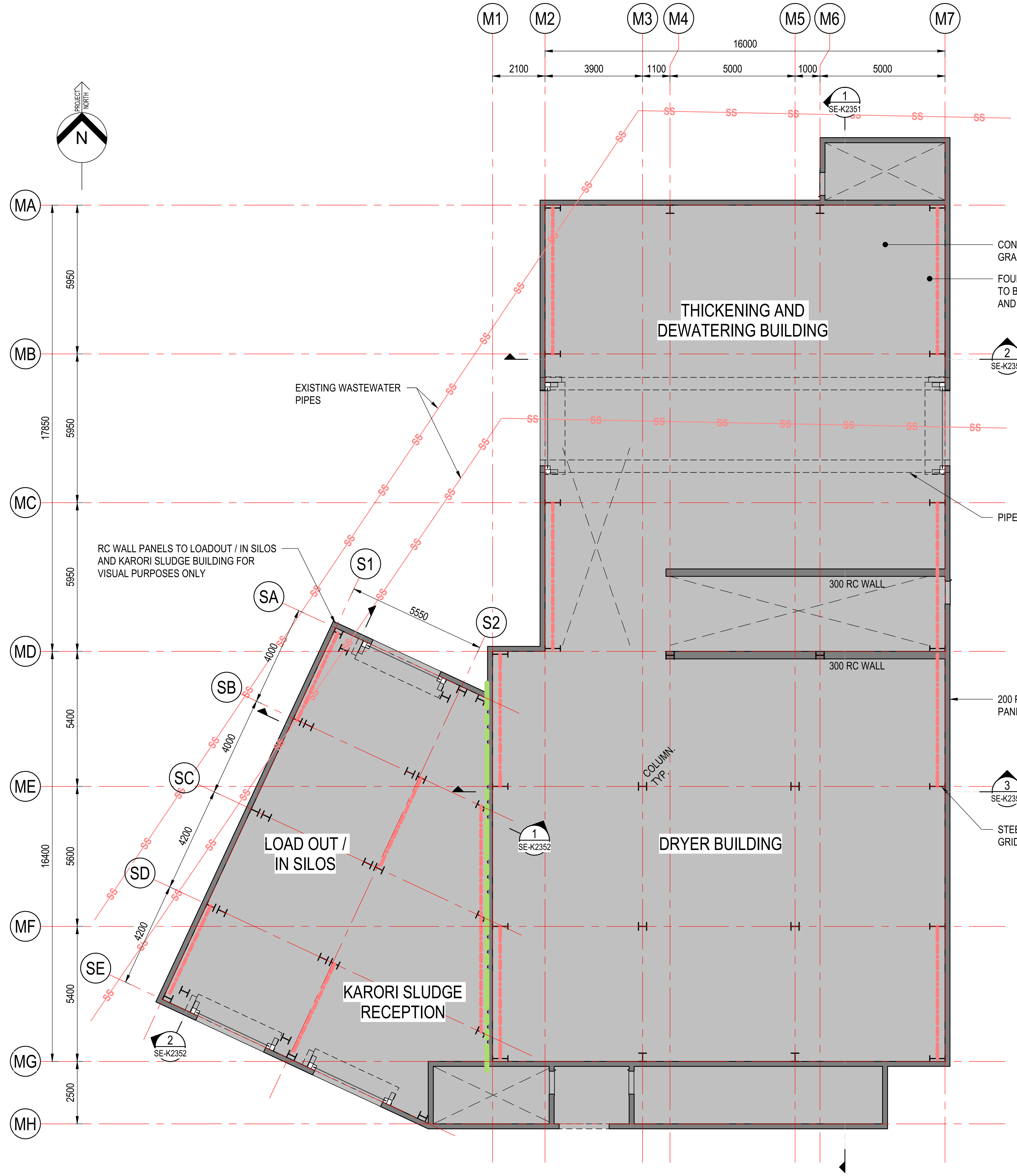
Rev. A

DO NOT SCALE

IF IN DOUBT ASK.

Document No. BIM 360://6511521-1916 SMURF/6511521-1916-SE-2020.rvt

Drawing Plotted: 22/09/2020 12:45:21 PM



PLAN - MAIN PROCESS BUILDING LEVEL 00

1 : 100

A1 REPRODUCTION SCALE: 100, 80, 60, 40, 20, 0mm

A3 REPRODUCTION SCALE: 50, 40, 30, 20, 10, 0mm

LEGEND

- STEEL COLUMN
- STEEL FRAMING
- PC PANEL WALLS
- SEISMIC GAP
- STEEL CROSS BRACE BAY

NOTES:

1.0 GENERAL

1.1 FOR PROJECT AND GENERAL NOTES REFER TO SE-0XXX SERIES OF DRAWINGS

2.0 ALLOWANCES

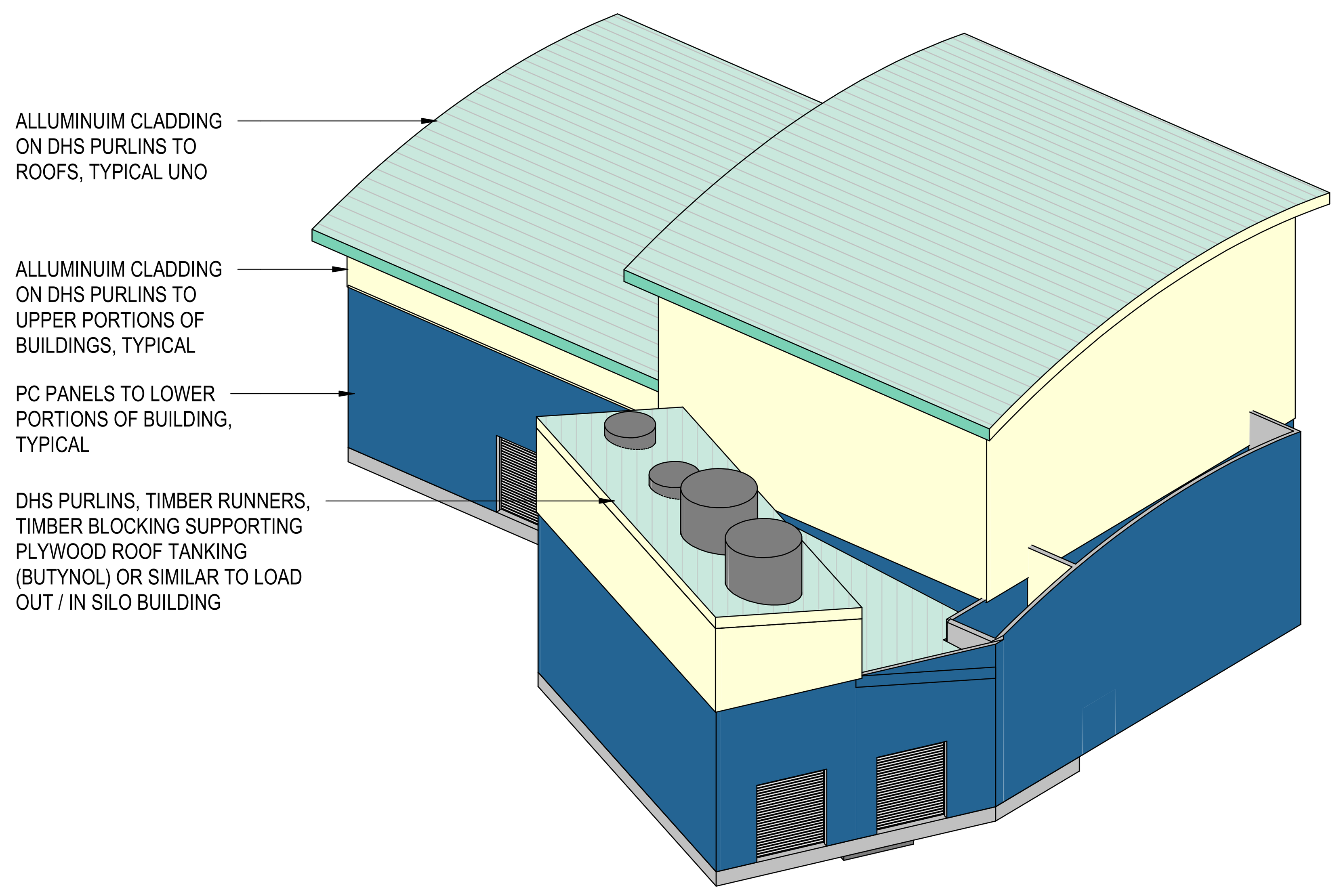
2.1 ALLOW 2 x VOLUME OF CONCRETE m³ COMPARED TO TE MANGA EXAMPLE

2.2 ASSUME 200 REINFORCED MASONARY WALLS AROUND PLANT ROOMS / ELECTRICAL ROOMS.

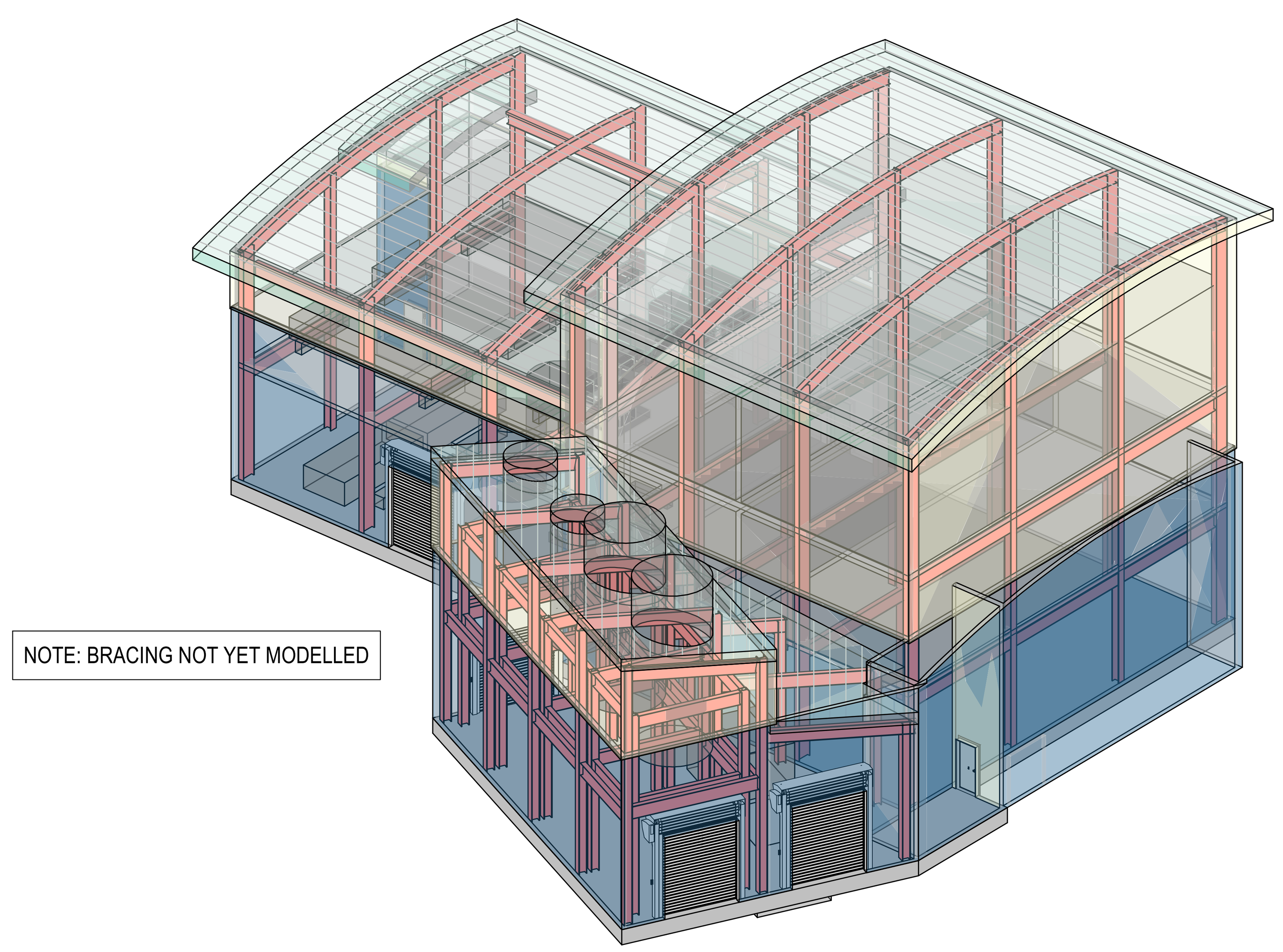
2.1 ALLOW FOR ROOF BRACING (NOT MODELED AT THIS STAGE).

2.4 ASSUME THAT LOAD OUT / IN SILO SUPPORT AND BUILDING ARE SEPERATE STRUCTURES.

2.5 SEPERATION BETWEEN SILO SUPPORT AND BUILDING TO ACCOMODATE SLS MOVEMENTS WITHOUT STRUCTURAL DAMAGE.



MAIN PROCESS BUILDING CLADDING



MAIN PROCESS BUILDING

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator: **Connect Water**, c/- Opus International Consultants Ltd, PO box 12 003 Thorndon, Wellington 6144, T 64 4 471 7000

Original Scale (A1): As indicated
Reduced Scale (A3)

Design		
Drawn	CSF	22.09.20
Dsg Verifier		
Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: MAIN PROCESS BUILDING - GA PLANS - SHEET 1

Discipline: STRUCTURAL

Drawing No.: 6511521-1916-SE-K2301

Rev.: A

DO NOT SCALE

IF IN DOUBT ASK.

Document No. BIM 360://6511521-1916 SMURF/6511521-1916-SE-2020.rvt

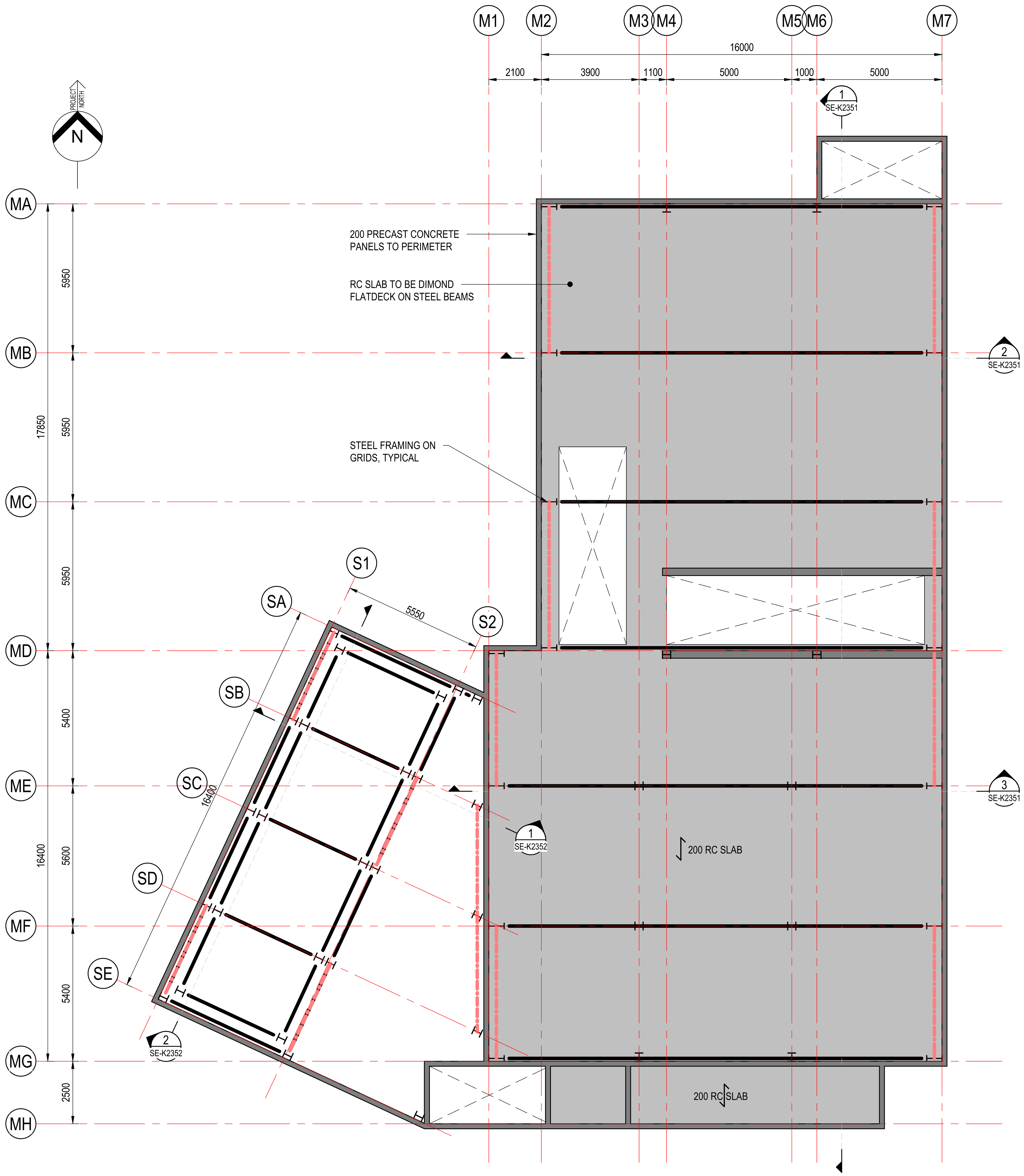
LEGEND

- STEEL COLUMN
- STEEL FRAMING
- PC PANEL WALLS
- SEISMIC GAP
- STEEL CROSS BRACE BAY

NOTES:

1.0 GENERAL

1.1 FOR PROJECT AND GENERAL NOTES REFER TO SE-0XXX SERIES OF DRAWINGS



PLAN - MAIN PROCESS BUILDING LEVEL 01

1 : 100

A1 REPRODUCTION SCALE 0mm 20 40 60 80 100

A3 REPRODUCTION SCALE 0mm 10 20 30 40 50

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator
Connect Water
c/- Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000

Original Scale (A1): As indicated
Reduced Scale (A3)

Design		
Drawn	CSF	22.09.20
Dsg Verifier		
Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: MAIN PROCESS BUILDING - GA PLANS - SHEET 2

