Engineering Standard

seqwater
WATER FOR LIFE

B-SPE-STD-017

Sludge Management Systems

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Version History

Rev	Date	Description	Author	SME	Owner	Approver
1	16/06/2025	Original Version				

(Refer Controlled Document in REX for Author, SME, Owner and Approver details)

Contents

1. Purpose

This document is part of a suite of Seqwater Engineering Standards which are in alignment with the Seqwater Quality Management System. Their purpose is to provide a consistent approach to the development, modification, and management of Seqwater infrastructure that is fit for purpose, economic over the life of the asset, and meets Seqwater's Work Health and Safety obligations.

This Standard Specification outlines Seqwater's minimum requirements and recommendations for the process design of sludge management systems at all Drinking Water Treatment Plants (WTPs). Section 5.1 specifies the sludge sources that are included and excluded from the scope of this document.

It provides guidelines based on general principles, criteria, background, and summary information that together form a comprehensive suite of sludge management system for conventional drinking water treatment plants. The specification includes details on calculating sludge weight and volume production, as well as the design of sludge storage and thickening, conditioning, dewatering, and disposal systems. Additionally, it reflects Seqwater's preferences, which have evolved over years of experience.

This primary focus of this specification is on process engineering design, including the process control narrative for the sludge system. It includes all the necessary information to support this objective. However, the document does not address detailed requirements for mechanical, civil, electrical, or control system design related to the equipment and processes referenced in this document. Relevant engineering standards and procedures are provided for guidance on these matters. Note that this specification does not include information on operating procedures or maintenance requirements for the equipment and systems discussed herein.

This document must be used in conjunction with the documents it references to assist in ensuring fit for purpose infrastructure. This Standard Specification is not intended to be relied on solely for design, supply, and installation works; advice from specialist engineers and/or manufacturers may be required on a case-by-case basis.

2. Scope

This Standard Specification applies to all Seqwater employees, contractors, suppliers and consultants working for or on behalf of Seqwater unless otherwise stated. It applies to all new assets and to all existing assets undergoing refurbishment or modification. It must be used in conjunction with other relevant Seqwater Engineering Standards and project specific documents to define the technical requirements for infrastructure design and construction.

Where single or discrete components of an existing non-compliant system are to be replaced, refurbished or modified, this standard should not automatically be applied to the entire system retrospectively, however consideration should be given, in consultation with relevant stakeholders, to the extent of the application of the standard outside of the components requiring replacement, refurbishment or modification, to ensure safe, economic, and fit for purpose infrastructure.

Seqwater Engineering Standards detail Seqwater's minimum requirements and recommendations to provide infrastructure that will be fit for purpose, and safe to operate and maintain. However, compliance with these requirements and recommendations does not remove, and cannot be relied on as meeting, the designer's overarching responsibility for ensuring infrastructure designed is fit for purpose and safe to construct, operate, maintain, and demolish. The designer must exercise appropriate due diligence to identify and manage hazards so far as is reasonably practicable.

Designers must also ensure compliance with relevant Australian Legislation, Standards, Codes and Guidelines (including those produced by Water Services Association of Australia). Where no Australian Standard exists for a particular application, work must conform to the most current version of an industry accepted international standard.

Deviation from meeting the minimum requirements in this Standard Specification requires written agreement from Seqwater as per the deviation process detailed in Procedure PRO-02205 X-PRO-STD-008 Asset Standards Management and Application. That process includes completion of a TEM-00224 X-TMP-STD-022 Asset Standards Deviation Request Form together with relevant supporting documentation, and submission by the Seqwater Project Representative to the Seqwater Engineering Mailbox. Where noted in this Standard Specification that Seqwater approval, agreement, or acceptance shall/must be sought, such approval, agreement or acceptance must be gained through the Seqwater Asset Standard Deviation process, as outlined above.

Responsibility for ensuring compliance with Seqwater Engineering Standards lies with those engaged in the management and execution of design, construction, and modification of Seqwater infrastructure. This includes modifications to the functional design of the infrastructure including technical changes made which would extend an asset outside of its design operating envelope and/or approved operation and maintenance practices.

Any ambiguities or conflicts identified between specific requirements within this Standard and project documents, another Seqwater Engineering Standard or Australian Legislation, Standards, Codes or Guidelines, these must be brought to the attention of the Seqwater Document Owner, via the Engineering Mailbox, for clarification. Where it is proposed to proceed without meeting the requirements of this standard, agreement must be obtained via the Deviation Process, as outlined above.

Seqwater undertakes regular updates of its Engineering Standards. Before utilising this Engineering Standard the complete list of Seqwater Engineering Standards should be reviewed to ensure currency and applicability of standards to be applied to the works. These can be accessed on the Waternet Engineering and Asset Standards page or using the REX Saved Search "Engineering Stds Controlled Documents by CD Owner".

3. Sludge System and Document Overview

This section provides a general overview of the design and redundancy philosophies guiding the development of this document on sludge management systems. A successful sludge management system requires a thorough understanding of the sources of sludges or residuals, their characteristics and quantities, processing options, chemical inputs, disposal methods, and relevant regulatory requirements.

3.1. Design Philospophy

The primary objectives of a typical sludge management system are to:

- Recover water from waste streams and return it to the front of the treatment plant, maximising production without compromising water quality.
- Reduce the water content in solid waste streams to minimise on-site storage and disposal costs.
- Ensure environmental compliance with site discharge regulations and waste management practices.
- Maintain production requirements by incorporating appropriately sized waste management systems.

The design approach for a sludge management system involves understanding its purpose and functions, followed by the application of relevant requirements to develop an effective solution. These systems can vary widely, ranging from containment in tanks and storage in lagoons to thickening, mechanical dewatering, and disposal or reuse solutions. A variety of sludge management techniques are employed across operational water treatment plants.

Sections 5.1 and 6.1 outline the typical waste sources that feed into the sludge management system, as well as waste streams that should be avoided. In conventional water treatment plants, liquid sludge primarily originates from two main sources:

- Sedimentation basin desludging or clarifier wasting
- Filter backwash

Based on these sources, two generic flowsheets (Figure 1 and Figure 2) illustrate key sludge processing stages commonly used in conventional drinking water treatment, as outlined in Section 3.1.1. These flowsheets shall not be viewed as the sole design options for new or existing sludge treatment plants. The design team may adapt the process based on the unique requirements of each facility. To finalise the processes, design, and performance criteria, it is advisable to conduct pilot studies or laboratory tests. These assessments should consider both the expected quality and quantity of the supernatant, as well as the capability of downstream barriers to effectively and safely manage that process stream.

Additionally, it is essential to adhere to the requirements or recommendations regarding water quality, environmental compliance, sludge production estimation, and specific design requirements for process units as outlined in this document.

3.1.1. Sludge system generic flowsheets

Figure 1 and Figure 2 present two generic flowsheets outlining the key process steps in a sludge management system for conventional drinking water treatment plants. The primary difference between these flowsheets lies in the additional treatment required for filter backwash water before it is combined with the sludges from sedimentation basins or clarifiers.