Discipline: STRUCTURAL

Drawing No. 6511521-1916-SE-K2311

Rev. A

Document No. BIM 360://6511521-1916 SMURF/6511521-1916-SE-2020.rvt

Drawing Plotted: 22/09/2020 12:45:22 PM

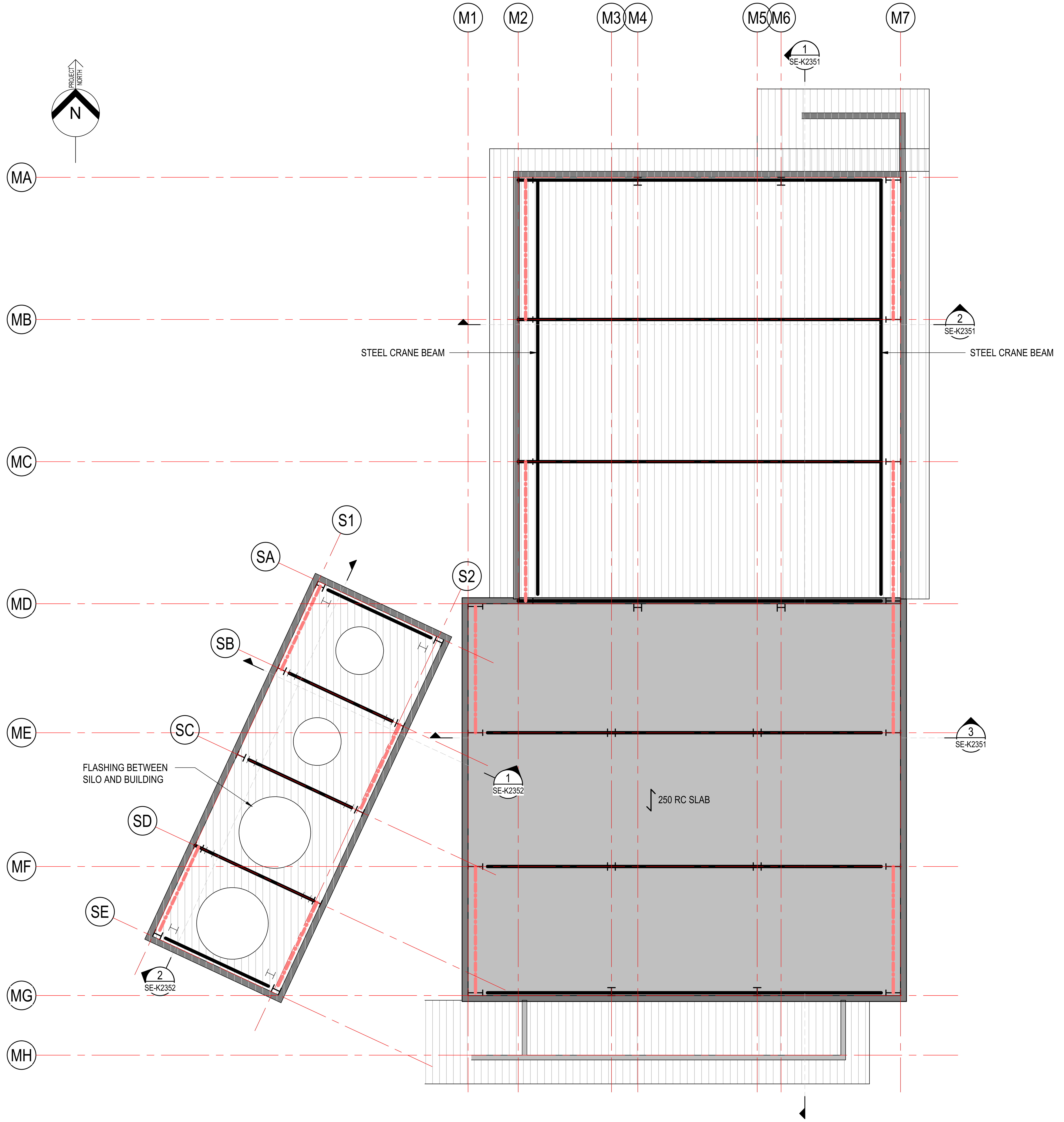
LEGEND

- STEEL COLUMN
- STEEL FRAMING
- PC PANEL WALLS
- SEISMIC GAP
- STEEL CROSS BRACE BAY

NOTES:

1.0 GENERAL

1.1 FOR PROJECT AND GENERAL NOTES REFER TO SE-0XXX SERIES OF DRAWINGS



PLAN - MAIN PROCESS BUILDING LEVEL 02

1 : 100

A1 REPRODUCTION SCALE: 0mm, 20, 40, 60, 80, 100

A3 REPRODUCTION SCALE: 0mm, 10, 20, 30, 40, 50

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator
Connect Water
c/- Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000

CONNECT WATER

Original Scale (A1): As indicated
Reduced Scale (A3)

Design		
Drawn	CSF	22.09.20
Dsg Verifier		
Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: MAIN PROCESS BUILDING - GA PLANS - SHEET 3

Discipline: STRUCTURAL

Drawing No.: 6511521-1916-SE-K2321

Rev.: A

DO NOT SCALE

IF IN DOUBT ASK.

Document No. BIM 360://6511521-1916 SMURF/6511521-1916-SE-2020.rvt

Drawing Plotted: 22/09/2020 12:45:22 PM

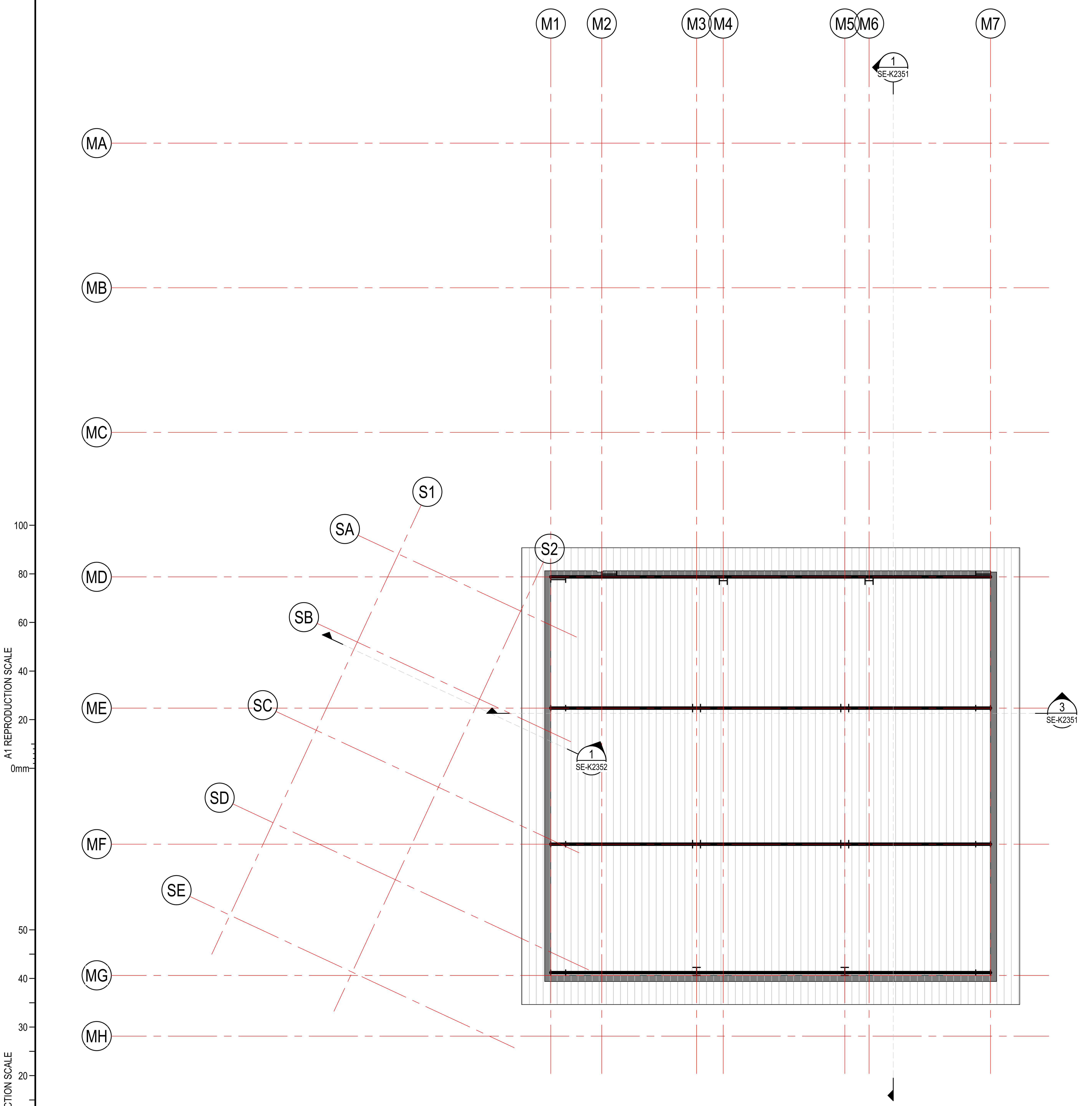
LEGEND

- STEEL COLUMN
- STEEL FRAMING
- PC PANEL WALLS
- SEISMIC GAP
- STEEL CROSS BRACE BAY

NOTES:

1.0 GENERAL

1.1 FOR PROJECT AND GENERAL NOTES REFER TO SE-0XXX SERIES OF DRAWINGS



PLAN - MAIN PROCESS BUILDING ROOF

1 : 100

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator
Connect Water
c/- Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000

CONNECT WATER

Original Scale (A1): As indicated
Reduced Scale (A3)

Design		
Drawn	CSF	22.09.20
Dsg Verifier		
Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: MAIN PROCESS BUILDING - GA PLANS - SHEET 4

Discipline: STRUCTURAL

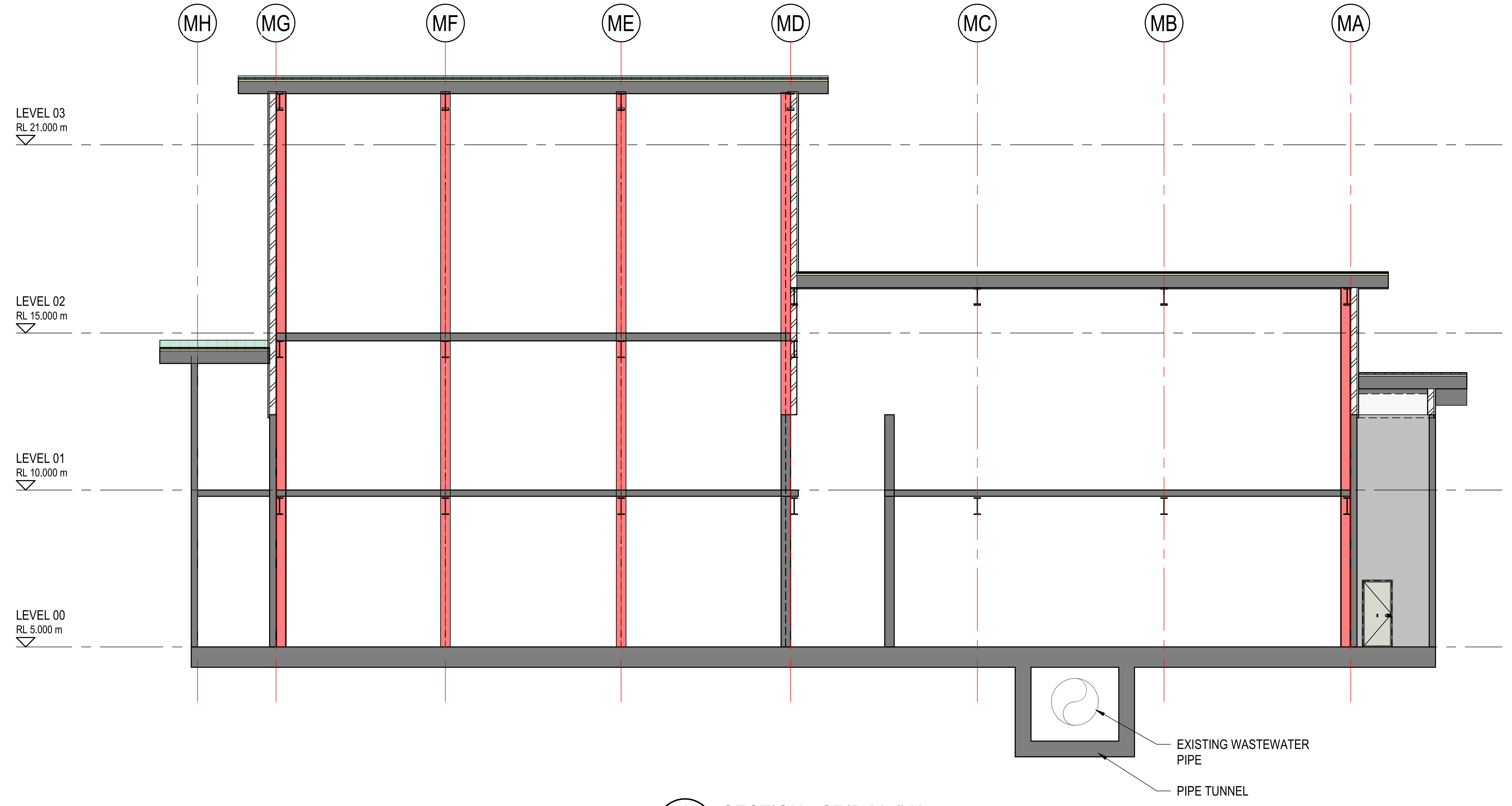
Drawing No. 6511521-1916-SE-K2331

Rev. A

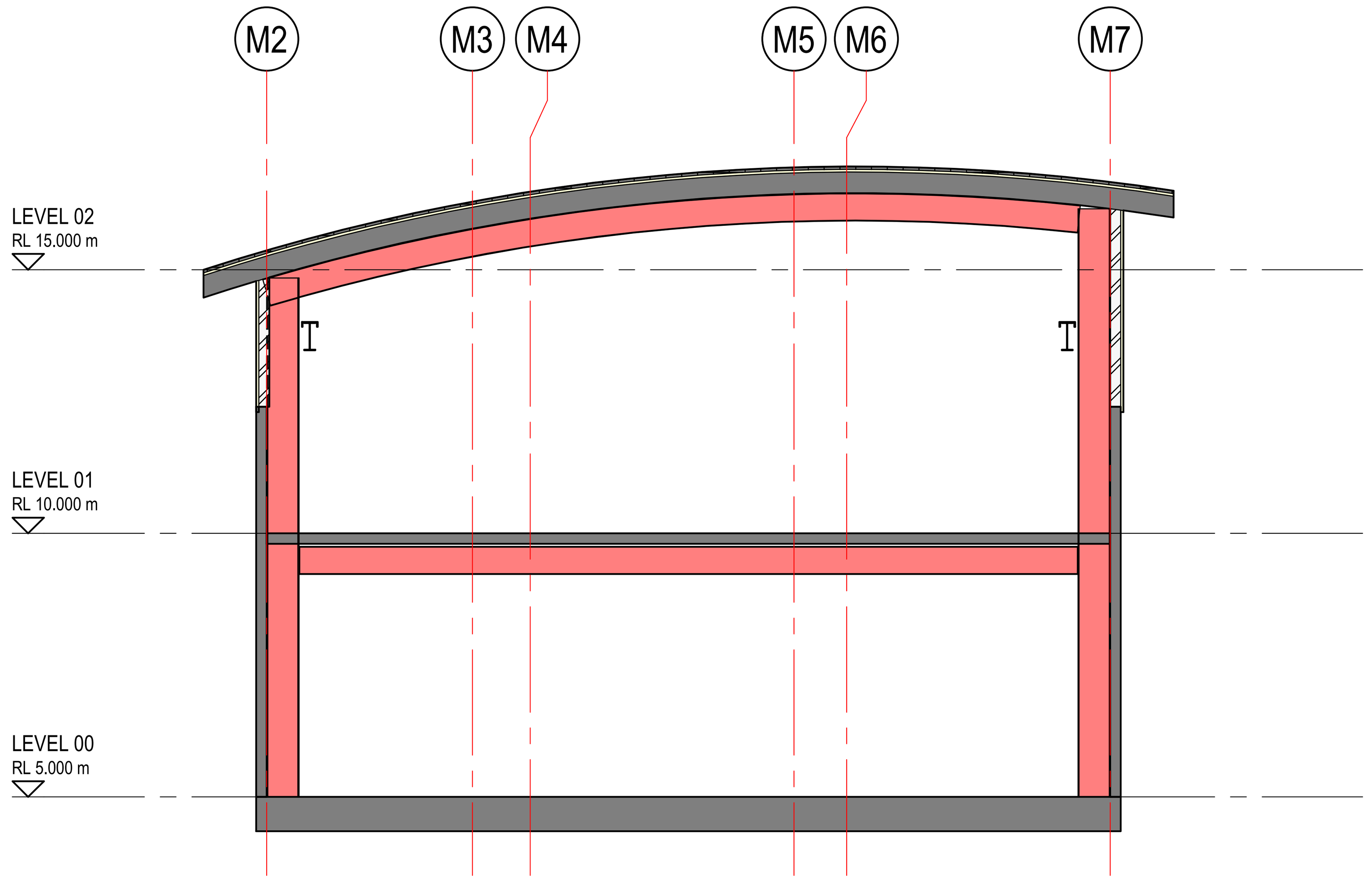
DO NOT SCALE

IF IN DOUBT ASK.

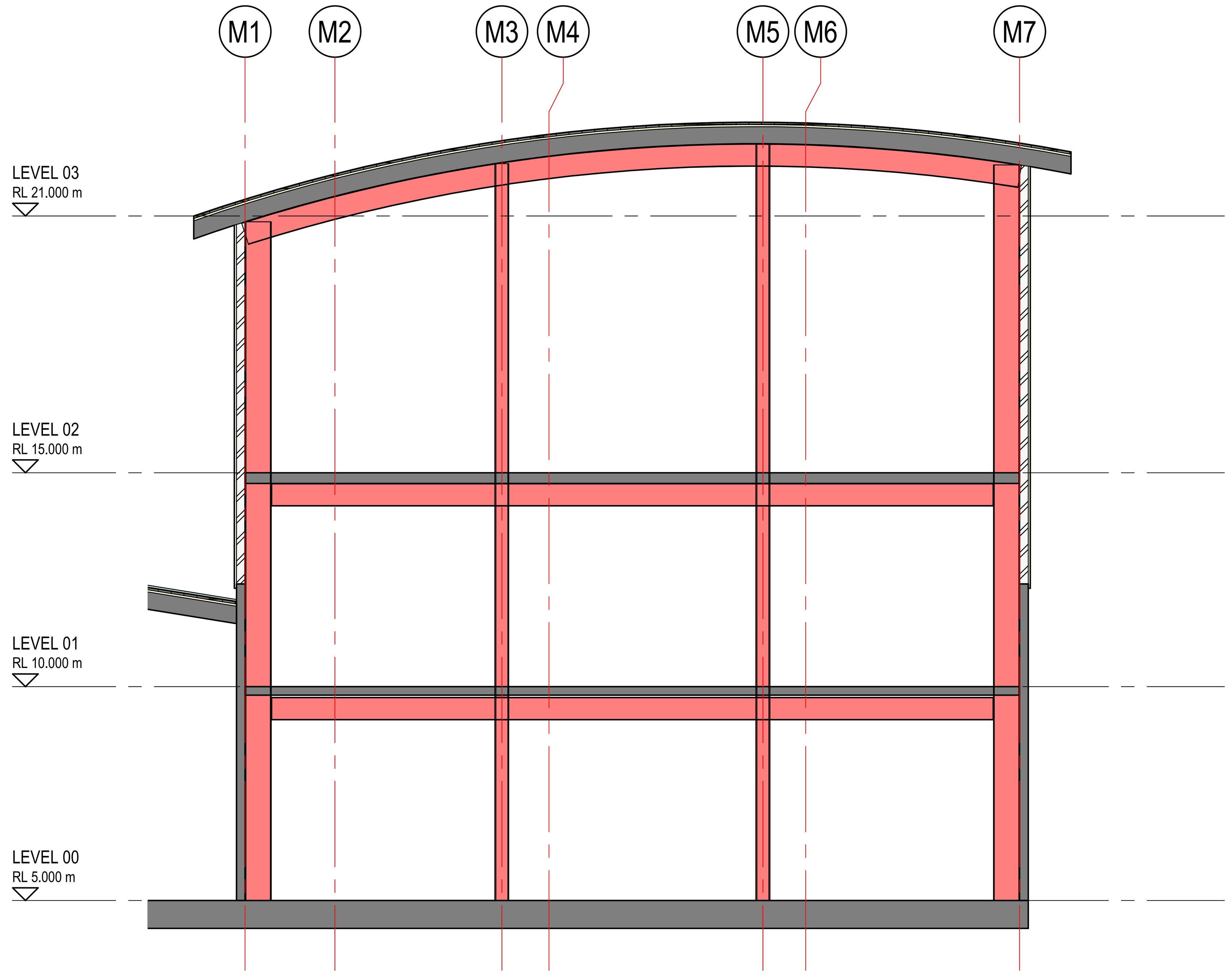
Document No. BIM 360://6511521-1916 SMUR/6511521-1916-SE-2020.rvt



1 SECTION - GRID M5/M6
SE-K2301 1 : 100



2 SECTION - GRID MB
SE-K2301 1 : 100



3 SECTION - GRID ME
SE-K2301 1 : 100

A1 REPRODUCTION SCALE 100 80 60 40 20 0mm

A3 REPRODUCTION SCALE 50 40 30 20 10 0mm

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator
Connect Water
c/- Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000
CONNECT WATER

Original Scale (A1) 1 : 100 Reduced Scale (A3)			
Design			
Drawn	CSF	22.09.20	
Dsg Verifier			
Dwg Check			

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: MAIN PROCESS BUILDING - GA SECTIONS - SHEET 1

Discipline: STRUCTURAL

Drawing No.: 6511521-1916-SE-K2351

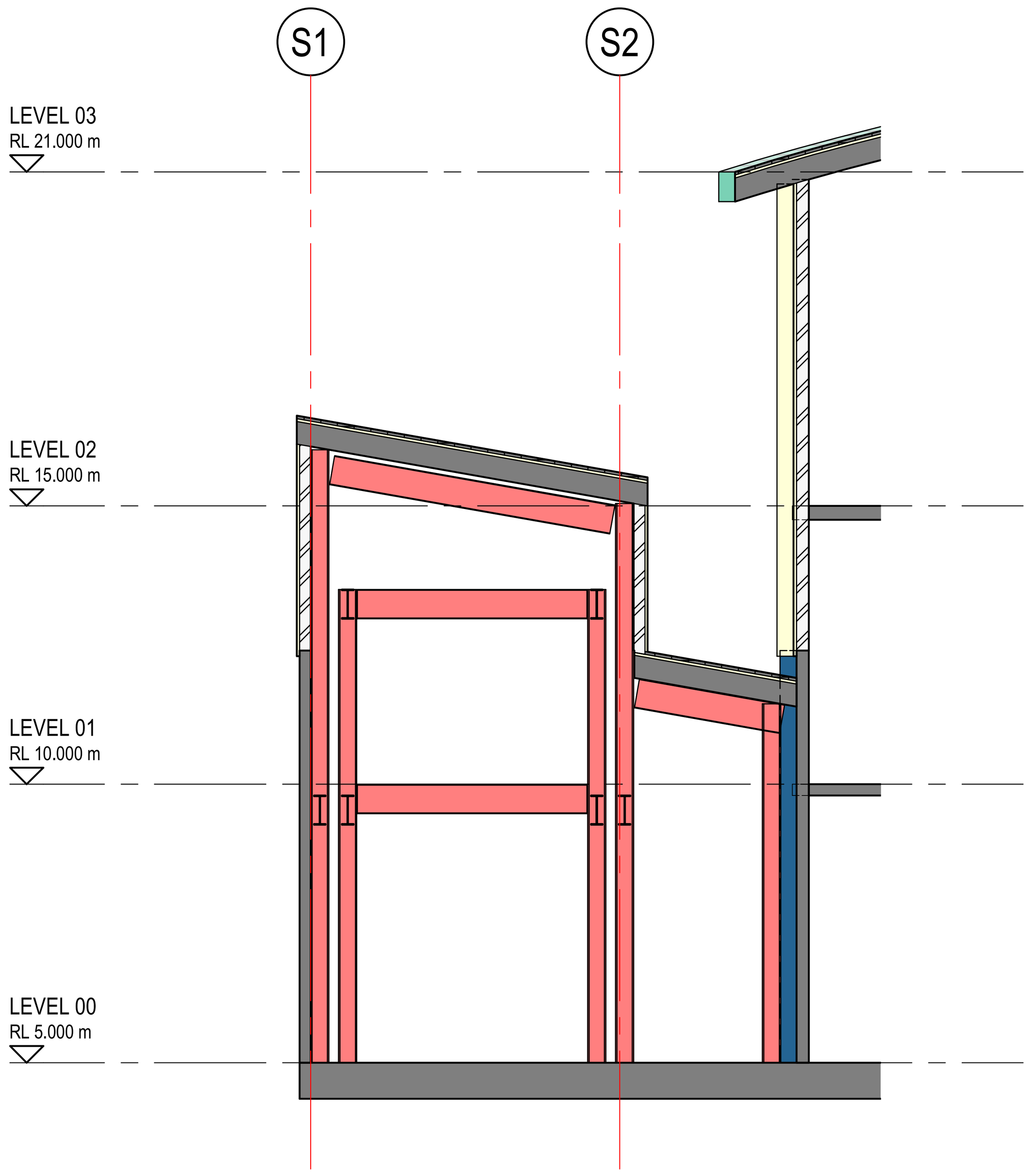
Rev.: A

DO NOT SCALE

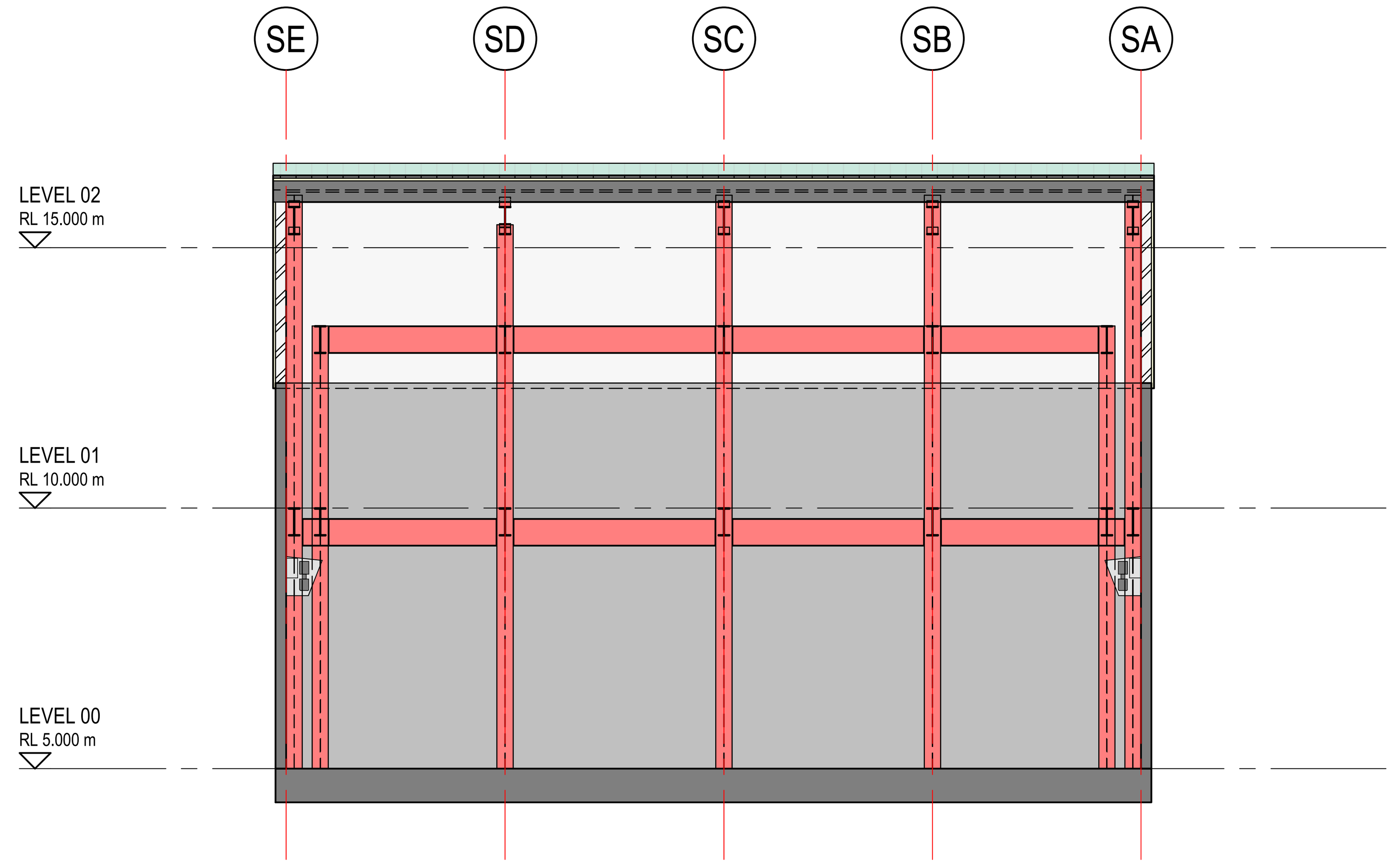
IF IN DOUBT ASK.

Document No. BIM 360://6511521-1916 SMURF/6511521-1916-SE-2020.rvt

Drawing Plotted: 22/09/2020 12:45:23 PM



1 SECTION - GRID SB
SE-K2301 1 : 100



2 SECTION - GRID S1
SE-K2301 1 : 100

A1 REPRODUCTION SCALE 0mm 20 40 60 80 100

A3 REPRODUCTION SCALE 0mm 10 20 30 40 50

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator
Connect Water
c/- Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000
CONNECT WATER

Original Scale (A1) 1 : 100
Reduced Scale (A3)

Design		
Drawn	CSF	22.09.20
Dsg Verifier		
Dwg Check		

Client: Wellington Water

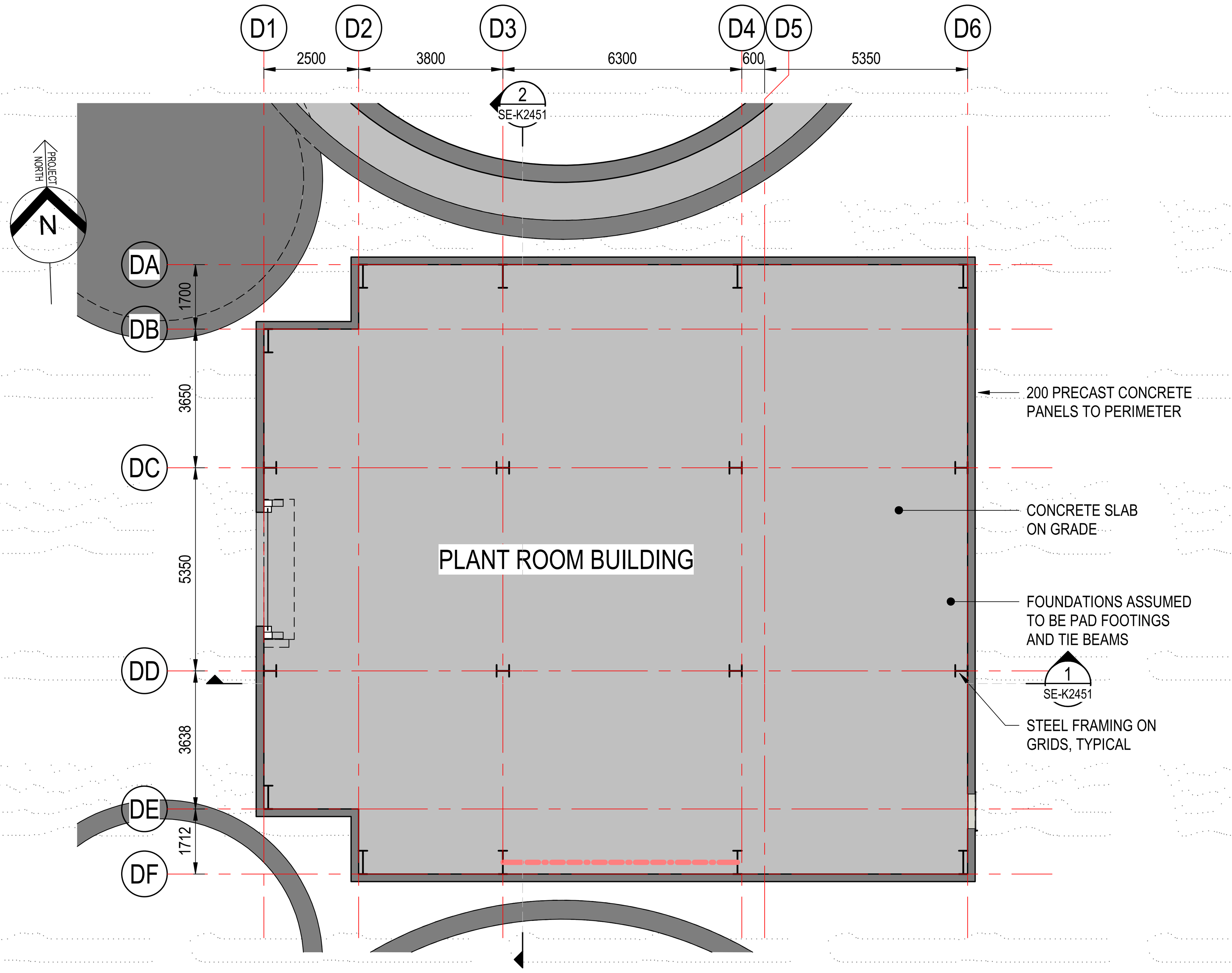
Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: MAIN PROCESS BUILDING - GA SECTIONS - SHEET 2

Discipline: STRUCTURAL

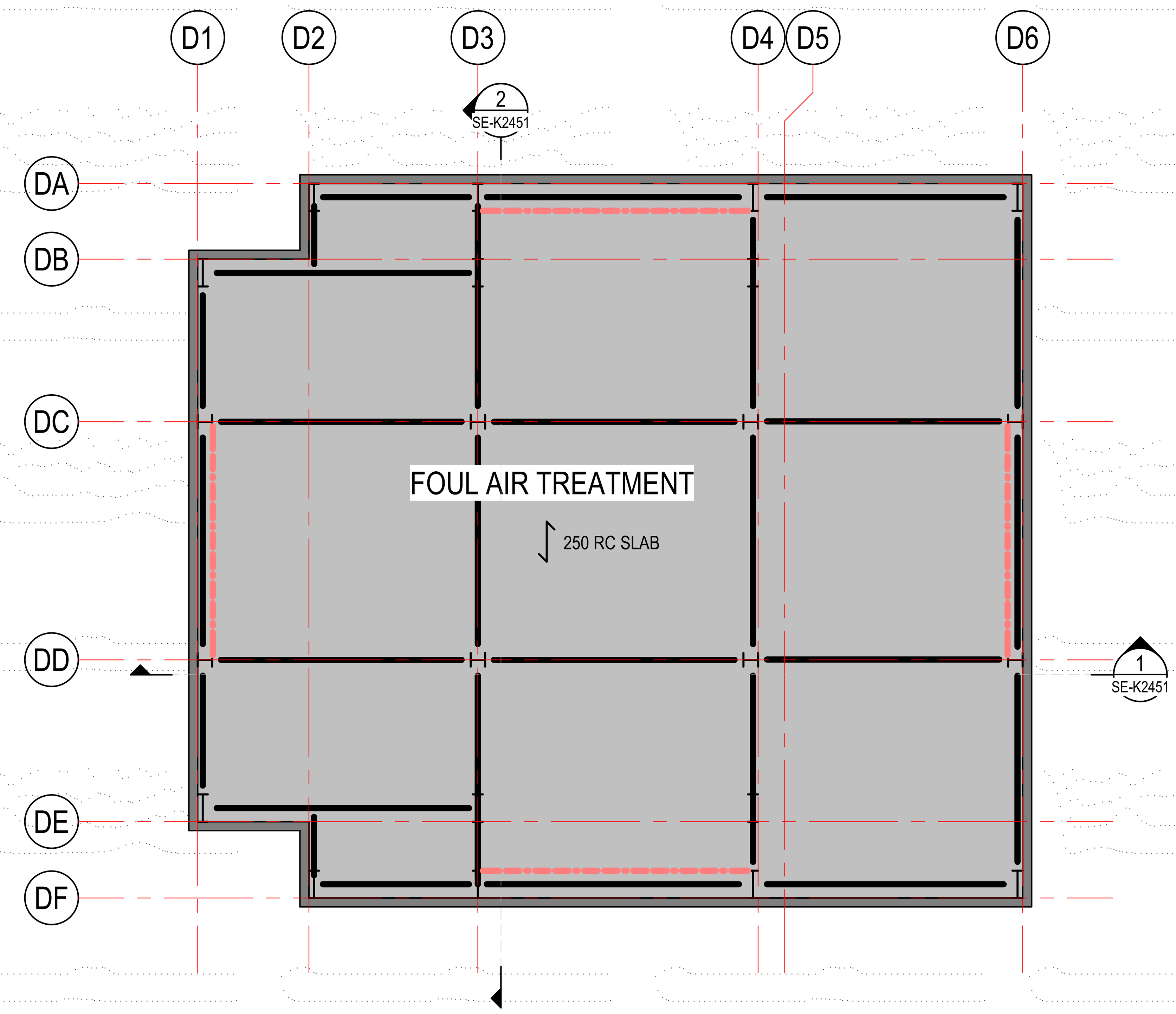
Drawing No.: 6511521-1916-SE-K2352 Rev.: A