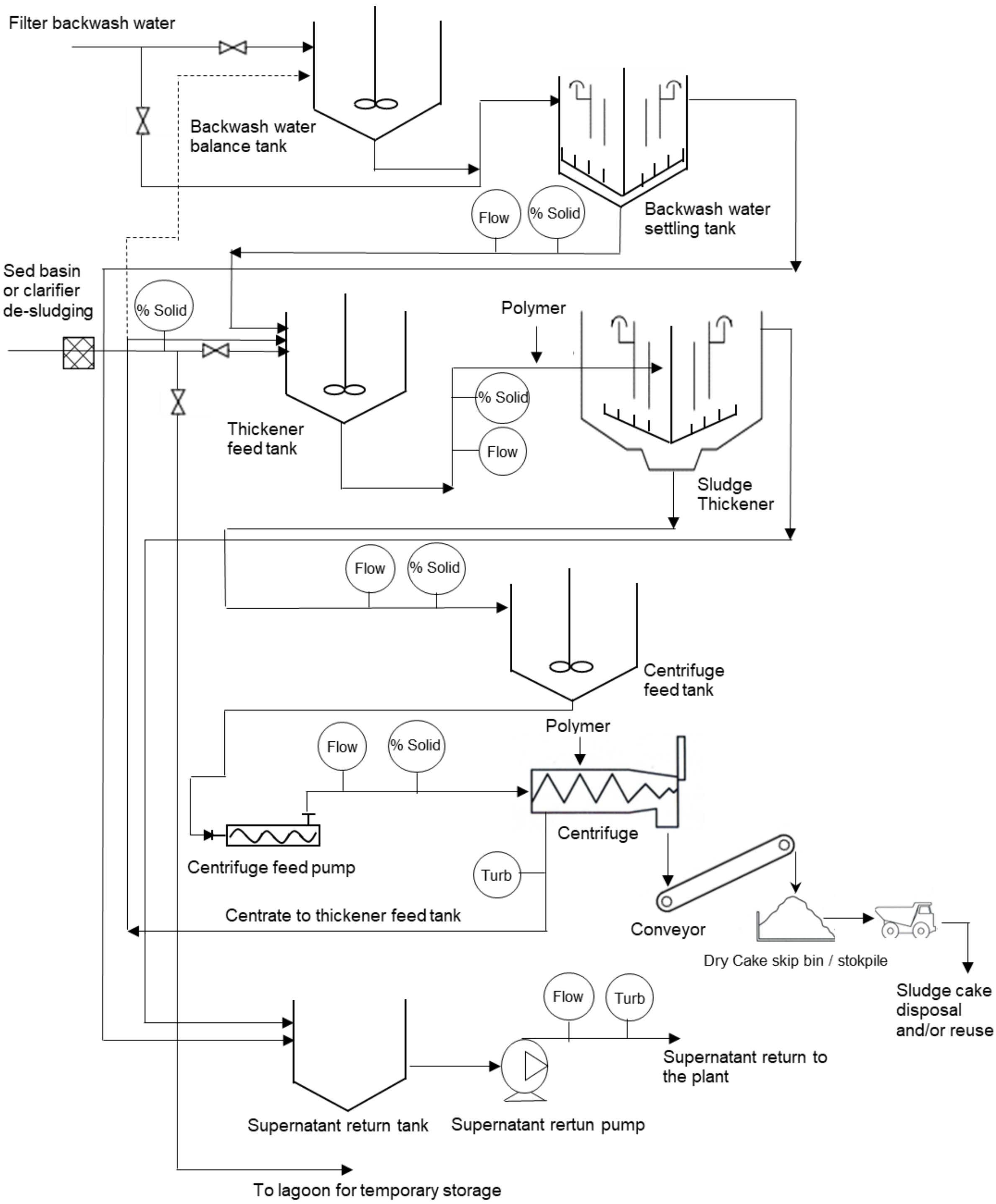


Figure 1 Typical flowsheet for sludge management system (separate inlet streams along with continuous filter backwash collection and recovery system)

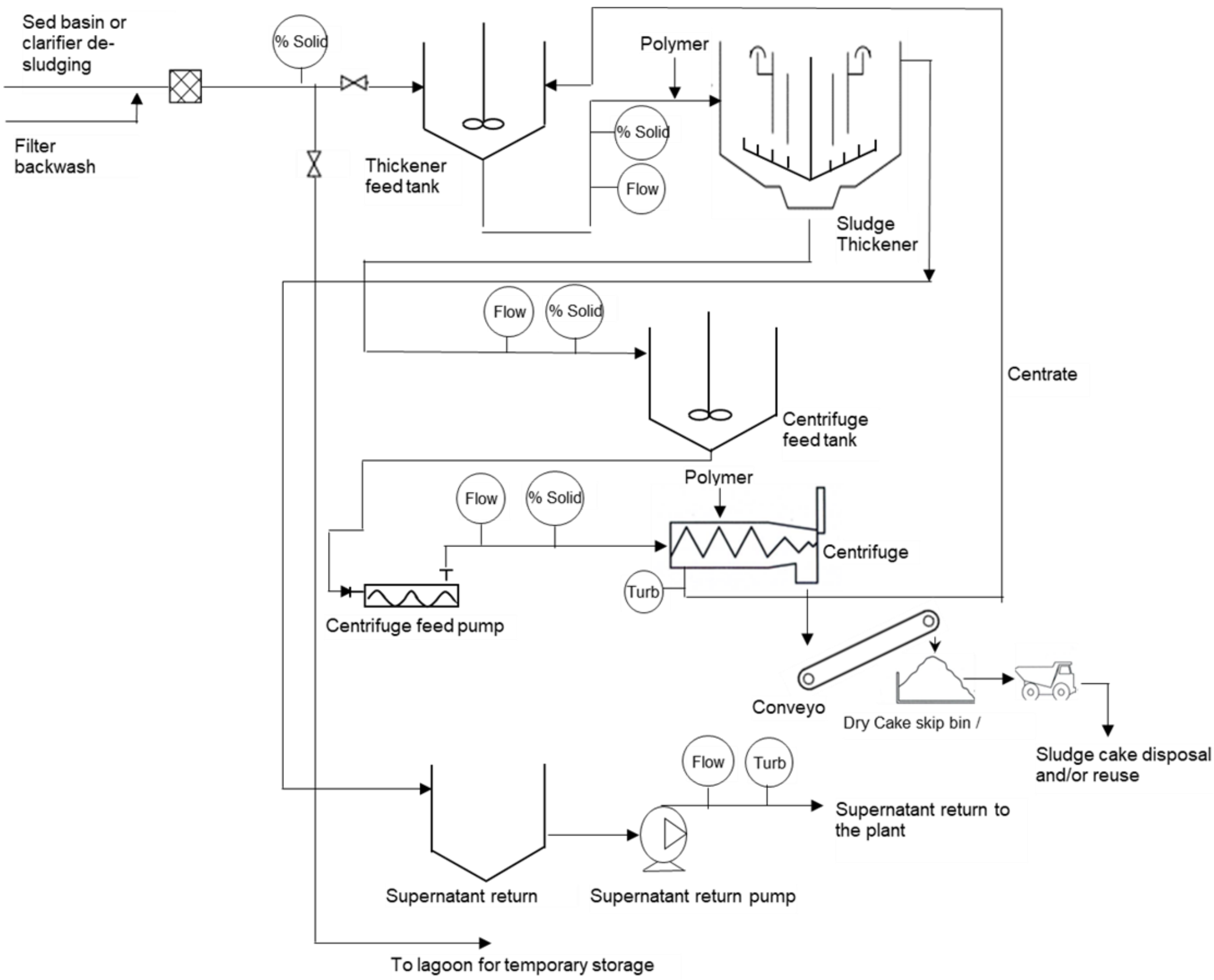


Figure 2 Typical flowsheet for sludge management system (combined inlet streams)

Although filter backwash water has a significantly lower solid concentration and pathogen loading, since studies suggest that about 70% - 90% of pathogens are captured in sedimentation or clarifier sludge, with only about 10% - 30% found in the filter backwash stream, it is produced in much greater volumes than the sedimentation or clarifier sludge.

As a result, it is strongly recommended to keep these two waste streams separate until the filter backwash water has been sufficiently settled to concentrate its solids. Premature mixing can significantly increase water quality risks during process upsets, particularly in plants where the ratio of supernatant return to raw water can occasionally be high.

Nonetheless, some plants may opt to mix sedimentation basin or clarifier sludge directly with filter backwash water to optimise equipment usage, as shown in Figure 2. In such cases, it is essential to ensure that the sludges are compatible, not pose any treatment or water quality risks, and that pathogen log reduction targets can still be met. Such decisions must be guided by a thorough understanding of source water quality, required pathogen log reduction targets and the configuration of the treatment train in operation. Where this approach is taken, a stochastic model that accounts for dynamic operating conditions is required, rather than relying on a steady-state model.

As illustrated in Figure 1, settled sludge from filter backwash water is combined with sedimentation basin or clarifier sludge in the thickener feed tank. To ensure uniform solid concentrations and keep solids in suspension, mixers are recommended for the continuous filter backwash balance tank, thickener feed tank, and centrifuge feed tank. Additionally, the first two tanks should be sized to accommodate high instantaneous flow rates.

In a continuous filter backwash water system, water is directed from the balance tank to a dedicated settling tank or an alternative clarification system. The settled sludge is then transferred to the thickener feed tank, while the supernatant is returned to the supernatant return tank. In contrast, a batch filter backwash system may use a single tank to handle flow balancing, settling, and draining. However, effective operation typically requires at least two tanks.

The thickener should receive feed from the feed tank at a constant rate, while the thickened sludge is directed to the mechanical dewatering system through a dedicated feed tank. The designer may consider evaluating the benefits of incorporating a lamella or alternative clarifier system upstream of the thickener, based on sludge characteristics and site-specific conditions.

Gravity transfer is preferred for moving thickened sludge to the dewatering feed tank, provided that a sufficient gradient can be maintained, the required line velocity is achievable, and the risk of blockage is minimised. An automated flushing system should be incorporated to clear thickened sludge transfer lines after any stoppage.

Where gravity transfer is impractical, progressive cavity pumps are typically recommended for transferring thickened sludge to the centrifuge feed tank and for feed to the centrifuge. However, peristaltic pumps are preferable for intermittent sludge system operations.

Centrifuges are illustrated in the flowsheets for mechanical dewatering, in line with Seqwater's current practices. The supernatant water from the thickener should flow into the supernatant return tank or, if no such return system exists, to a lagoon or other appropriate environment.

If filtrate or centrate from mechanical dewatering cannot be discharged directly into the local sewage system, it should be returned to the thickener feed tank or the filter backwash balancing tank in a continuous system, ensuring appropriate blending while considering proximity and hydraulic factors. In batch filter backwash collection systems, filtrate or centrate should not be directed to the filter backwash balance tank to prevent inappropriate blending and disruptions in settling cycle operations.

Water from the supernatant return tank is pumped to the head of the plant, with online monitoring of flow and turbidity. Additionally, a bypass line is necessary for desludging the sedimentation basin or clarifier, facilitating temporary storage in lagoons or solids drying beds to manage periods of high sludge production. The system should also account for the capability to direct centrate to temporary storage, addressing potential water quality hazards associated with elevated levels of polymer acrylamide monomer.

Polymer dosing is required for thickener feed and mechanical dewatering feed and may also be necessary for post-backwash balance tank or backwash settling tank feed. To ensure effective sludge settling, thickening, and dewatering, polymer dosage shall be controlled using an online flow meter and based on solid concentration data derived from either laboratory or online analyses.

The selection of polymer type should follow the guidelines outlined in Section 6.2. Manual sampling should be performed to verify polymer monomer content, ensuring compliance with the water quality requirements specified in Sections 4.1 and 8. Furthermore, real-time acrylamide mass balance calculations should be integrated into the SCADA system to support operators in optimising the sludge management process.

These flowsheets are designed without provisions for discharging liquid sludge into the environment or the local sewage system. However, where local environmental regulations allow and water security is not significantly impacted, discharging sedimentation basin or clarifier sludges and/or filter backwash sludges into the local sewage system, or downstream of the raw water abstraction point, may be considered. This is contingent upon meeting the applicable discharge quality criteria and satisfying the environmental requirements outlined in Section 4.2

Similarly, discharging filtrate or centrate from sludge dewatering directly into the local sewerage system is preferable where trade waste agreements can be established with the local sewerage authority. Additionally, the system may need to be equipped with a billing flow meter, sample arrangements, and, where hydraulic capacity is constrained or affected by infiltration, a balance tank with a mixer to avoid diurnal peaks and/or wet weather events. These requirements should be coordinated with the local sewerage authority. Section 4.2 provides further details on environmental requirements for sludge disposal.

For sites seeking a trade waste discharge license, sufficient holding capacity is typically required to prevent discharges during peak flow periods and/or when infiltration issues arise, particularly during periods of high rainfall. It is important to ensure sufficient hydraulic capacity to allow for flow modulation, particularly for higher-risk inputs such as centrate.

The design should evaluate the provision of a lagoon for temporary storage of liquid sludge to manage periods of higher liquid sludge production, equipment failures or process upsets. This is particularly critical where sewer access is not available. Additionally, provisions and cost estimates for effluent collection and management must be included in such cases.

3.2. Design Criteria

Plant production and raw water quality can vary significantly due to factors such as weather conditions and demand fluctuations. Consequently, specific set percentile values for raw water flow, turbidity and dissolved organics may not be applicable to the design of all treatment plants.

Design criteria for sludge systems depends on various factors, including anticipated treated water demand, grid connectivity (whether on-grid or off-grid), operating conditions during extreme water quality events, and options for liquid sludge management and storage. Each treatment plant requires a customised approach to effectively address its unique challenges and regulatory requirements.

The design criteria for sludge systems shall be determined on a project-by-project basis, with the project Basis of Design (BoD) serving as the reference for these criteria. This approach ensures that each system is appropriately tailored to meet the specific requirements and conditions of the project. The BoD shall clearly define all the foundational parameters and design assumptions that influence the configuration, operation, and performance of the sludge handling facilities. It also provides clarity, promote alignment among stakeholders, and supports informed decision-making throughout the design process.

At a minimum, the BoD should include the following key parameters:

- Sources and characteristics of sludge,
- Design flows and loading conditions, including data selection criteria,
- Sludge treatment objectives and processes considered,
- Sludge disposal or reuse strategies,
- Required utilities and supporting infrastructure,
- Control philosophy and level of automation,
- Key design assumptions and constraints.

3.3. Hydraulics and Plant Design

Developing hydraulic profiles is a crucial step in designing a sludge management system. This is particularly vital for the system's operation, as optimising gravity flow for sludge and supernatant water transfer lines would enhance energy efficiency and minimise the use of transfer equipment, which simplifies operations.

Hydraulic profiles are essential for:

- Ensuring that the hydraulic gradient is adequate for flow through various units,
- Establishing the necessary head for pumps, and
- Preventing flooding of sludge and plant facilities during peak flow periods.

In addition to the overall hydraulics of the water treatment plant, separate hydraulic calculations must be established for all sludge process units and transfer lines.

Before creating the hydraulic profiles for the sludge plant, design criteria, sizing of process units, solids balances, and plant layout must be defined. Once these factors are established, interconnecting piping should be preliminarily sized, and hydraulic profiles should be developed for both peak and average flow rates.

The development of hydraulic profiles must account for frictional head losses in pipes, minor head losses from valves and other control devices, and head losses from control structures such as weirs.

Based on the preliminary hydraulic profiles, a trade-off or optimisation analysis should be conducted to finalise pipe sizing, pump selection, and equipment locations, taking into account energy costs, operability, and maintenance requirements. Section 9 provides an overview of the general design and installation requirements for sludge treatment plants, including recommendations for the selection of tanks, equipment, and instruments.

3.4. Asset Redundancy

This standard specification does not outline redundancy requirements for all essential equipment, except for pumps and centrifuges.

The project shall assess final quantities and redundancy needs for equipment, tanks, thickeners, mixers, transfer lines, and instruments on a case-by-case basis. Contingency plans shall be considered for significant potential single points of failure and for assets that cannot easily be taken offline. The tanks should be sized to handle high instantaneous flow rates and provide sufficient detention time to accommodate potential process upsets without disrupting plant production.

Generally, the redundancy assessment will take into account factors such as site size, availability, criticality requirements, usage, location, staffing, reliability, operability, maintainability, regulatory obligations, Seqwater standard requirements, and any other relevant considerations.

3.5. Structure of the document

This document is organised to help users easily locate specific information regarding sludge sources, production, thickening and dewatering, water quality requirements for recycling, and environmental disposal requirements for conventional drinking water treatment plants. Below is a brief description of each section:

Section 4 – Drinking Water Quality and Environmental Requirements: This section discusses water quality requirements for any return water, along with environmental regulations for the disposal and reuse of solids and liquids.