Document No. BIM 360://6511521-1916 SMURF/6511521-1916-SE-2020.rvt



PLAN - DIGESTER PLANT ROOM BUILDING LEVEL 00

1 : 100



PLAN - DIGESTER PLANT ROOM BUILDING LEVEL 01

1 : 100

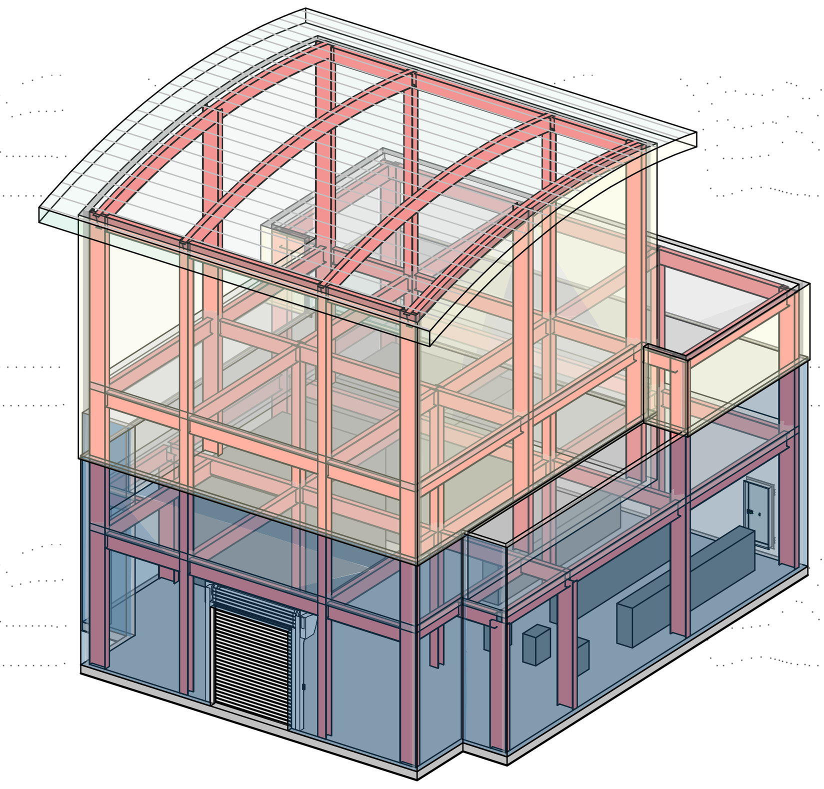
LEGEND

- STEEL COLUMN
- STEEL FRAMING
- PC PANEL WALLS
- SEISMIC GAP
- STEEL CROSS BRACE BAY

NOTES:

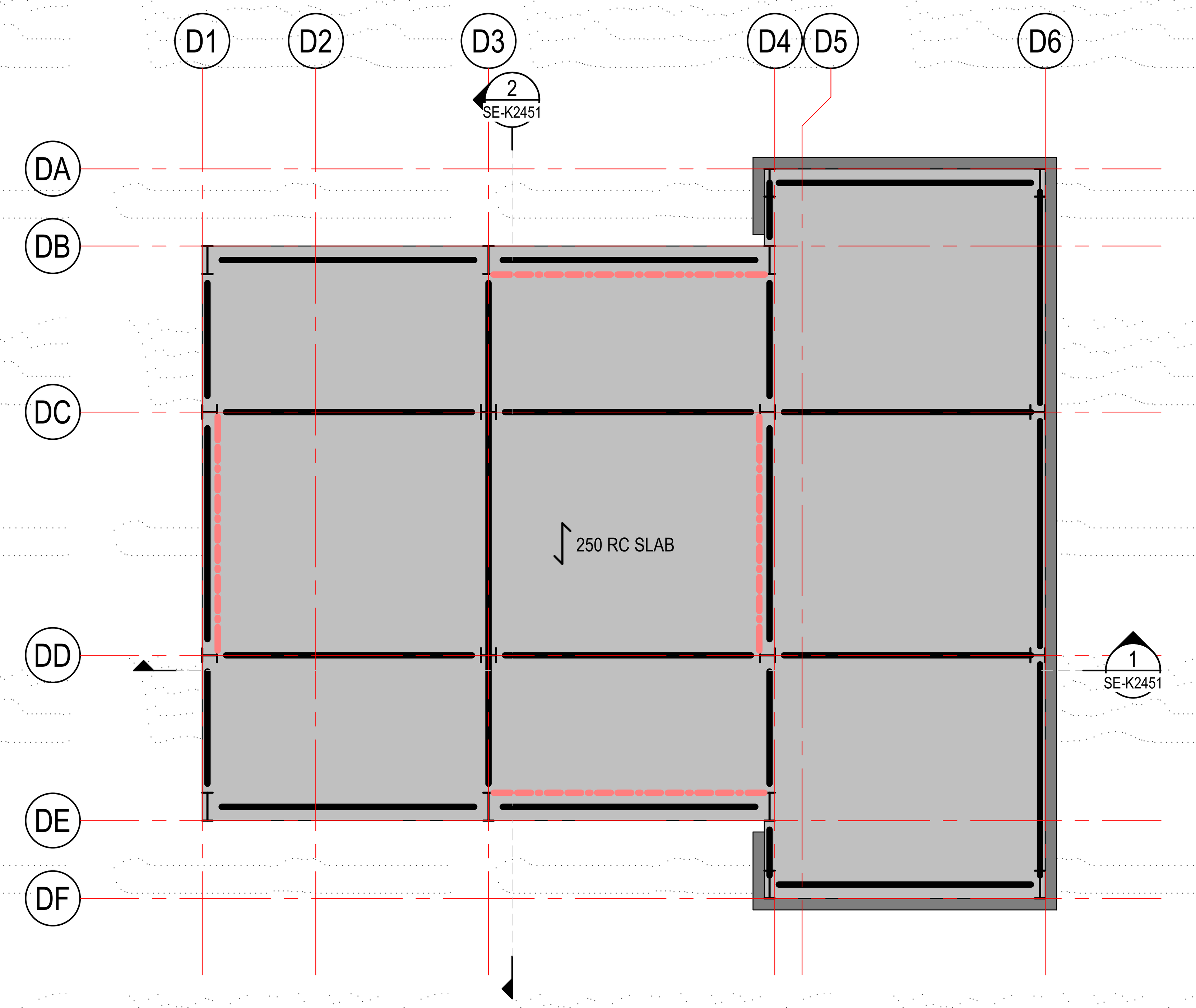
1.0 GENERAL

1.1 FOR PROJECT AND GENERAL NOTES REFER TO SE-0XXX SERIES OF DRAWINGS



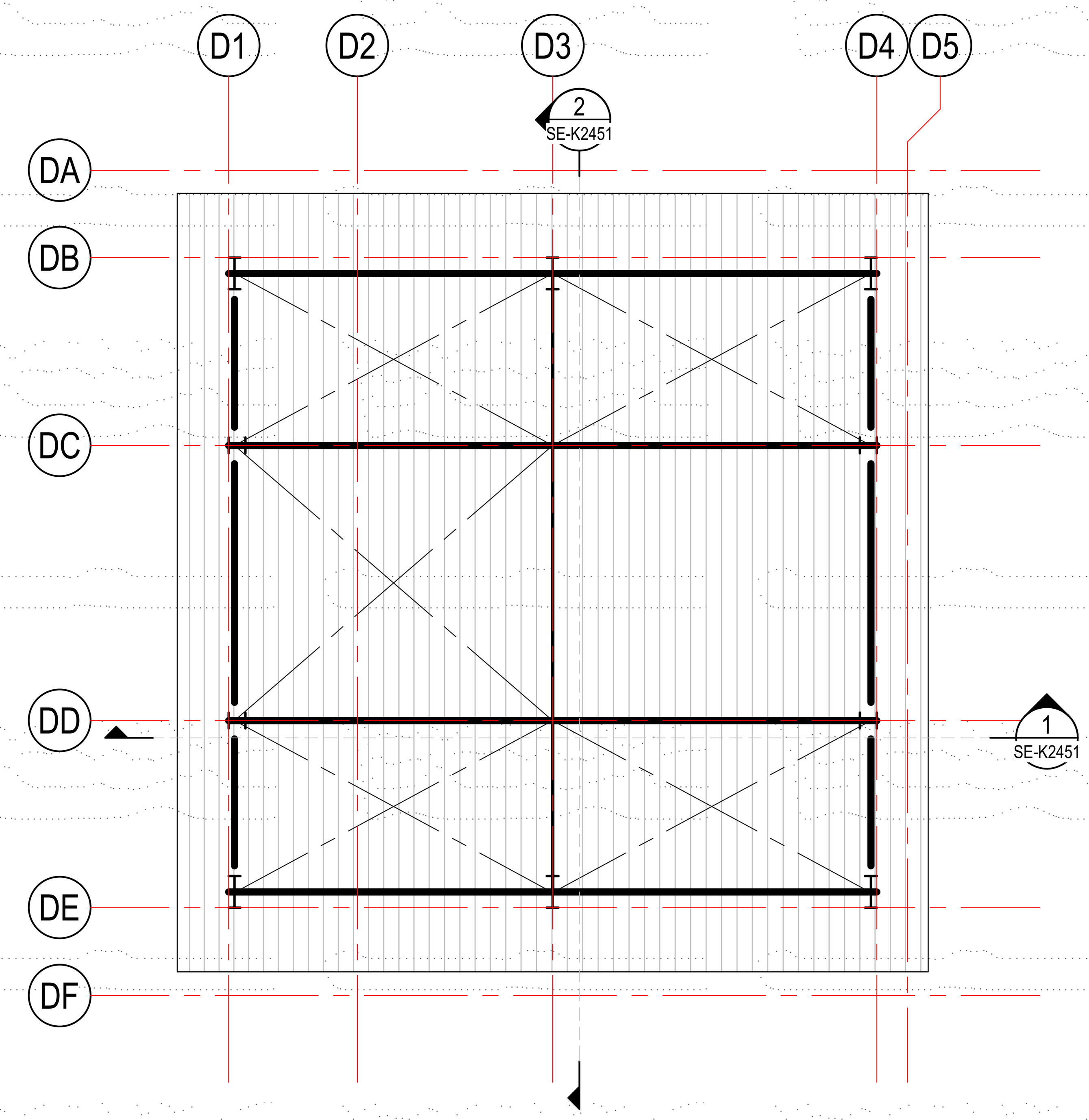
NOTE: BRACING NOT YET MODELLED

PLANT ROOM BUILDING



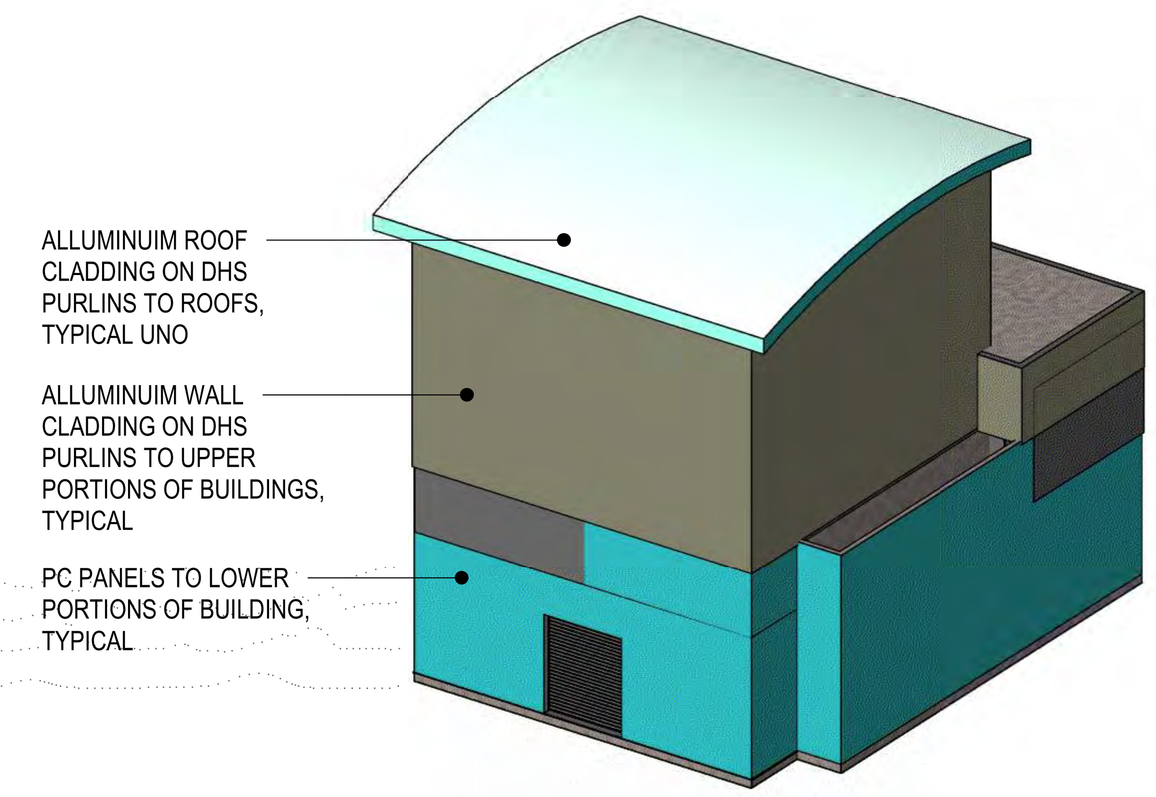
PLAN - DIGESTER PLANT ROOM BUILDING LEVEL 02

1 : 100



PLAN - DIGESTER PLANT ROOM BUILDING ROOF

1 : 100



PLANT ROOM BUILDING CLADDING

A1 REPRODUCTION SCALE

A3 REPRODUCTION SCALE

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator
Connect Water
c/- Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000

Original Scale (A1) As indicated Reduced Scale (A3)	Design		
	Drawn	CSF	22.09.20
	Dsg Verifier		
	Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DIGESTER PLANT ROOM BUILDING - GA PLANS