Section 5 – Sludge Sources, Properties, Testing, and Production: This section outlines potential sludge sources, characteristics, and testing methods that significantly impact sludge settleability and dewatering. It also includes calculations for theoretical dry solid and liquid sludge production volumes, along with recommendations.

Section 6 – Sludge Collection, Conditioning, and Thickening: This section specifies design details for sludge collection, conditioning, and thickening systems.

Section 7 – Dewatering Process: This section describes strategies for selecting dewatering processes, provides high-level information about various methods, and details the design requirements for dewatering using decanting centrifuges.

Section 8 – Supernatant Return System: This section presents design details for the supernatant return system, including water quality monitoring requirements and allowable limits.

Section 9 – General Requirements: This section outlines general design and installation requirements for the sludge management system, referencing other applicable standards.

Sections 10 to 0: These sections include definitions, abbreviations, references, related materials, and information on revision changes.

4. Drinking Water Quality and Environment Requirements

For any new design or modification to an existing sludge management system, it must be ensured that the drinking water quality criteria and site environmental requirements are strictly achieved.

4.1. Drinking Water Quality Requirements

Seqwater is dedicated to ensuring drinking water quality management in accordance with the *Water Supply (Safety and Reliability) Act 2008*. This commitment is outlined in its POL-00012 Water Quality Policy Statement and PLN-00004 Drinking Water Quality Management Plan (DWQMP), both developed under the framework of the Australian Drinking Water Guidelines (ADWG) established by NHMRC. Additionally, Seqwater's water quality criteria and specifications for each treatment step are detailed in SPE-00320 Water Treatment Plant (WTP) and Supply System – Process Validation Standard.

In drinking water treatment plants, after the settling and/or dewatering of solids from liquid sludge, the collected supernatant is typically returned to the head of the treatment plant. This practice is essential at sites requiring volume reduction in liquid discharge to the environment or where compliance with zero liquid discharge is mandated.

However, returning supernatant water to the head of the plant can pose significant hazards to the main WTP processes if not properly managed and monitored. Risks include the presence of high level of unreacted monomers from polymers used for sludge treatment, increased pathogen loading, cyanotoxins from potential cyanobacteria blooms, and elevated solid loading. Additionally, factors that inhibit coagulation efficacy, such as soluble manganese, taste and odour compounds, and algal organic matter, can adversely affect the quality of the return water.

The design must ensure that the quality and flow of the returned supernatant meet the desired standards without adversely affecting drinking water quality. For detailed requirements regarding the efficient management of the supernatant return system, including system design, control, monitoring, and allowable contaminant limits, please refer to Section 8.

4.2. Environment Requirements

Seqwater is committed to meeting environmental management requirements established in the *Environmental Protection Act 1994, the Waste Reduction and Recycling Act 2011,* and other relevant environmental legislations. This commitment is demonstrated in POL-00027 Environment Policy Statement and PLN-00296 Environmental Management Manual. The environmental performance requirements for each Water Treatment Plant are documented in the relevant site-specific Site Environment Management Manual (SEMM), and where applicable this includes approval conditions for any authorised contaminant release locations.

For the modification, refurbishment or improvement of an existing sludge treatment system, the design shall be consistent with relevant legislation and any existing approval conditions. The designer must also consider whether an amendment to an existing approval may be required, whether the need to seek an approval is triggered or if an approval may be surrendered. For a new facility, consideration shall be given to whether the proposed design is likely to trigger as an Environmentally Relevant Activity (ERA) as defined in Schedule 2 of the *Environmental Protection Regulation 2019,* and whether pre-lodgement advice is required.

An ERA is triggered and requires an Environmental Authority (a type of approval) under the *Environmental Protection Act 1994* if it involves conducting any of the following activities that permit waste, treated or untreated, to be released into the environment:

a. Desalinating 0.5 ML or more of water per day;

b. Treating 10 ML or more of raw water per day;

c. Carrying out advanced treatment of 5 ML or more of water per day.

However, a water treatment ERA does not include:

d. Treating water in a manner that allows liquid or solid waste to be released only to:

    i. Local government's sewerage infrastructure;

    ii. A facility specified in the Environmental Protection Act (1994), (the EP Act) Schedule 2, sections 55, 60, 61, or 62;

e. Treating water if the only treatment involves disinfection or fluoridation;

f. Treating water in conjunction with an activity covered by EP Act Schedule 2, sections 55, 60, 61, 62, or 63.

Therefore, for example, a water treatment plant with a capacity equal or greater than 10 ML/day which may generate liquid or solid waste to be released to the environment is classified as a prescribed ERA as per *Schedule 2 of the Environmental Protection Regulation (2019).* Consequently, an Environment Authority (EA) is required under the *Environmental Protection Act (1994)* to operate the prescribed ERA.

In determining whether to grant, and how to condition, an EA for an ERA that may affect water, the administrating authority (currently *Department of the Environment, Tourism, Science, and Innovation*, DESI) will consider designs proposing releases into the environment based on the *management hierarchy for surface or groundwater,* as outlined in the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*. The preferred order for managing the release of wastewater or contaminants to waters is as follows:

g. *First:* Reduce the production of wastewater or contaminants by minimising water use.

h. *Second*: Prevent waste and implement effective waste prevention measures.

i. *Third*: Evaluate treatment and recycling options and implement appropriate treatment and recycling practices.

j. *Fourth*: Assess the following options for wastewater or contaminants in the specified order:

    i. Appropriate treatment and release to a waste facility or sewer.

    ii. Appropriate treatment and release to land.

    iii. Appropriate treatment and release to surface waters or groundwater.

The definitions of advanced treatment, of wastewater or contaminants, sewerage service provider, waste facility and waste prevention mentioned above can be found in Section 10.

It is important to note that if a facility does not trigger as a prescribed ERA, an EA is generally not required. However, the obligations under the *Environmental Protection Act 1994* must still be met. For example, Seqwater must comply with the following provisions of the Act:

- General environmental duty (section 319),
- Duty to restore the environment (section 319C),
- Duty to notify environmental harm (section 320-320G),

- Offence of causing serious or material environmental harm (sections 437-439),
- Offence of causing environmental nuisance (section 440),
- Offence of depositing prescribed water contaminants in waters and related matters (section 440ZG),
- Offence to place contaminant where environmental harm or nuisance may be caused (section 443).

It is important to note that conventional water treatment plants (WTPs) with a capacity of less than 10 ML/day, as well as those with a capacity greater than 10 ML/day that do not release to the environment, do not meet the threshold for classification as a prescribed ERA under Schedule 2 of the *Environmental Protection Regulation 2019* (the EP Regs). Consequently, an ERA for water treatment is unlikely to be required. Nonetheless, an assessment of other applicable approvals must still be undertaken.

Seqwater must still comply with the provisions of *the Environmental Protection Act 1994* when considering its activities and operations, particularly in relation to potential or actual environmental releases. This includes the General Environmental Duty (GED) under Section 319, whereby Seqwater must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonably practicable measures to prevent or minimise the harm. Other provisions such as under Section 440ZG which relate to depositing prescribed water contaminants in waters and related matters will also be directly relevant.

The Environment Team must be consulted in the planning and design of all new sludge management systems, as well as any modification to existing systems. Early consultation is strongly recommended, as the terminology used in the EP Act and EP Regs carries specific definitions that are critical for accurate interpretation and compliance.

4.2.1. Liquid sludge disposal

The disposal of liquid sludge primarily involves the management of filter backwash water and liquid residuals from clarifier or sedimentation basin desludging. It may also include the water produced during vessel drain-down, cleaning and other sources.

Many water treatment plants need to be designed to comply with zero liquid discharge requirements. However, if permitted under the EA license and documented in the Site Environment Management Manual (SEMM), some sites may dispose of liquid residuals directly or after further treatment, such as thickening and dewatering, under specific conditions.