Discipline: STRUCTURAL

Drawing No. 6511521-1916-SE-K2401

Rev. A

DO NOT SCALE

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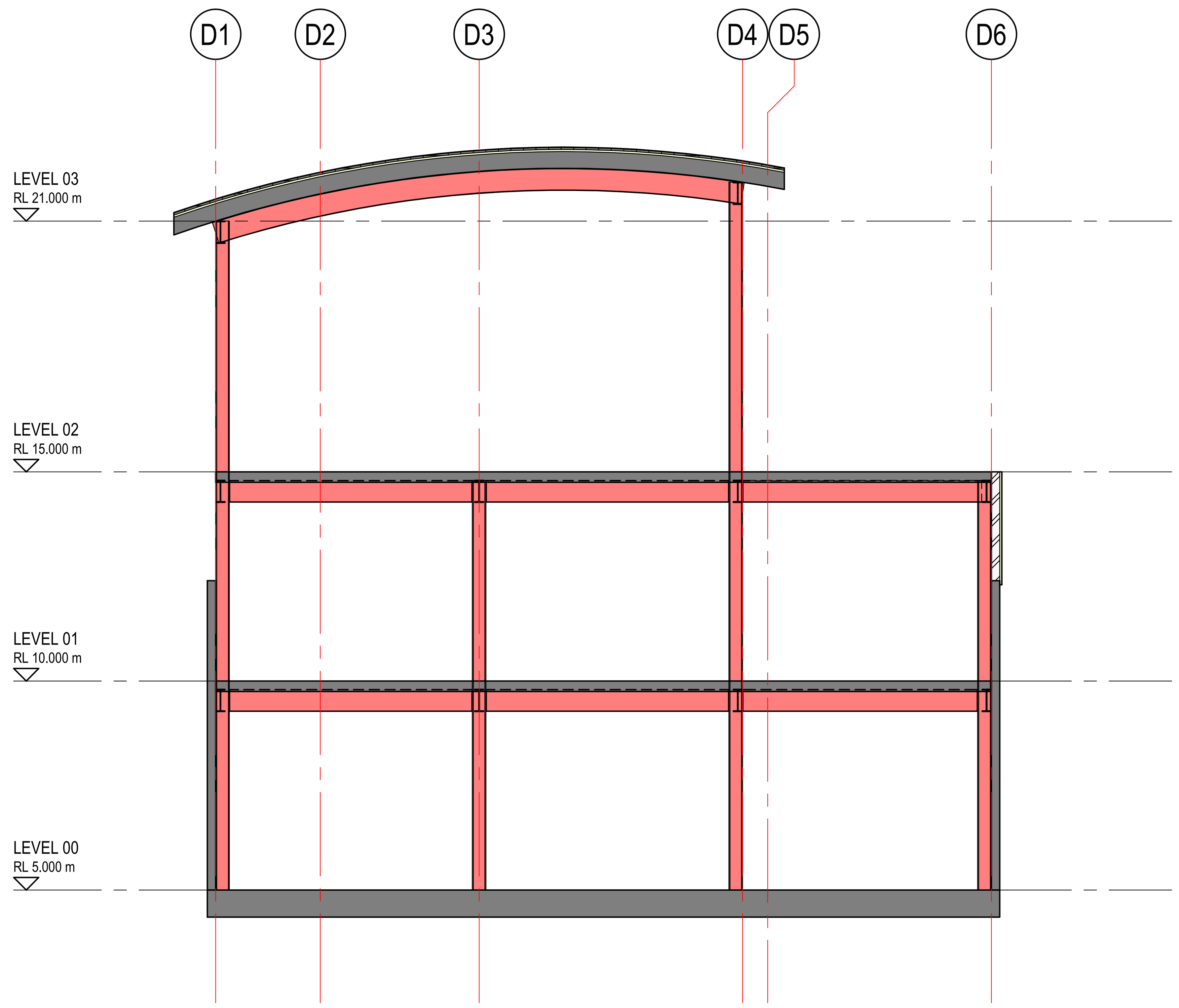
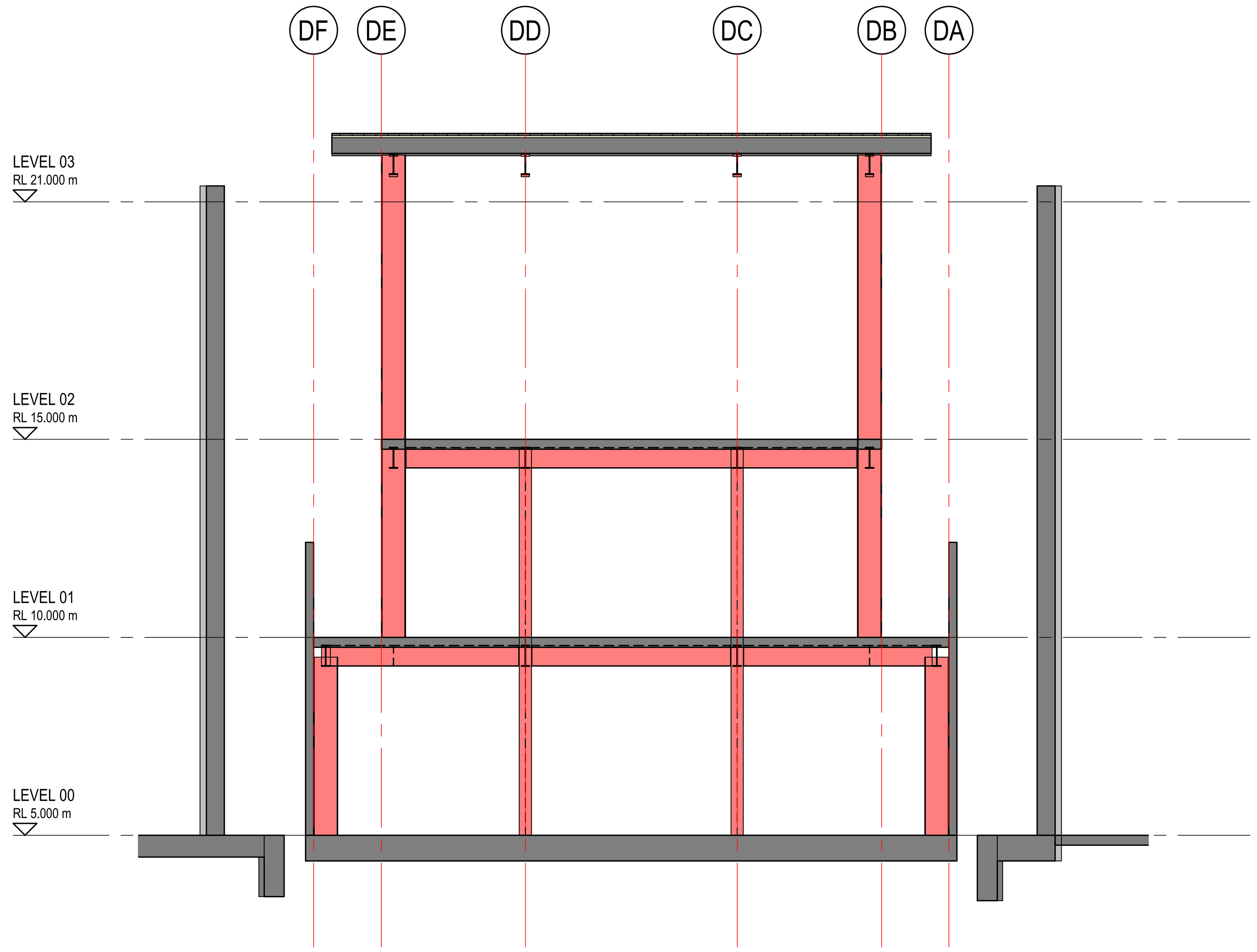
Drawing Plotted: 22/09/2020 12:45:35 PM



1 SECTION - GRID DD
SE-K2401 1 : 100



2 SECTION - GRID D3
SE-K2401 1 : 100

A1 REPRODUCTION SCALE: 0mm, 20, 40, 60, 80, 100

A3 REPRODUCTION SCALE: 0mm, 10, 20, 30, 40, 50

FOR INFORMATION
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR CONCEPT REPORT	AW	CSF	CAFF	22.09.20

Drawing Originator: Connect Water, c/- Opus International Consultants Ltd, PO box 12 003 Thorndon, Wellington 6144, T 64 4 471 7000

Original Scale (A1): 1 : 100
Reduced Scale (A3):

Design		
Drawn	CSF	22.09.20
Dsg Verifier		
Dwg Check		

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DIGESTER PLANT ROOM BUILDING - GA SECTIONS

Discipline: STRUCTURAL

Drawing No. 6511521-1916-SE-K2451

Rev. A

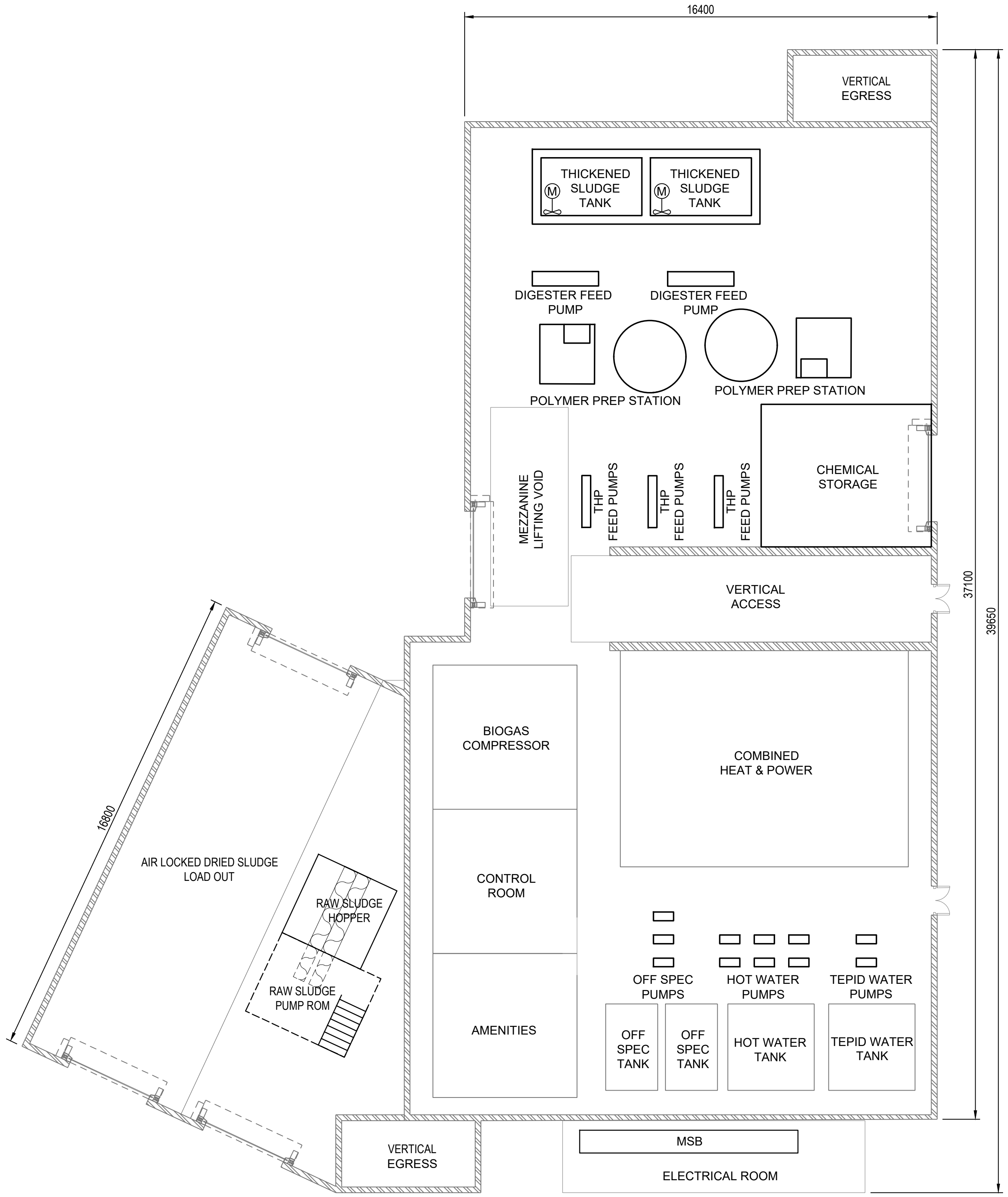
DO NOT SCALE

IF IN DOUBT ASK.

Document No. BIM 360://6511521-1916 SMURF/6511521-1916-SE-2020.rvt

A1 REPRODUCTION SCALE

A3 REPRODUCTION SCALE



SITE LAYOUT - LEVEL 0

1:100

ORIGINAL DRAWING IN COLOUR

CONCEPT DESIGN
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
+	FOR INFORMATION	RBP	RPH		15.09.20

Drawing Originator
Connect Water
c/- WSP Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000

CONNECT WATER

Original Scale (A1) 1:100	Design	R.HAVERLAND	15.09.20
	Drawn	R. PRAJAPATI	15.09.20
Reduced Scale (A3) 1/2 SHOWN	Dsg Verifier		
	Dwg Check		

Approved For Construction*

Date

* Refer to Revision 1 for Original Signature

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DLD + TD MAIN PROCESS BUILDING GENERAL ARRANGEMENT SHEET 1

Discipline: MECHANICAL

Drawing No.: 6511521-1916-MA-K1001

Rev.: A

Plotted By: Rahul Prajapati

DO NOT SCALE - IF IN DOUBT ASK

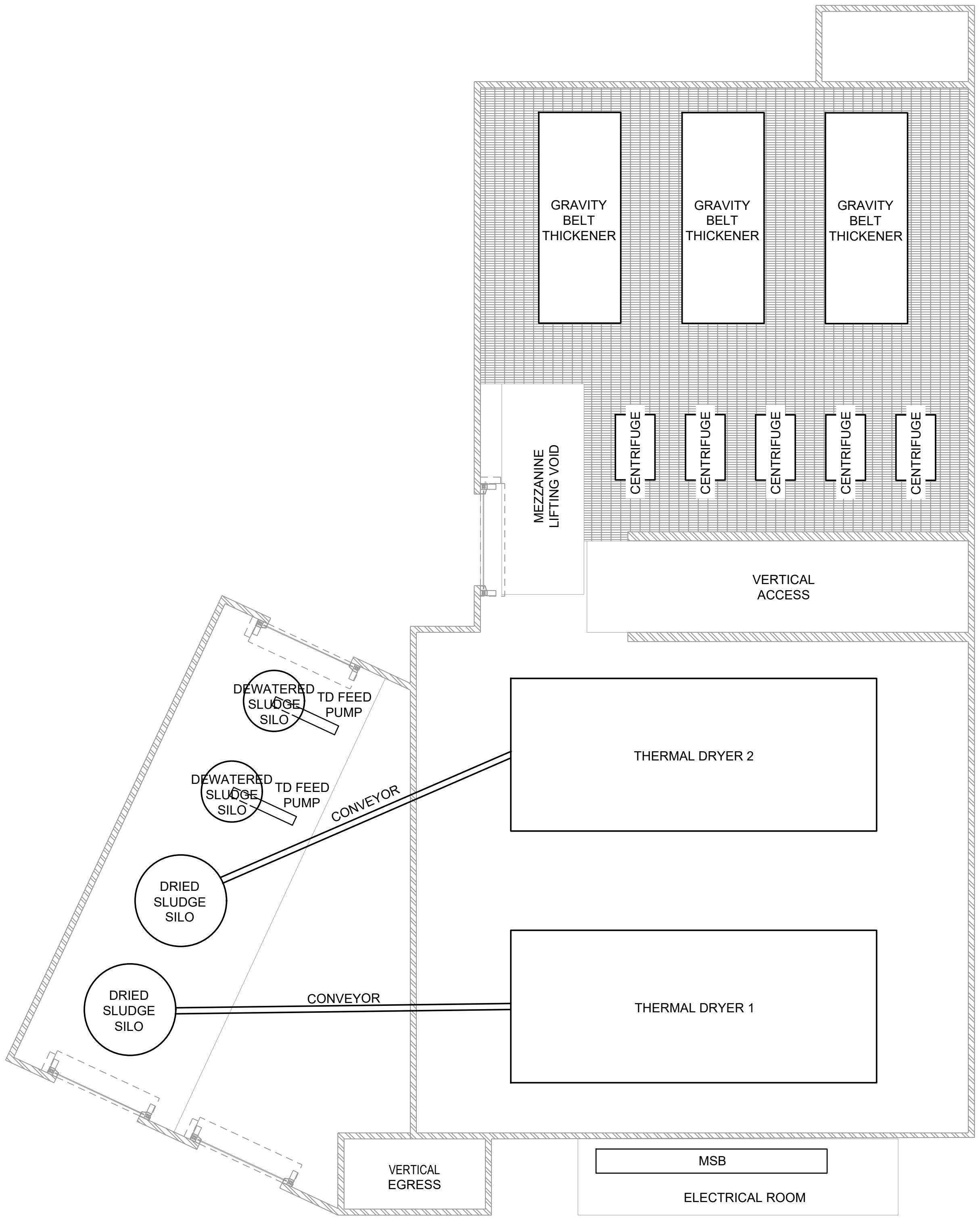
Drawing Plotted: 22 Sep 2020 8:56 am

Document Path: P:\6511\6511521\CAD_1916 - SMURF

Document No. 6511521-1916-MA-K1001.DWG

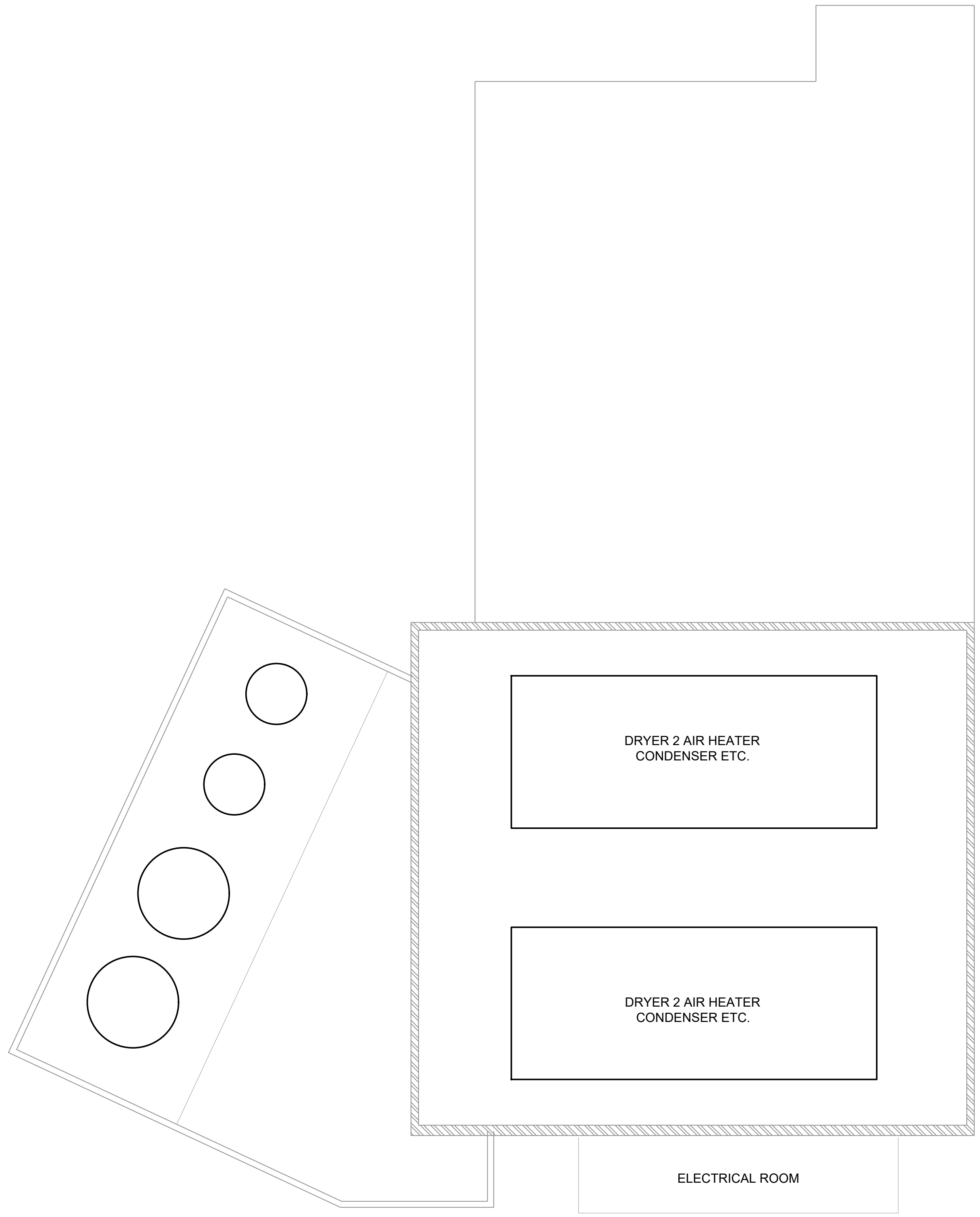
A1 REPRODUCTION SCALE
0mm 20 40 60 80 100

A3 REPRODUCTION SCALE
0mm 10 20 30 40 50



SITE LAYOUT - LEVEL 1

1:100



SITE LAYOUT - LEVEL 2

1:100

ORIGINAL DRAWING IN COLOUR

CONCEPT DESIGN
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
+	FOR INFORMATION	RBP	RPH		15.09.20

Drawing Originator
Connect Water
c/- WSP Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000

CONNECT WATER

Original Scale (A1) 1:100
Reduced Scale (A3) 1/2 SHOWN

Design	R.HAVERLAND	15.09.20	Approved For Construction*
Drawn	R. PRAJAPATI	15.09.20	
Dsg Verifier			
Dwg Check			Date

* Refer to Revision 1 for Original Signature

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DLD + TD MAIN PROCESS GENERAL ARRANGEMENT SHEET 2

Discipline: MECHANICAL

Drawing No. 6511521-1916-MA-K1002

Rev. A

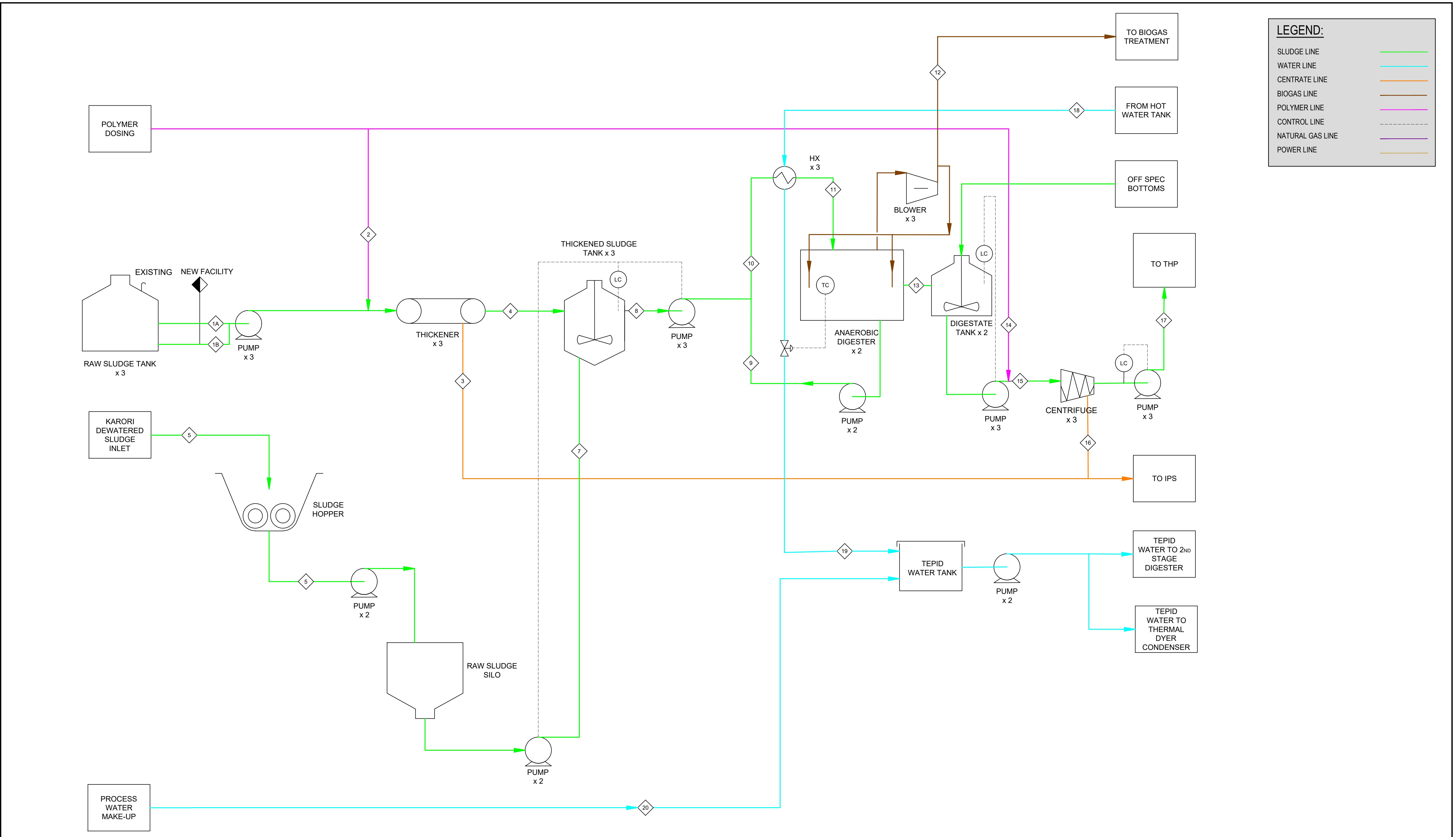
Plotted By: Rahul Prajapati

DO NOT SCALE - IF IN DOUBT ASK

Drawing Plotted: 22 Sep 2020 8:56 am

Document Path: P:\651\6511521\CAD_1916 - SMURF

Document No. 6511521-1916-MA-K1002.DWG



		Stream description	Sludge tank outlet (PS)	Sludge tank outlet (WAS)	Pre-thickener dosing	Thickener centrate	Thickened sludge tank Moa inlet	Karori dewatered Sludge inlet	Karori sludge to silo	Karori slugde to blending with Moa	Thickened Sludge Tank outlet	Digester 1 recycle	Digester 1 Heater inlet	Digester 1 Inlet	Digester Biogas	Digester 1 Digestate	Dewatering Poly dosing	Into 1st stage Dewatering	Dewatering Centrate	Dewatering Outlet to THP	Hot water to digester 1 HX	Tepid Water Tank Inlet	Tepid water tank make-up
Parameter	**Unit**	**Stream Number**	1A	1B	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Flow	t/h		20.1	86.5	0.9	91.9	15.5	0.2	0.2	0.2	15.7	15.7	31.4	31.4	0.4	15.2	1.6	17.0	15.5	1.5	13.1	13.1	2.8
Flow	m3/h		20.1	86.5	0.9	91.9	15.5	0.2	0.2	0.2	15.7	15.7	31.4	31.4	432.6	15.2	0.0	1.6	17.0	15.5	1.5	13.1	13.1
DS	%		1.3%	0.7%	0.2%	-	5.5%	22.0%	22.0%	22.0%	5.7%	2.6%	4.2%	4.2%	0.0%	2.6%	0.2%	2.4%	0.1%	25.0%	-	-	-
Temperature	deg C		15	15	15	15	15	15	15	15	15	38	27	38	38	38	15	36	36	36	74	37	15
VSS	g/kg		11	6	-	-	47	187	187	187	48	17	33	33	-	17	-	16	-	165	-	-	-

ORIGINAL DRAWING IN COLOUR

CONCEPT DESIGN
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
B	FOR INFORMATION - SCHEDULE UPDATED	RBP	LBA	CAFF	29.04.21
A	FOR INFORMATION	RBP	RPH	CAFF	15.09.20

Drawing Originator
Connect Water
c/- WSP Opus International Consultants Ltd
PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000

Original Scale (A1) AS SHOWN
Reduced Scale (A3) 1/2 SHOWN

Design	S.BURGESS	15.09.20
Drawn	R. PRAJAPATI	15.09.20
Dsg Verifier		
Dwg Check		

Approved For Construction*
Date
* Refer to Revision 1 for Original Signature

Client: Wellington Water

Project: WELLINGTON
SLUDGE MINIMISATION FACILITY

Title: DLD + TD
PROCESS FLOW DIAGRAM
SHEET 1

Discipline: PROCESS

Drawing No. 6511521-1916-PA-K1001
Rev. B

Document Path: P:\6511521\CAD_1916 - SMURF
Document No. 6511521-1916-PA-K1001.DWG

Plotted By: Rahul Prajapati
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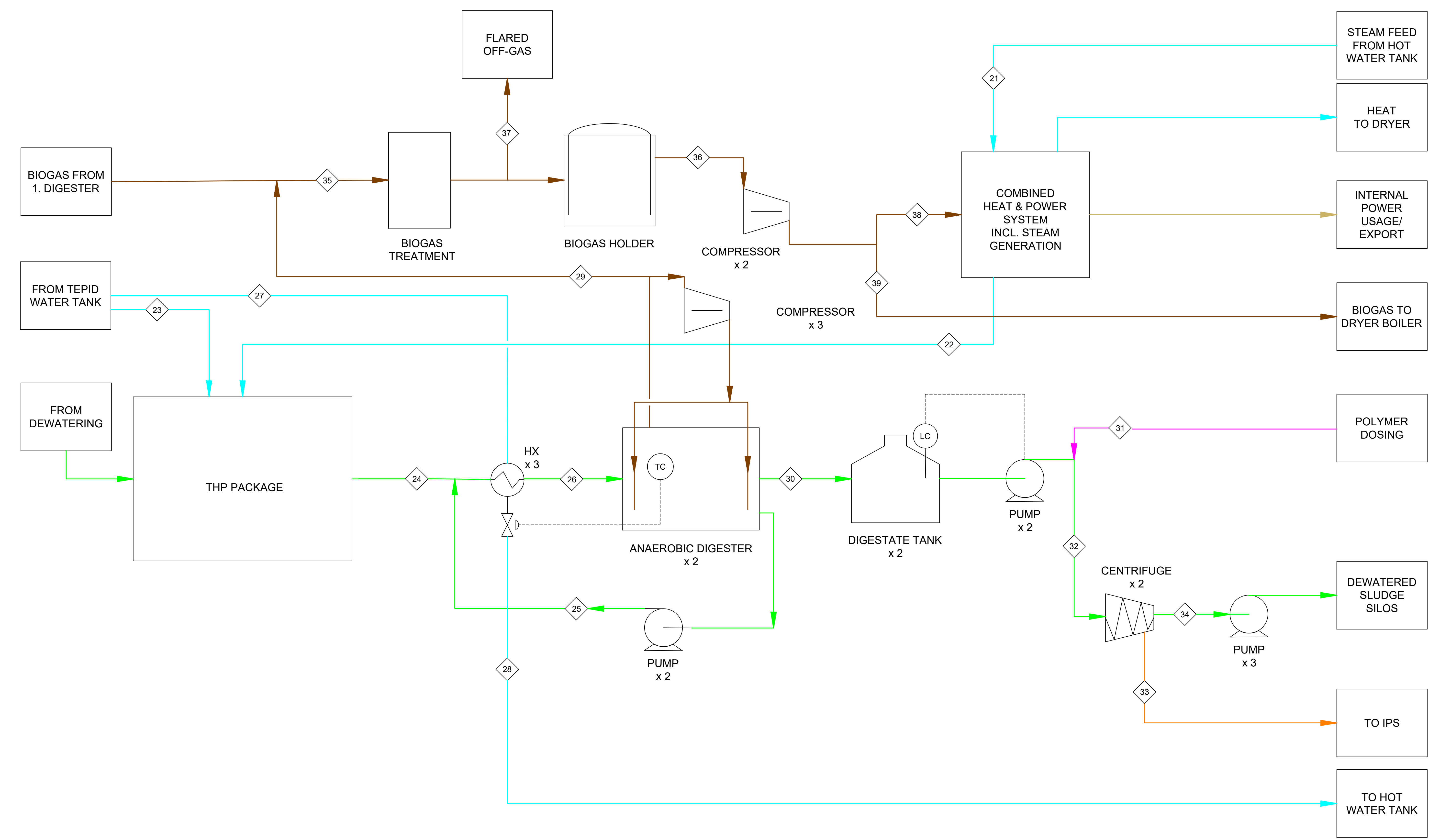
Drawing Plotted: 03 May 2021 2:40 pm



		Stream description	Hot water to steam module	Steam CHP to THP	Tepid Water for dilution	THP Outlet	Digester 2 recycle	Digester 2 inlet	Tepid water to Digester 2HX	Digester 2 HX water outlet	Digester 2 Biogas Outlet	Digester 2 digestate	Final Dewater Poly dose	Final Dewater Inlet	Final Dewater Centrate	Dewatered Sludge to Silo	Biogas to Treatment	Compres sor inlet	Biogas to Flare	Biogas to CHP	Biogas to Boiler
Parameter	**Unit**	**Stream Number**	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Flow	t/h		0.4	0.4	1.9	3.8	0.0	3.8	4.0	4.0	0.1	3.8	1.6	5.3	4.4	0.9	0.5	0.5	0.0	0.5	0.0
Flow	m3/h		0.4	69.8	1.9	3.8	0.0	3.8	4.0	4.0	64.4	3.8	1.6	5.3	4.4	1.2	497	472	24.8	467.0	5.0
DS	%		-	-	-	10.0%	8.3%	10.0%	-	-	-	8.3%	0.2%	5.9%	0.4%	32.0%	-	-	-	-	-
Temperature	deg C		74	184	33	99	40	40	33	89	40	40	15	33	33	33	38	38	38	38	38
VSS	g/kg		-	-	-	66	51	66	-	-	-	51	-	36	0	195	-	-	-	-	-

ORIGINAL DRAWING IN COLOUR

CONCEPT DESIGN
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
B	FOR INFORMATION - SCHEDULE UPDATED	RBP	LBA	CAFF	29.04.21
A	FOR INFORMATION	RBP	LBA	CAFF	15.09.20

Drawing Originator
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Wellington 6144
T 64 4 471 7000

CONNECT WATER

Original Scale (A1) AS SHOWN	Design	S.BURGESS	15.09.20	Approved For Construction*
	Drawn	R. PRAJAPATI	15.09.20	
Reduced Scale (A3) 1/2 SHOWN	Dsg Verifier			
	Dwg Check			Date

* Refer to Revision 1 for Original Signature

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DLD + TD PROCESS FLOW DIAGRAM SHEET 2

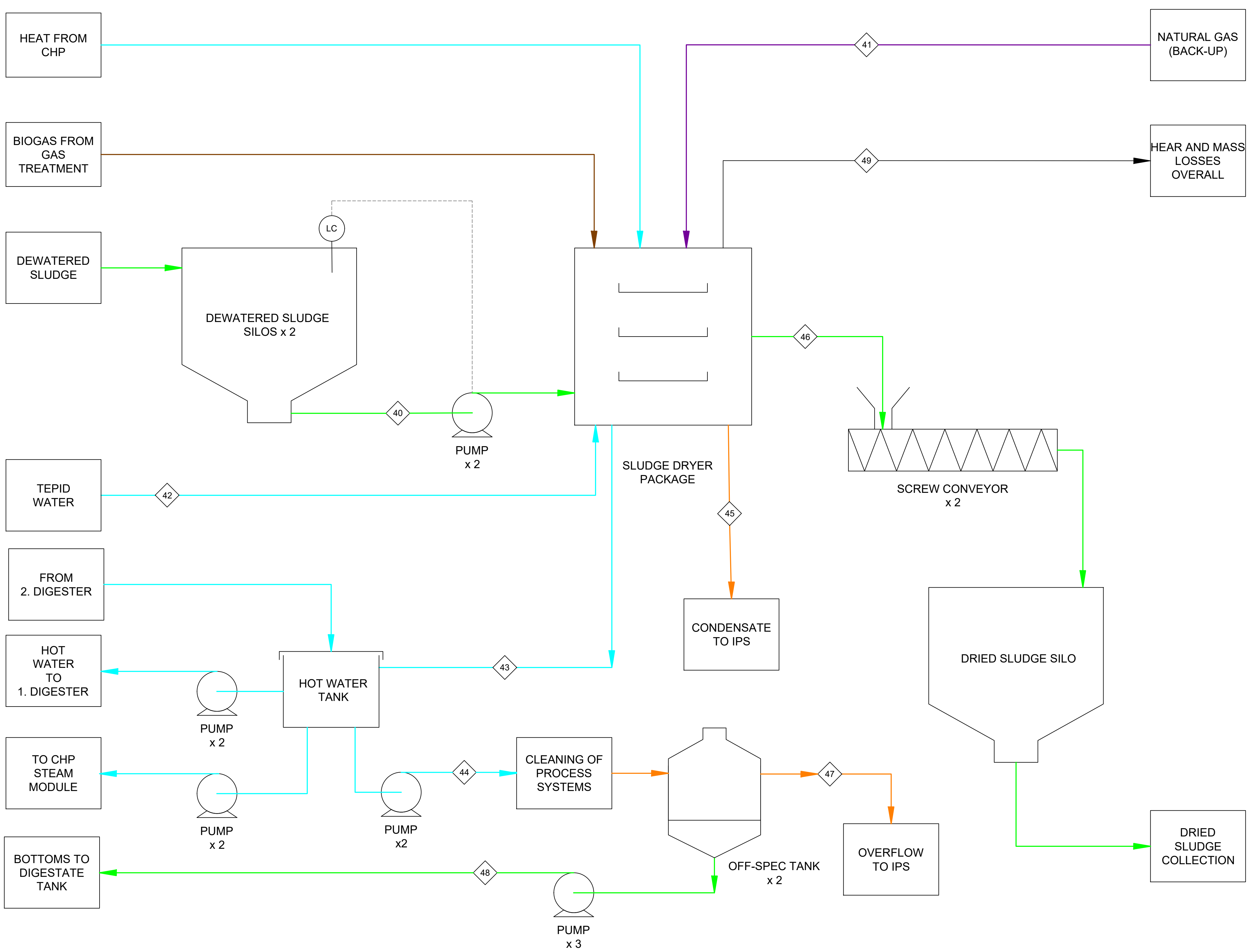
Discipline: PROCESS

Drawing No. 6511521-1916-PA-K1002

Rev. B

A1 REPRODUCTION SCALE 0mm 20 40 60 80 100

A3 REPRODUCTION SCALE 0mm 10 20 30 40 50



		Stream description	Dewatered Sludge to Dryer	Natural Gas	Tepid Water to dryer	Surface Condenser returns	To cleaning of process systems	Condensate	Dried Sludge outlet	Off-spec overflow to IPS	Off-spec bottoms to digestate tank	heat and mass losses
Parameter	**Unit**	**Stream Number**	40	41	42	43	44	45	46	47	48	49
Flow	t/h		0.9	0.0	10.0	10.0	0.5	0.6	0.3	0.3	0.3	0.9
Flow	m3/h		1.2	0.0	10.0	10.0	0.5	0.6	0.7	0.3	0.3	615
DS	%		32.0%	-	-	-	-	1.0%	90.0%	-	-	-
Temperature	deg C		33	-	33	67	74	70	50	74	74	200
VSS	g/kg		195	-	-	-	-		540	-	-	-

HEAT BALANCE (positive figures represent energy uptake, in kW)

Operation	sludge	process water	condensate	energy put in	waste heat	power	energy source
Digester 1 HX	427	-427		0	136		hot water
THP Unit	228			-228			steam
CHP Unit		228		-3060	1669	1163	biogas
Digester 2 HX	-263	263					hot sludge
Thermal Dryer	7	400	26	-33	-400		biogas+ waste heat