When liquid residual disposal is an option, the following disposal areas can be considered:

- *Downstream locations of the source* (e.g., river or dam), from which raw water is abstracted. For this type of release, whether intermittent or regular, contaminant limits must meet the conditions of the EA.
- *Discharge to a sewage system*, which depends on the trade waste license agreement with the local sewerage authority and the capacity of the nearby sewage treatment plant to handle the sludge. The design needs to ascertain and address trade waste licensing specific conditions and associated life cycle costs.
- *Lagoons for temporary storage,* subject to the requirements of the *Environmental Protection Act 1994* and relevant EA conditions. It will be necessary to remove solids from the lagoon at some point; see Section 7.2.1 for lagoon design considerations.

4.2.2. Reuse of Dewatered Sludge

The objectives of the *Waste Reduction and Recycling Act 2011* include, but are not limited to, promoting waste avoidance and reduction, enhancing resource recovery and efficiency, and minimising the overall impact of waste disposal. The *End of Waste Code for Water Treatment Residuals (ENEW07503318)* (DESI, 2024) was developed to facilitate the lawful conversion of water treatment residuals, such as alum sludge from Seqwater's conventional water treatment plants, into beneficial reuse products.

The design must ensure that the water treatment residuals produced from the sludge dewatering system comply with the requirements (resource quality criteria) outlined in the *End of Waste Code for Water Treatment Residuals (ENEW07503318)*. It is important to note that this End of Waste Code does not cover residuals generated by desalination and advanced water treatment plants.

4.2.3. Extreme Water Quality Events

Raw water quality can vary significantly due to heavy rain events, floods, algal blooms, droughts and other factors. Such variations may lead to increased solid production from the sludge system, either due to higher levels of suspended solids in the raw water or from increased coagulant dosing to manage elevated turbidity or dissolved organics.

The sludge system design must account for these extreme events, following the adopted BoD outlined in Section 3.2. Where necessary, the design should also consider implementing alternative temporary storage or treatment arrangements and incorporate provisions for emergency releases to the environment, if permitted under applicable EA conditions in accordance with the *Environment Protection Act 1994.* Demonstrating compliance with the General Environmental Duty (GED) requires that these exceptional conditions are adequately planned to prevent and minimise any adverse environmental impacts so far as is reasonably practicable.

5. Sludge Sources, Properties, Testing and Production

The main objective of a water treatment processes is to remove impurities that present in raw water in the form of suspended organic or inorganic solids, colloids, dissolved inorganic and organic constituents, viruses, bacteria, algae, protozoa cysts and those added into the water for treatment.

5.1. Sludge Sources

The substances removed during water treatment typically include suspended and colloidal clay, organic materials eliminated through sedimentation and filtration, and debris such as floating material and algae, which are filtered out from the raw water by screens. Additionally, metal impurities from coagulants and other chemicals may also be retained in the sludge.

The semi-solid sludge and liquid residuals produced by drinking water treatment plants can originate from several sources, including:

- Suspended solids and algae present in the source water.
- Coagulants added to remove solids and organics, which precipitate out during treatment.
- Organic compounds and colour removed during the treatment process.
- Additional chemicals used as coagulation, flocculation, or filtration aids (e.g., polymers).
- Adsorbents, such as Powder Activated Carbon (PAC), added to eliminate taste and odour compounds or dissolved organics.
- Dissolved chemicals that precipitate out during treatment, such as iron and manganese, or those removed through water softening.
- Filter backwash water and possibly filter-to-waste water. However, filter-to-waste water should be considered for return to the head of the plant due to its very low solid content.

Other potential sources include:

- Biological growth within processes, particularly in biological filters, which can be challenging to quantify.
- Floats from Dissolved Air Flotation (DAF) or Dissolved Air Flotation Filters (DAFF).
- Sludges generated from lime saturators.
- Spent solid sorbents used for the adsorption of inorganic or organic components.
- Brine solutions resulting from the regeneration of ion exchange resins or sorbents.
- Sediments from water reservoirs.
- Water from membrane backwash.
- Water from vessel drain-down.
- Water from the cleaning of vessels and pipes.

The following waste streams generated in the treatment plants should not be directed to the sludge system and should be managed separately:

- Reverse osmosis concentrates.
- Onsite stormwater, roof water, clean bund water, sink waste.
- Onsite sewage.
- Spill chemicals,

5.2. Sludge Characteristics

The majority of drinking water treatment sludge typically contains naturally occurring particulates, such as clay and silt, along with algae, colour-causing colloids, dissolved organics, precipitates from coagulant chemicals, polymers, powder activated carbon, insoluble precipitates from soluble metal ions, and a small amount of filter media from backwashing. Understanding the physical, chemical, and biological properties of sludge is essential for determining effective sludge management techniques and designing suitable facilities.

Sludge characteristics can vary significantly from one location to another and even over time within the same treatment plant. These variations depend on factors such as the quality of the source raw water, the type and quantity of coagulants used, the coagulation mechanism, pH levels, and the addition of chemicals for adsorption or oxidation.

5.2.1. Physical Properties

Several physical properties of residual sludge can be used to define its ability to handle, convey, thicken, and dewater prior to disposal and beneficial use. The most studied physical properties that can affect the thickening, dewatering and handling process are:

- Solids content,
- Density,
- Particle size distribution,
- Rheological properties,
- Percentage of ash content or ratio of solids, and
- Specific resistance.

Separate discussion regarding the above properties is not included here except some details about percentage of ash content and specific resistance which are covered in Section 5.3.

Coagulant sludges from raw water with low total suspended solids (TSS) tend to contain a high percentage of coagulant precipitates, such as aluminium hydroxide, which are gelatinous and thixotropic in nature - appearing solid but reverting to liquid when disturbed. When coagulating water with substantial algae concentrations, the resulting sludges are light and have low solid concentrations.

Alum coagulant sludges contain substantial amounts of both non-removeable and removeable water. Non-removeable water, which includes bound water and surface or vicinal water, cannot be removed mechanically, Bound water is chemically bound to solid particles, while vicinal water adheres to the surfaces of solid particles through adsorption and adhesion forces.

Removable water consists of capillary or interstitial water and entrapped floc water or free water. Capillary water is trapped within the crevices and spaces of flocs or particles, bound by capillary forces, and can become free water if the structure is destroyed or mechanically squeezed out. Floc water, or free water, remains in the voids of the flocs like a sponge, unaffected by capillary forces and fundamentally is the easiest water fraction to remove mechanically.

The sludge cake solids content from mechanical dewatering processes is determined by the inherent solids composition as they form and the applied pressure. Polymer conditioning of sludges during dewatering, while increasing floc size and liquid-solid separation efficiency, does not alter internal floc structure and does not affect internal bound and/or vicinal water. Due to this, mechanical dewatering solids concentration levels in the sludge cake from alum sludge (i.e. 15% to 25%) is always found to be well below lime sludge levels (i.e. 25% to 60%), no matter what process is used.

5.2.2. Chemical Properties

The chemical properties of sludge play a crucial role in determining its disposal or reuse methods, as well as its manageability, thickening, and dewatering capabilities. These properties are closely linked to the chemical composition of the raw water, including dissolved and suspended organic matter, algae removed during treatment, and chemical coagulants. Moreover, overdosing of polymer can significantly affect the handling characteristics of the centrifuge solid cake.

The pH and dissolved solids in the liquid portion of residual sludge typically mirrors those found in the treated water. It is essential to assess the metal content in residual sludge, as it can influence landfill disposal options, lead to violations of sewage regulations due to effluent releases, and present toxicity risks to aquatic ecosystems if discharged into rivers or streams. Many heavy metals (aside from the coagulant salt metals) are introduced as impurities in coagulants and other treatment chemicals. Therefore, careful selection and specification of these materials are critical to minimising their concentrations and ensuring compliance with the resource quality criteria outlined in Section 4.2.2.

5.2.3. Biological Properties

Water treatment residual sludges can contain bacteria, protozoan cysts, oocysts, and viruses that are removed during the treatment processes. However, it is not possible to generalise the number of microorganisms present per unit volume of sludge produced, and their presence does not directly impact the coagulation sludge processing.