ORIGINAL DRAWING IN COLOUR

CONCEPT DESIGN
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
B	FOR INFORMATION - SCHEDULE UPDATED	RBP	LBA	CAFF	29.04.21
A	FOR INFORMATION	RBP	LBA	CAFF	15.09.20

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Connect Water
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PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000
CONNECT WATER

Original Scale (A1) AS SHOWN
Reduced Scale (A3) 1/2 SHOWN

Design	S.BURGESS	15.09.20
Drawn	R. PRAJAPATI	15.09.20
Dsg Verifier		
Dwg Check		

Approved For Construction*
Date
* Refer to Revision 1 for Original Signature

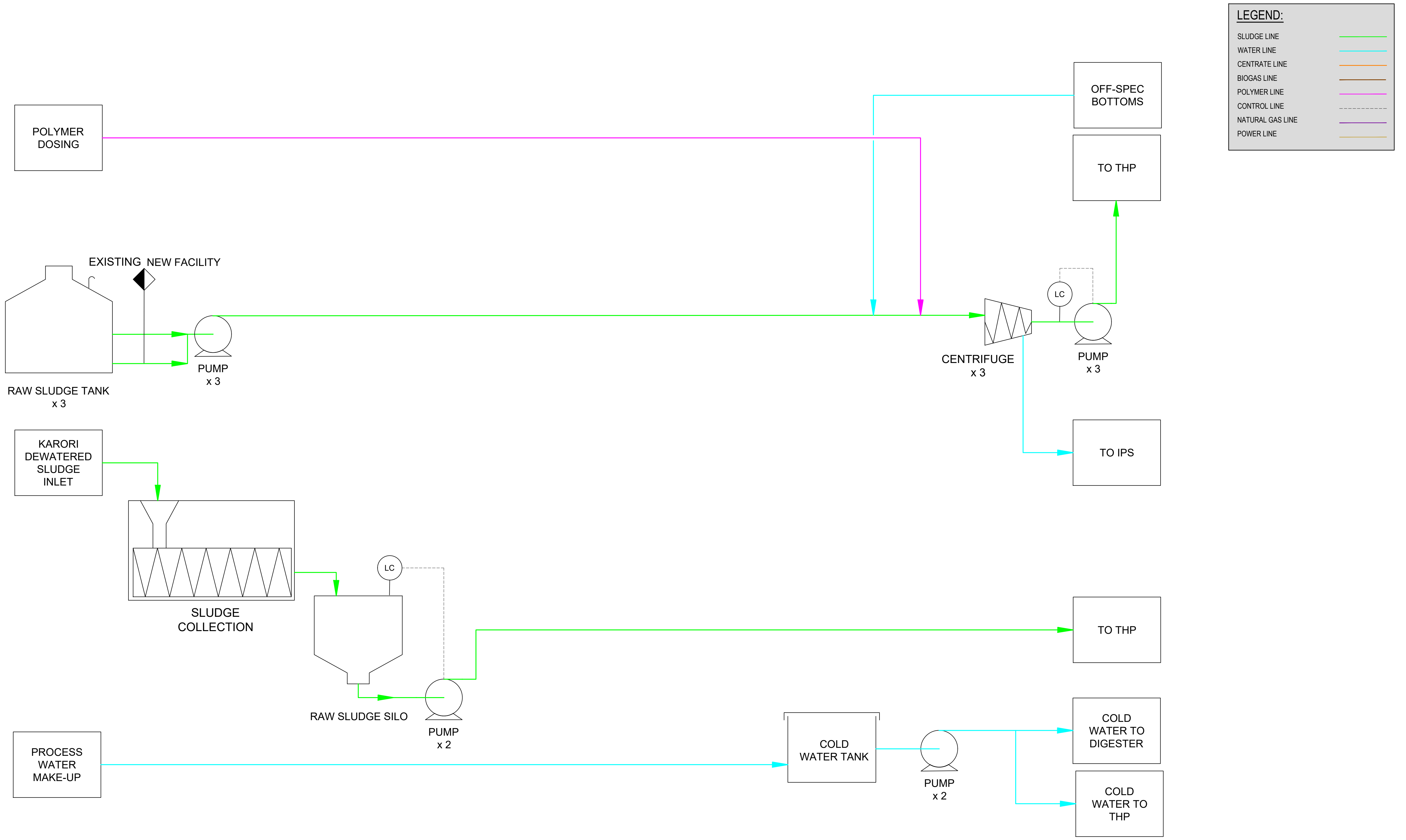
Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DLD + TD PROCESS FLOW DIAGRAM SHEET 3

Discipline: PROCESS

Drawing No. 6511521-1916-PA-K1003 Rev. B



A1 REPRODUCTION SCALE: 100, 80, 60, 40, 20, 0mm

A3 REPRODUCTION SCALE: 50, 40, 30, 20, 10, 0mm

ORIGINAL DRAWING IN COLOUR

CONCEPT DESIGN
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No.	Revision	By	Chk	Appd	Date
A	FOR INFORMATION	RBP	LA	SCB	06.11.20

Drawing Originator: Connect Water c/- WSP Opus International Consultants Ltd PO box 12 003 Thorndon Wellington 6144 T 64 4 471 7000

Original Scale (A1): AS SHOWN
Reduced Scale (A3): 1/2 SHOWN

Design	S.BURGESS	04.11.20
Drawn	R. PRAJAPATI	04.11.20
Dsg Verifier		
Dwg Check		

Approved For Construction*
Date
* Refer to Revision 1 for Original Signature

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: LD + TD PROCESS FLOW DIAGRAM SHEET 1

Discipline: PROCESS

Drawing No.: 6511521-1916-PA-K2001

Rev.: A

Document Path: P:\6511521\CAD_1916 - SMURF

Document No. 6511521-1916-PA-K2001.DWG

Plotted By: Rahul Prajapati

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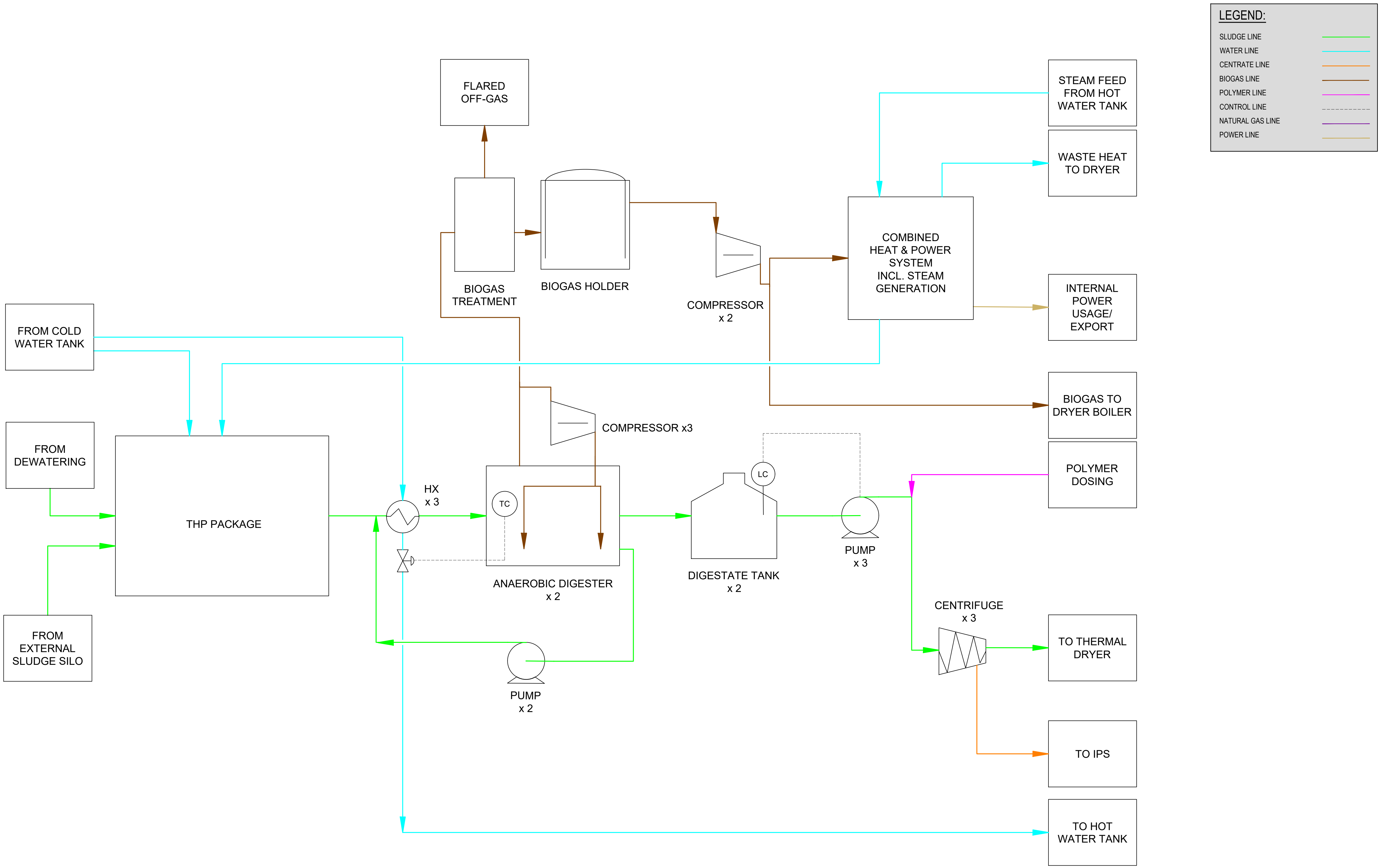
Drawing Plotted: 06 Nov 2020 10:23 am



ORIGINAL DRAWING IN COLOUR

CONCEPT DESIGN
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No.	Revision	By	Chk	Appd	Date
A	FOR INFORMATION	RBP	LA	SCB	06.11.20

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PO box 12 003 Thorndon
Wellington 6144
T 64 4 471 7000

Original Scale (A1): AS SHOWN
Reduced Scale (A3): 1/2 SHOWN

Design	S.BURGESS	04.11.20	Approved For Construction*
Drawn	R.PRAJAPATI	04.11.20	
Dsg Verifier			
Dwg Check			Date

* Refer to Revision 1 for Original Signature

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: LD + TD PROCESS FLOW DIAGRAM SHEET 2

Discipline: PROCESS

Drawing No.: 6511521-1916-PA-K2002 Rev.: A

Plotted By: Rahul Prajapati

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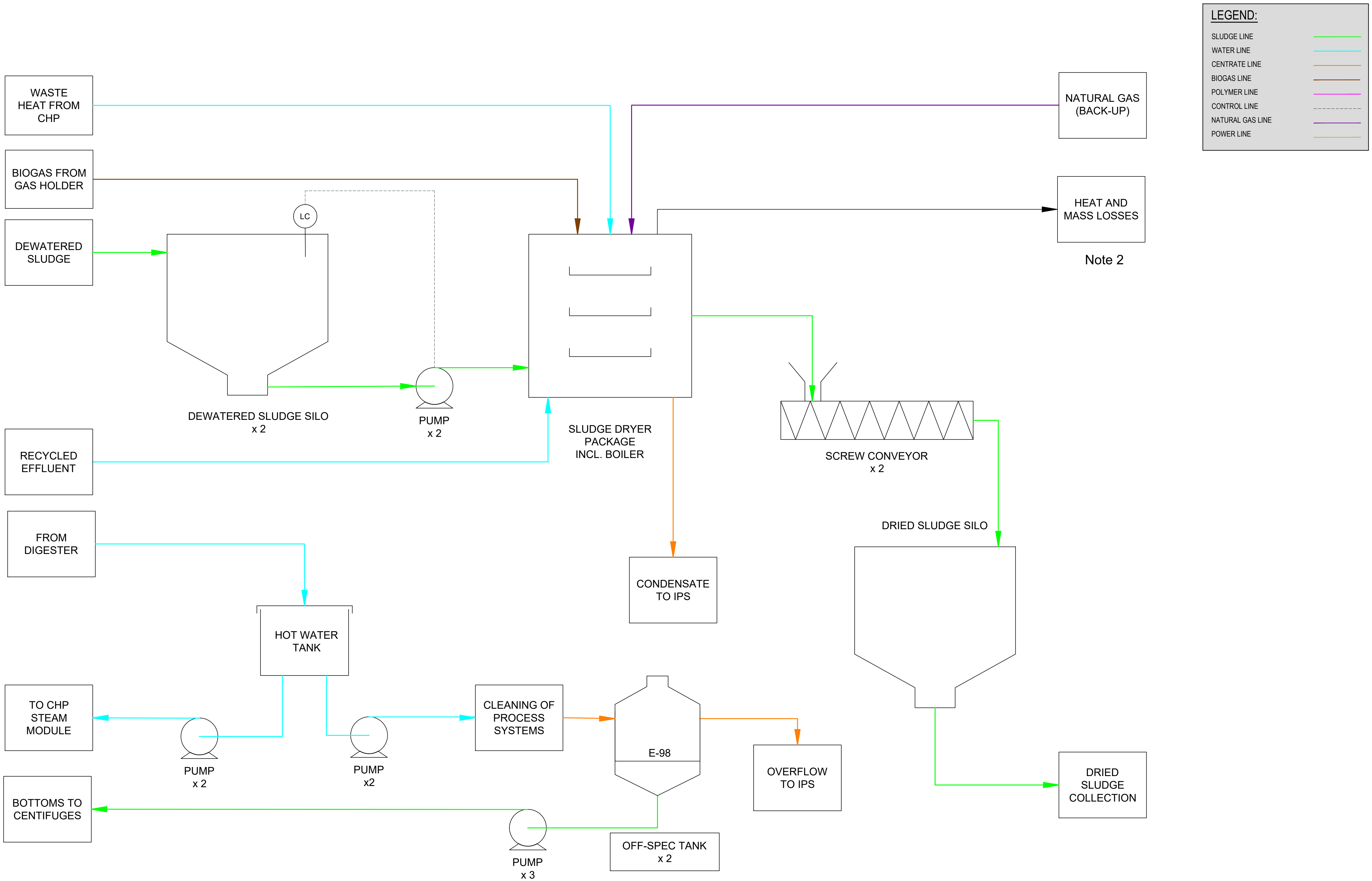
Drawing Plotted: 06 Nov 2020 10:23 am

Document Path: P:\6511521\CAD_1916 - SMUF

Document No. 6511521-1916-PA-K2002.DWG

A1 REPRODUCTION SCALE

A3 REPRODUCTION SCALE



A1 REPRODUCTION SCALE 0mm 20 40 60 80 100

A3 REPRODUCTION SCALE 0mm 10 20 30 40 50

ORIGINAL DRAWING IN COLOUR

CONCEPT DESIGN
NOT FOR CONSTRUCTION

No.	Revision	By	Chk	Appd	Date
A	FOR INFORMATION	RBP	LA	SCB	06.11.20

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PO box 12 003 Thorndon
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CONNECT WATER

Original Scale (A1) AS SHOWN
Reduced Scale (A3) 1/2 SHOWN

Design	S.BURGESS	04.11.20	Approved For Construction*
Drawn	R. PRAJAPATI	04.11.20	
Dsg Verifier			
Dwg Check			Date

* Refer to Revision 1 for Original Signature

Client: Wellington Water

Project: WELLINGTON
SLUDGE MINIMISATION FACILITY

Title: LD + TD
PROCESS FLOW DIAGRAM
SHEET 3

Discipline: PROCESS

Drawing No. 6511521-1916-PA-K2003

Rev. A

Plotted By: Rahul Prajapati

DO NOT SCALE - IF IN DOUBT ASK

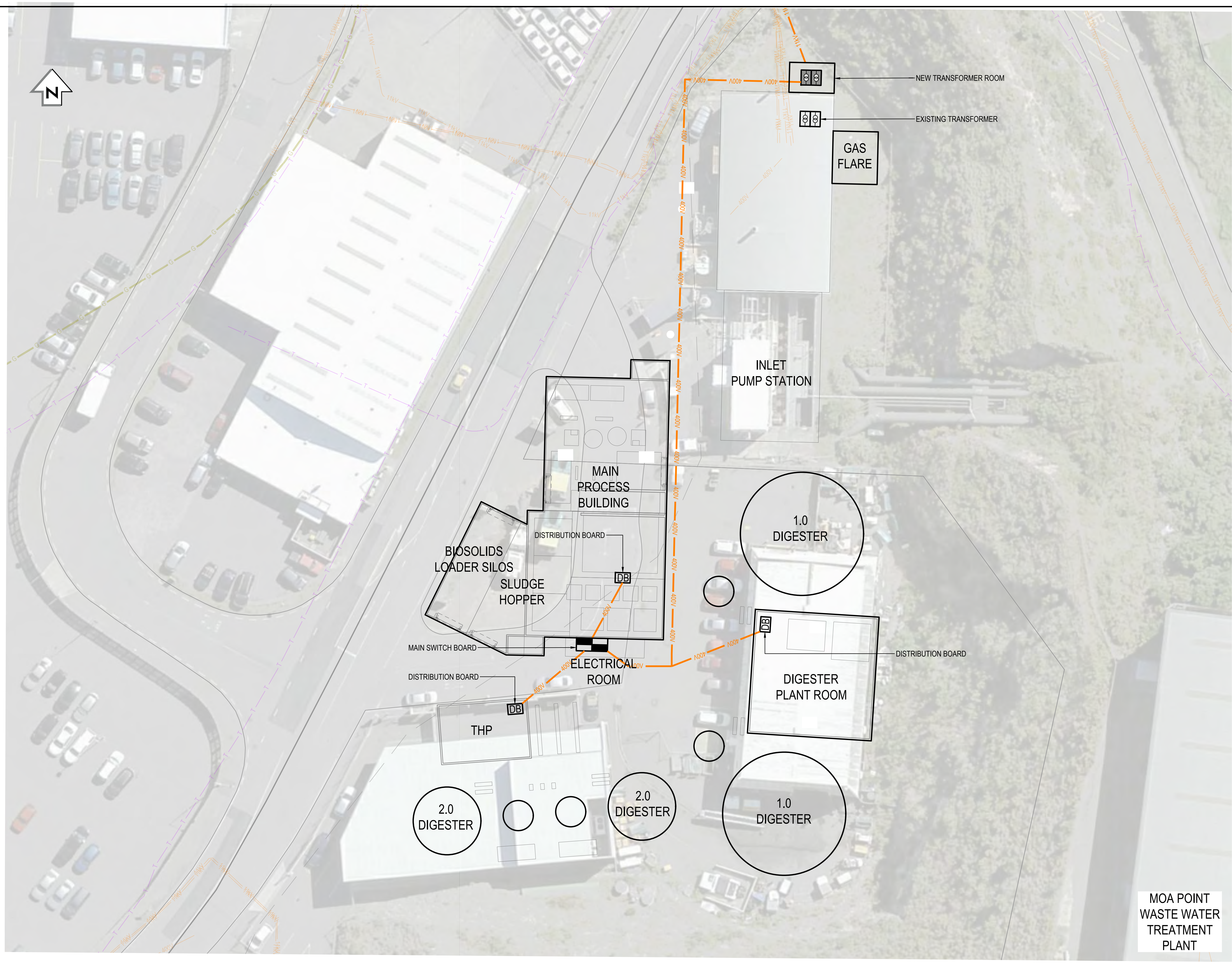
Drawing Plotted: 06 Nov 2020 10:24 am

Document Path: P:\651\6511521\CAD_1916 - SMURF

Document No. 6511521-1916-PA-K2003.DWG

A1 REPRODUCTION SCALE 0mm 20 40 60 80 100

A3 REPRODUCTION SCALE 0mm 10 20 30 40 50



UTILITIES LEGEND

GAS - POWERCO	G
EXISTING 400V U/G POWER	400V
NEW 400V/G POWER	400V
EXISTING 11kV U/G POWER	11kV
NEW 11kV U/G POWER	11kV
33kV U/G POWER	33kV
TELECOMMS / CHORUS	T
NEW TRANSFORMER	
EXISTING TRANSFORMER	
DISTRIBUTION BOARD	DB
MAIN SWITCH BOARD	

ORIGINAL DRAWING IN COLOUR

FOR INFORMATION
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SERVICES LAYOUT
1:250

No.	Revision	By	Chk	Appd	Date
A	FOR INFORMATION	RBP	RPH		15.09.20

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CONNECT WATER

Original Scale (A1) AS SHOWN
Reduced Scale (A3) 1/2 SHOWN

Design	Z.BOKANY	15.09.20	Approved For Construction*
Drawn	R. PRAJAPATI	15.09.20	
Dsg Verifier			
Dwg Check			Date

* Refer to Revision 1 for Original Signature

Client: Wellington Water

Project: WELLINGTON SLUDGE MINIMISATION FACILITY

Title: DLD + TD EXISTING AND NEW SERVICES LAYOUT

Discipline: ELECTRICAL

Drawing No.: 6511521-1916-BE-K1001 Rev. A

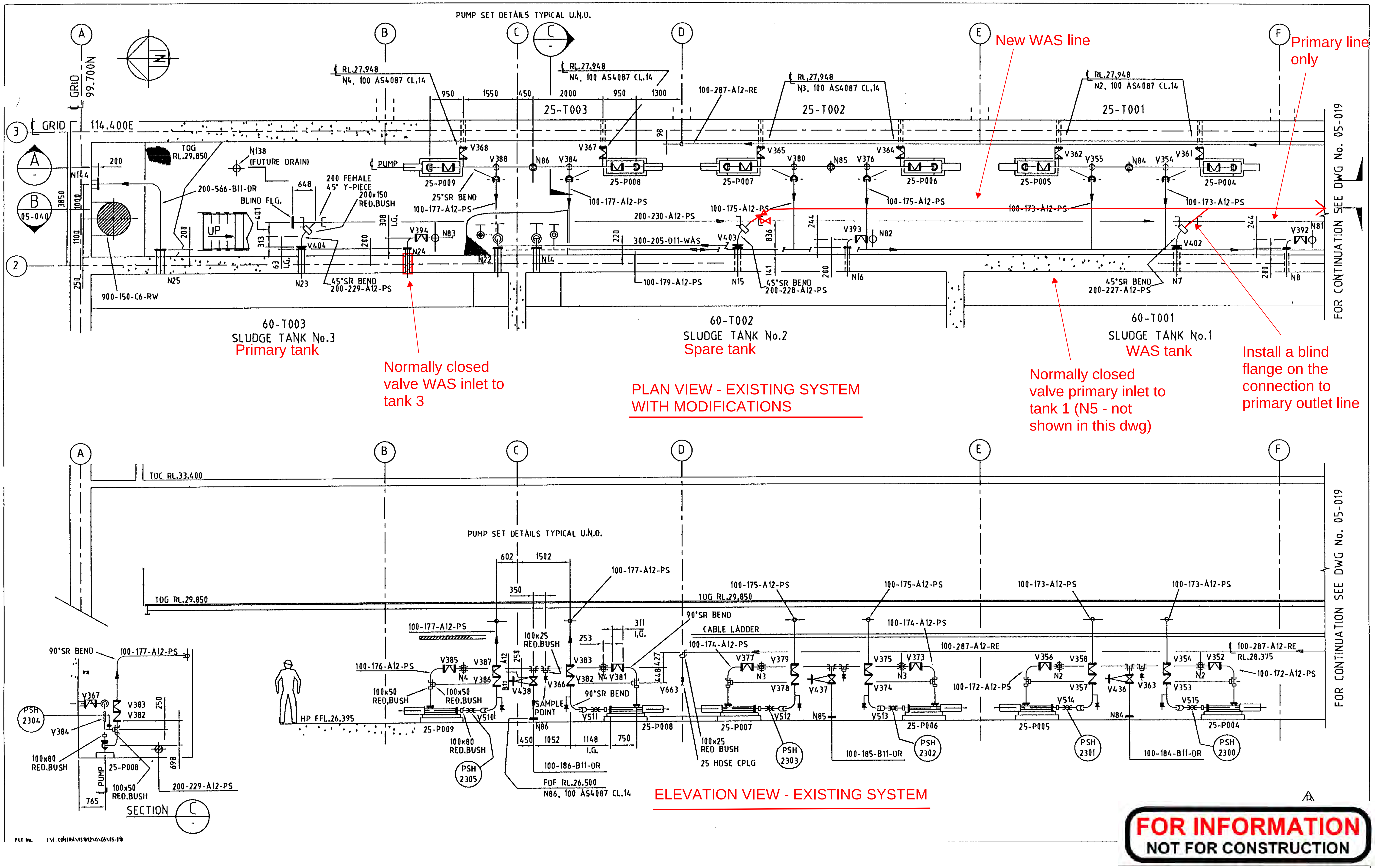
Plotted By: Rahul Prajapati

DO NOT SCALE - IF IN DOUBT ASK

Drawing Plotted: 22 Sep 2020 8:59 am

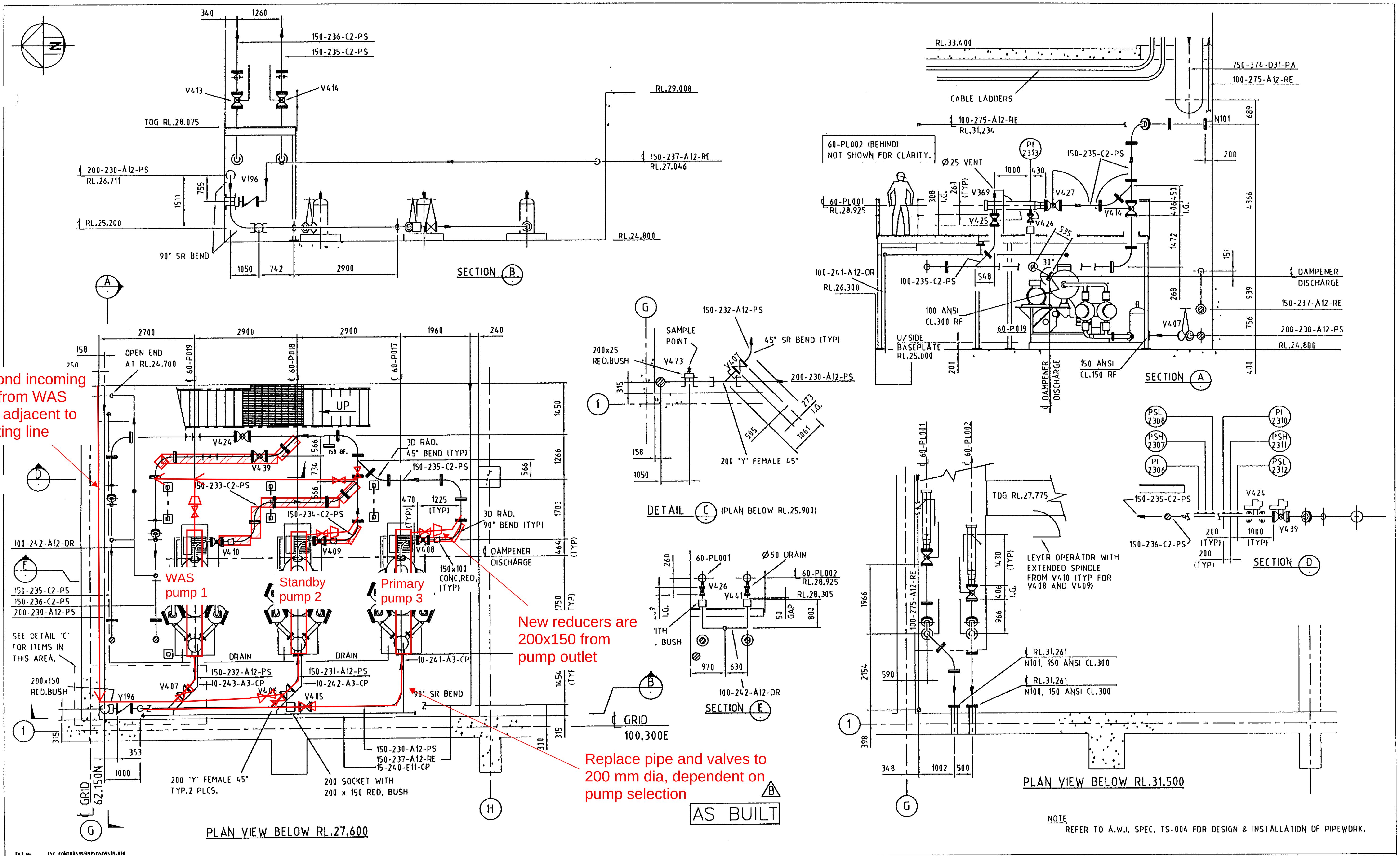
Document Path: P:\651\6511521\CAD_1916 - SMURF

Document No. 6511521-1916-BE-K1001.DWG



PROPOSED MODIFICATIONS TO RAW SLUDGE PUMPING SYSTEM

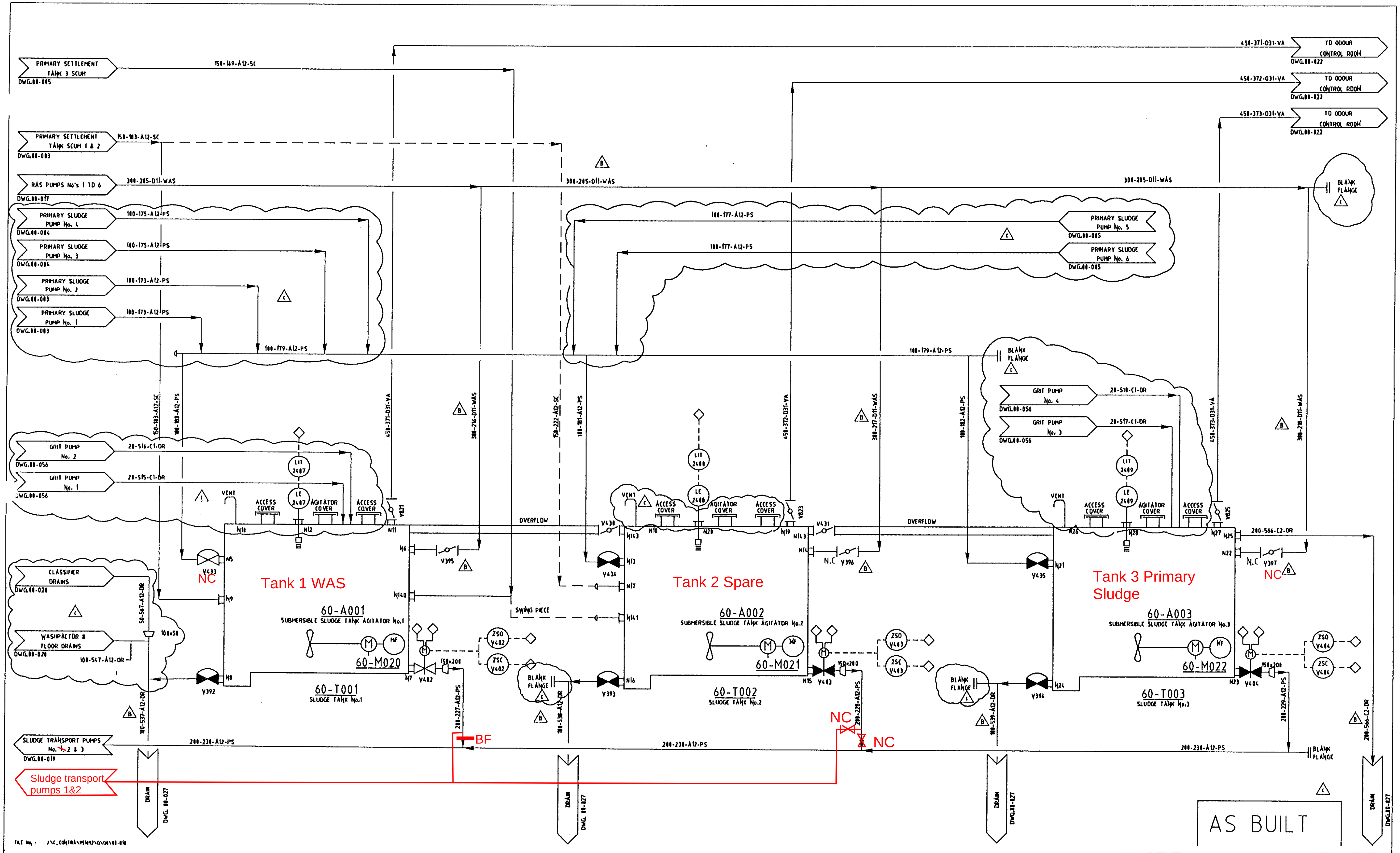
SHEET 1 OF 4



PROPOSED MODIFICATIONS TO RAW SLUDGE PUMPING SYSTEM

SHEET 2 OF 4

FOR INFORMATION
NOT FOR CONSTRUCTION



FOR INFORMATION
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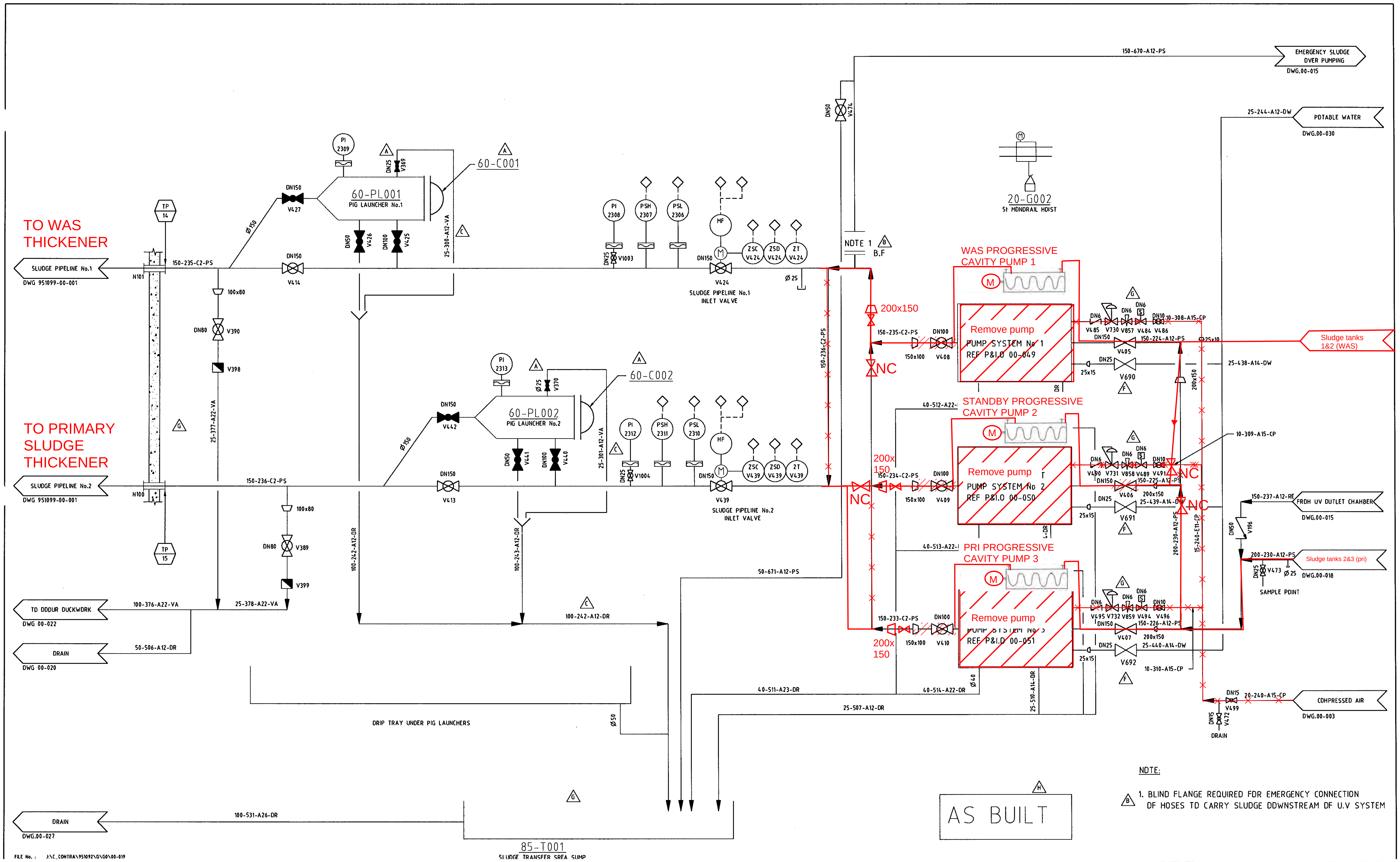
PROPOSED MODIFICATIONS TO RAW SLUDGE PUMPING SYSTEM P+ID

SHEET 3 OF 4



PROPOSED MODIFICATIONS TO RAW SLUDGE PUMPING SYSTEM

SHEET 4 OF 4

FOR INFORMATION
NOT FOR CONSTRUCTION