5.3. Sludge Testing

Several laboratory tests can be conducted to assess the properties of sludge, as well as its settling and dewatering capabilities. These tests include:

- Percentage of Ash Content or Ratio of Solids
- Capillary Suction Time (CST)
- Specific Resistance to Filtration (SRF)
- Settling Test

These bench-scale tests are crucial for understanding changes in sludge characteristics, enabling adjustments to process parameters in order to achieve optimised performance and identify process limitations. A correlation should be established between the results of these tests and the effectiveness of dewatering or thickening processes. Additionally, these tests can serve as operational control tools. Sludge testing must be conducted according to the preferences of the dewatering equipment manufacturers and polymer suppliers.

Beyond these tests, several other methods, such as the filter leaf test, laboratory-scale centrifuge or spin testing, and thermogravimetric analysis (e.g., DS(A)KBKopp, which predicts achievable solids content in sludge cake), can also be utilised to further describe sludge dewatering. However, details on these additional tests are not included here. For information related to polymer selection, please refer to Section 6.2.

5.3.1. Percentage of Ash Content

Percentage of Ash Content is an important parameter to measure for sludge dewatering. It refers to the ratio of Fixed Solids (FS) to Total Solids (TS) for a sludge. Fixed solids are determined after incinerating a dried sludge sample at temperature around 550°C ± 25°C, and total solid is determined after drying the sample at 105°C as stated below:

$$Ash\ Content\ (\%) = \frac{Weight\ of\ solids\ after\ incineration\ at\ 550^{o}c\ \pm 25^{o}c\ of\ a\ dried\ sample}{Weight\ of\ total\ solids\ after\ drying\ a\ sample\ at\ 105°C} x100$$

The above equation is represented in literature in many ways including as the ratio of Volatile Solids (VS) to Fixed Solids (FS) or the ratio of Volatile Solids (VS) to Total Solids (TS). Here, volatile solids refer to the solids that lost weight after incineration at 550°C ± 25°C from the total solids. The relationship among VS, TS, DS and percentage of ash content can also be provided by the followings:

TS = VS + FS

VS (%) = 100 – Ash Content (%)

Sludges tend to dewater better as the percentage of ash content increases. Many centrifuge suppliers use % of ash content as a benchmark for the dewatering capability of a sludge. According to a centrifuge manufacturer, the dry solid percentage in solid cake can be increased by about 5% if the ash content increased from 20% to 30% for a sludge sample.

5.3.2. Capillary Suction Time (CST)

Capillary Suction Time (CST) measures how readily a sludge sample releases its water. The CST test quantifies the time it takes for the liquid portion of the sludge to travel a fixed distance, typically one centimetre, using two electrodes to gauge this distance.

The test result provides a quick indication of dewaterability, but it is most valuable when correlated with other tests, such as Specific Resistance to Filtration (SRF). For unconditioned sludge, a typical CST time is around 200 seconds. In contrast, conditioned sludge, which is necessary to achieve the desired cake quality from the dewatering process, typically has a CST time of 10 seconds or less.

CST can serve as a screening test for assessing conditioning polymer types and determining the optimal polymer dosage for dewatering. This testing can be easily performed using commercially available standardised kits.

5.3.3. Specific Resistance to Filtration (SRF)

Specific Resistance to Filtration (SRF) refers to a measure of the rate at which a sludge can be dewatered. The specific resistance of a sludge can be determined from filtration data with the following formula:

$$r = \frac{2PA^2m}{\mu W} \tag{1}$$

Where,

r = specific resistance to filtration, m/kg

P = Pressure drop across sludge cake, N/m^2

A = Surface area of filter, m^2

μ = Viscosity of filtrate, N.s/m^2

W = Weight of dry solids deposited per volume of filtration, kg/m^3

m = Slope of the graph t/V (s/m^3) vs V (m^3), where t time of filtrate (sec) and V filtrate volume (m^3), slope unit is s/m^6.

Although specific resistance is developed for the vacuum filtration process, it is also found to be useful parameter for sludge dewatering by gravity settling, dewatering and other processes. SRF values can be used as an index of dewaterability rather than as well-defined sludge properties. SRF data is found to be useful for comparing sludges and the effects of polymer on dewatering. Sludges with SRF values below 10 x 10^{10} m/kg are found to be dewatered well and values above 100 x 10^{10} m/kg are considered to be difficult to dewater.

5.3.4. Settling Test

Settling is a crucial process for gravity sludge thickening and, to some extent, for filter backwash settling tanks. Given that liquid sludge characteristics can vary significantly, it is essential to design and operate thickening facilities based on criteria derived from settling tests.

Settling tests are typically conducted in the laboratory using bench-scale batch methods. In these tests, a measuring cylinder is filled with the sludge sample, allowed to settle, and the position of the liquid-suspension interface is measured at various time intervals. Different polymer doses and types can be added to assess their impact on sludge settleability. A stirrer may also be included, depending on the specific test procedure and objectives.

Two key parameters used to quantify sludge settling characteristics are settling velocity and Sludge Volume Index (SVI). The settling behaviour of sludge is influenced by its concentration, floc formation, and bridging tendencies after polymer addition. It can be classified into four distinct regimes:

1. discrete particle settling,
2. non-discrete flocculant settling,
3. zone settling (or hindered settling), and
4. compressive settling.

Each particle settles at its own characteristic terminal settling velocity, which is determined by factors such as size, shape, density, and porosity. When solids concentration exceeds a threshold limit, the particles become hindered by one another, resulting in collective settling known as zone settling. If the concentration increases beyond a critical limit, the settling behaviour shifts to compressive settling. A batch settling curve can be plotted to analyse the relationship between liquid-suspension interface height and time, helping to identify the settling regimes.

The Surface Overflow Rate (SOR) for sizing a gravity thickener can be determined based on zone settling velocity, considering an appropriate safety factor. Higher settling velocities generally allow higher SORs, while lower settling velocities require lower SORs to ensure efficient thickening and prevent overflow problems.

SVI measures the volume of 1 gram of sludge after 30 minutes of settling, expressed in mL/g. It is calculated by dividing the settled sludge volume (mL/L) by the total suspended solids concentration (g/L). Sludges with SVI values below 100 mL/g are generally considered to have good settleability.

Because the SVI test is empirical, it can be prone to errors. To address this, the diluted SVI (DSVI) test is used for concentrated sludges by diluting the sample with process effluent until the settled volume after 30 minutes reaches 250 mL/L or less. To minimise the effects of small diameter measuring cylinders on solids settling, a larger diameter cylinder or settleometer is employed. When a stirrer is used, the test is referred to as Stirred SVI or SSVI.

SVI can be used in drinking water sludge systems, although it is more commonly applied in wastewater treatment. It serves as a useful tool for evaluating sludge settling characteristics and optimising sludge management processes. However, it should be used in conjunction with other tests and factors, such as polymer dosages, coagulant types, and other sludge properties, to provide a more comprehensive assessment of the treatment system's performance.

5.4. Mass and Voulme of Sludge Production

Accurate calculation of the mass and volume of sludge production, including the percentage of solid retention, is critical for effective sludge management and system optimization. Understanding the quantity of sludge generated enables the proper sizing of treatment equipment—such as thickeners, dewatering units, and storage facilities—ensuring efficient operation and preventing overloading. These calculations are also essential for regulatory compliance, supporting waste disposal monitoring, and ensuring the safe handling and treatment of sludge. Furthermore, knowing the mass and volume of sludge produced is key for planning disposal or reuse strategies, including transport, storage, energy recovery, or land application. Therefore, precise sludge production calculations are vital for cost-effective operation, environmental protection, and the long-term sustainability of sludge management system.

The theoretical volume of liquid sludge and the amount of dry solids produced can be estimated based on raw water quality, treatment methods, and chemical usage. It is recommended to calculate liquid sludge volume and dry solid mass production by considering these specific factors, rather than relying on general rules of thumb based on a percentage of treated water. Dry solid sludge production is typically calculated by summing contributions from various sources, including coagulant addition, suspended solids removal, organic matter or colour removal, dissolved metal removal, algae removal, and sludge generated by other chemicals. This approach ensures a more accurate estimate of sludge production.

5.4.1. Sludge from Coagulation Process

Coagulation is typically the first step in the drinking water treatment process, involving the addition of chemical agents to condition suspended, colloidal, or dissolved materials, making them removable through subsequent processes such as flocculation, sedimentation, and filtration. The chemicals used in coagulation generate sludges that consists of both precipitates formed by chemical reactions and solids and organics present in the source water. The quantity of precipitate produced is influenced by the type of coagulants used, as well as the levels of suspended solids, dissolved organics, and inorganics in the source water.

In Seqwater, aluminium sulfate (alum) is the most commonly used coagulant, though alternatives such as aluminium chlorohydrate, polyaluminium chloride, poly DADMAC, ferric chloride, and ferric sulfate are also viable options. Polyacrylamide is frequently employed as a flocculation and filtration aid in treatment plants. Understanding the properties of the resulting sludge is crucial for effective handling, treatment, and disposal, as these properties largely depend on the coagulants used and the concentration of suspended solids present.

5.4.1.1. Aluminium Sulfate (Alum)

When aluminium sulfate (alum) is added to water for coagulation, the reaction produces aluminium hydroxide which precipitates out following the reactions as stated below:

$$Al_2(SO_4)_3{\cdot}14H_2O \rightarrow 2Al(OH)_3\,(s) + 6H^+ + 3SO_4^{2-} + 8H_2O \qquad (2)$$

$$Al_2(SO_4)_3{\cdot}14H_2O \rightarrow 2Al(OH)_3\,.3H_2O\,(s) + 6H^+ + 3SO_4^{2-} + 2H_2O \qquad (3)$$

Stoichiometrically, one mole of trivalent aluminium ion (Al^{3+}) will produce one mole of aluminium hydroxide, or one mole of $Al_2(SO_4)_3{\cdot}14H_2O$ will yield two moles of amorphous $Al(OH)_3$ solid. In terms of mass, 594.4 g of $Al_2(SO_4)_3{\cdot}14H_2O$ will stoichiometrically produce 156 g of $Al(OH)_3$, assuming complete precipitation of aluminium. This results in a theoretical Dry Solid (DS) production ratio of 0.26 kg of DS/kg of alum as $Al_2(SO_4)_3{\cdot}14H_2O$, without considering any bound water.

A range of dry solid production ratios per kg of alum, from 0.2 to 0.44, has been reported in the literature, based on various scenarios, laboratory testing, and empirical equations.

Most of the literature estimates dry solid production from alum coagulation using the stoichiometric ratio of 0.26 kg of DS/kg of alum, as described in the equation above (2). However, some studies account for three molecules of bound water in the aluminium hydroxide, such as $Al(OH)_3{\cdot}3H_2O$ described in the equation above (3), which increases the stoichiometric ratio to (264/594.4) or 0.44 kg of DS/kg of alum.

If this stoichiometric ratio is expressed in terms of Al_2O_3, it becomes 1.53 kg of dry solid per kg of Al_2O_3. For elemental aluminium (Al), the ratio is 2.9 kg of DS/kg of Al, assuming no bound water. When considering the three molecules of bound water, the ratio becomes 2.59 kg of DS/kg of Al_2O_3 and 4.89 kg of DS/kg of Al.

Where site specific sludge production data is not available from laboratory analysis, Seqwater prefers using a sludge production ratio of 0.44 kg of DS/kg of alum for equipment sizing and theoretical sludge production calculations to achieve a conservation design. However, for environmental release calculations, Seqwater prefers using a ratio of 0.26 kg of DS/kg of alum.

5.4.1.2. Aluminium Chlorohydtate (ACH)

When aluminium chlorohydrate (ACH) is added to water for coagulation, the reaction produces aluminium hydroxide which precipitates out following the reaction as given below:

$$Al_2(OH)_5Cl \rightarrow Al_2(OH)_5 + Cl^- + H_2O \rightarrow 2Al(OH)_3\,(s) + H^+ + Cl^- \qquad (4)$$

Stoichiometrically, one mole of trivalent aluminium ion (Al^{3+}) will produce one mole of aluminium hydroxide solid or one mole of $Al(OH)_5Cl$ will produce two moles of amorphous $Al(OH)_3$ solid or for Al_2O_3 the sludge production ratio becomes to 1.53 kg of DS/kg of Al_2O_3 following the above equation (4). The ratio becomes to 2.59 kg of DS/kg of Al_2O_3 with three bound water.

5.4.1.3. Ferric Chloride

Similar to alum, when ferric chloride is added to water for coagulation, the reaction produces ferric hydroxide precipitate as shown in the following reaction:

$$FeCl_3 + 3H_2O \rightarrow Fe(OH)_3\,(s) + 3H^+ + 3Cl^- \qquad (5)$$

Stoichiometrically, one mole of trivalent ferric ion (Fe^{3+}) will produce one mole of ferric hydroxide solid or 1.9 kg of DS/kg of Fe following the above equation (5).

In terms of mass or considering molecular weight, 162.2 gm of $FeCl_3$ will produce stoichiometrically 106.8 gm of $Fe(OH)_3$ which becomes the theoretical solid production ratio of 0.66 kg dry solid/kg of $Fecl_3$. This ratio changes to 0.99 kg of DS/kg of $Fecl_3$ when three molecules of bound water considered in sludge production calculations considering $Fe(OH)_3.3H_2O$.

5.4.1.4. Ferric Sulfate

Similar to ferric chloride, when ferric sulfate is added to water for coagulation, the reaction produces ferric hydroxide precipitate as shown in the following reaction:

$$Fe_2(SO_4)_3.9H_2O \rightarrow 2Fe(OH)_3\,(s) + 3H^+ + 3SO_4^{2-} + 3H_2O \qquad (6)$$

In terms of mass or considering molecular weight, 562 gm of $Fe_2(SO_4)_3.9H_2O$ will produce stoichiometrically 213.6 gm of $Fe(OH)_3$ which becomes the theoretical solid production ratio of 0.38 kg DS/kg of $Fe_2(SO_4)_3.9H_2O$ and considering $Fe(OH)_3$ with three bound water as $Fe(OH)_3.\ 3H_2O$, the ratio becomes to 0.57 kg of DS/kg of $Fe_2(SO_4)_3.9H_2O$.

5.4.1.5. Suspended solids or turbidity removal

The fraction of sludge production for raw water suspended solids can be easily estimated from raw water Total Suspended Solid (TSS) data. If TSS data is not available, the fraction of sludge production for TSS can be estimated from readily available raw water turbidity data. However, there is a high degree of variability in the TSS/Turbidity ratio depending on the particle size distribution, shape, density and organic content. Consequently, site-specific calibration or empirical relationships are often necessary to improve sludge production estimates based on turbidity data.

The TSS-to-Turbidity removal ratio (g of solid/m^3 of water/NTU removed) for water sources typically ranges between 1 to 2, with a recommended value of approximately 1.5 for raw water turbidity levels above 10 NTU. For raw water turbidity levels of 10 NTU or lower, a TSS-to-Turbidity removal ratio of 1.0 is usually recommended. When raw water TSS data available (in g of solid/m^3 of water), it should be used preferentially for the estimation of sludge production instead of relying on the generic TSS-to-Turbidity removal ratios.

5.4.1.6. Algae removal

Generally, site specific data is necessary to accurately predict solids production from algae removal. In practice, algal blooms are for a relatively short period, and its impacts on average plant solid production would be expected to be small. However, during the event of an algal bloom, this may have impact on sludge characteristics and may require some adjustment to polymer dosing for dewatering or conditioning of dewatering feed.

In absence of site-specific raw water algae data, the measurement of chlorophyll A can be translated to an indicative suspended solids from algae using a co-relation.

5.4.1.7. Organics or colour removal

The fraction of sludge production from organics can be easily estimated from dissolved organics removal data. Where organics removal data cannot be obtained or predicted, the fraction of sludge production from organics can be estimated from true colour removal. The fraction of sludge production has been reported in literature in the range of 0.1 to 0.2 mg/L of solid production per unit of Hazen unit of true colour removed.

5.4.2. Polymer and PAC Addition

The amount of polymer used in coagulation/flocculation, pre-filter aids, or sludge thickening shall be included in the sludge solids calculation. The polymer dose should be converted to dry solids using the ratio of 1 kg of dry sludge per 1 kg of polymer added.

Similarly, the sludge solids resulting from the use of PAC for taste and odour removal shall be adjusted to account for the applied dose.

5.4.3. Dissolved Iron and Manganese Removal

Normally, dissolved iron (Fe^{2+}) precipitates out as solid ferric hydroxide $Fe(OH)_3$ and produces about 1.9 kg of sludge/kg of dissolved iron removal from oxidation with oxygen or chlorine. However, if potassium permanganate is used as an oxidant, stoichiometrically, 2.43 kg of sludge is produced/ kg of dissolved iron removal as per the following reaction.

$$3Fe(HCO_3)_2 + KMnO_4 + 2H_2O \rightarrow 3Fe(OH)_3\ (s) + MnO_2\ (s) + KHCO_3 + 5CO_2 \quad (7)$$

$$3Mn(HCO_3)_2 + 2KMnO_4 \rightarrow 5MnO_2\ (s) + 2KHCO_3 + 2H_2O + 4CO_2 \quad (8)$$

Dissolved manganese (Mn^{2+}) normally precipitates out as solid manganese oxide (MnO_2) and produces 1.58 kg sludge/kg of dissolved manganese removal from oxidation with oxygen or chlorine. If potassium permanganate is used for oxidation, stoichiometrically, 2.64 kg of sludge is produced/kg of manganese removal following the above equation.

5.4.4. Lime Addition

When lime is added to raw water for pH correction, only the impurities in the lime should be considered in the sludge mass calculation, as these impurities contribute to sludge formation. However, when lime is dosed into filtered water, these impurities are not included in the sludge mass balance, as they do not enter the sludge system. Instead, the impurities settle out either in the pipeline or in the reservoir. Lime sludge produced from impurities in the lime saturator, however, should be included in the sludge mass balance.

Lime precipitation sludges produced during water softening, primarily composed of calcium carbonate and magnesium hydroxide, are not covered in this document.

5.4.5. Summary of Recommended Values and Ranges for Sludge Production

Table 1 below provides the ranges for the calculations of dry solid production from the removal of contaminants and the addition of various chemicals as discussed above and found in literature. The table also includes the recommended values to be used for the estimation of sludge production in the design.

Table 1 Ranges and recommended values for dry solid production from removal of contaminants and addition of chemicals.

Process / Chemical	Unit	Reported range of ratios	Recommended Ratio
Coagulation with alum as $Al_2(SO_4).14H_20$	kg dry solid/kg coagulant	0.2 to 0.44	0.44[a] 0.26[b]
Coagulation with alum or ACH as Al_2O_3	kg dry solid/kg Al_2O_3	1.15 to 2.59	2.59[a] 1.53[b]
Coagulation with $FeCl_3$	kg dry solid/kg coagulant	0.6 to 0.99	0.99[a] 0.66[b]
Coagulation with $Fe_2(SO_4)_3.9H_2O$	kg dry solid/kg coagulant	0.34 to 0.57	0.57[a] 0.38[b]
Turbidity removal >10 NTU	g dry solid/m^3 of water/NTU removed	1.0 to 2.0	1.5[c]
Turbidity removal <= 10 NTU	g dry solid/m^3 of water/NTU removed	~1	1
Organics or Ture colour removal	g dry solid/m^3 of water/HU (true colour) removed	0.1 to 0.2	0.15

[a] Use when site specific laboratory data is not available, use for equipment sizing and sludge production calculations to achieve a conservative design.

[b] Use for environmental release calculation.

[c] Use only when representative raw water data is unavailable.

Process / Chemical	Unit	Reported range of ratios	Recommended Ratio
Polymer	kg dry solid/kg polymer	1	1
PAC	kg dry solid/kg PAC	1	1
Dissolved Fe removal	kg dry solid/kg Fe	Depends on oxidant types	1.9 (for O_2 or Cl_2) 2.43 (for $KMnO_4$)
Dissolved Mn removal	Kg dry solid/kg Mn	Depends on oxidant types	1.58 (for O_2 or Cl_2) 2.64 (for $KMnO_4$)

Once the theoretical dry solid production is estimated, the sludge volume calculation, thickener sizing, and centrifuge feed rate can be determined based on other assumptions. Additionally, the solid cake production rate from the centrifuges can be calculated if the percentage of solids or moisture content in the cake is known.

Appendix A shows sample calculations for the estimation of dry solid production using the recommended values as tabulated above.

Where actual field sludge production data is available from the plant operation or from the laboratory testing, these values should be used instead of the above recommended values.

5.4.6. Sludge Volume

Liquid or wet sludge volume can be approximately calculated from the estimated dry solid production, solid concentration, and specific gravity of sludge. The estimation of wet sludge volume is needed for equipment sizing for each sludge collection step.

The sludge volume at a WTP can vary seasonally or monthly depending on the quality of the source water quality, treatment chemicals used and the production rate.

The volume of sludge primarily depends on its water content and with slight contribution on the properties of solid matter. The sludge volume can be calculated using the following equation:

$$V = \frac{W_s \times 1000}{\rho_w S_s C_S} \qquad (9)$$

Where,

V = Volume of liquid sludge in ML/day

W_s = Weight of dry solid kg/day

ρ_w = Density of water kg/m^3

S_s = Specific gravity of wet sludge

C_s = Concentration or % of solid

Specific gravity of liquid sludge can be calculated from solid specific gravity and percentage of solids in the sludge. Appendix A shows sample calculations for the estimation of liquid sludge volume.

6. Sludge Collection, Conditioning and Thickening

6.1. Liquid Sludge Collection

Normally, in a conventional water treatment plant, liquid sludge is mainly collected from:

- Sedimentation basin desludging or clarifier underflow, and
- Filter backwash water including Biological Activated Filter (BAC).

Other liquid sludge collection sources may include:

- Dissolved Air Floatation (DAF) desludging,
- Lime softening,
- Lime saturator de-sludging,
- Ion exchange or softener regeneration solution,
- Pre-sedimentation,
- Process system draining, washing of flushing.

6.1.1. Sedimentation Basin Desludging

Sludge is periodically removed from sedimentation basins to prevent solids from carrying over to the filters. The frequency of desludging typically increases when the raw water has high solid levels or when plant production is elevated.

The liquid removed during this process may contain approximately 0.5% to 2.5% (v/v) of plant flow, with solid concentrations generally ranging from 0.2% to 1% (w/v). However, during desludging, the instantaneous solid concentration can fluctuate significantly along the travelling bridge, from the coagulation/flocculation end to the settling water channel and vice versa. Literature indicates that about 70% to 90% of solids are collected during the desludging of sedimentation basins or clarifiers, depending on the specific design of the plant.

Seqwater employs various arrangements for sludge collection from sedimentation basins, including:

- Traveling bridges with submersible pumps,
- Traveling bridges with rakes and pumps in sumps,
- Traveling bridges with rakes and decant valves in sumps.

When submersible pumps are utilised, they transport settled sludge through individual discharge lines to a suitably sized common gutter surrounding the basin, which connects to the receiving tank via pipework. For other arrangements, settled sludge is transferred from sumps to the receiving tank through pipework.

The detailed design requirements for sedimentation basin desludging systems and associated equipment are not covered in this specification but should be addressed in the sedimentation basin design documents.

This document outlines the components of the sludge collection system from sedimentation basin desludging, which consist of:

- Sludge balancing tanks or thickener feed tanks,
- Pipework and instrumentation.

6.1.1.1. Sludge balancing tank / thickener feed tank

A sludge balancing or thickener feed tank is critical for effective sludge management, as it provides a controlled and consistent supply of sludge to the thickening process. The tank allows for the accumulation and stabilisation of sludge before it enters the thickener, ensuring uniform flow and solids concentration. This helps optimise the performance of the thickening equipment, preventing fluctuations that could affect sludge dewatering and downstream processes. Additionally, by temporarily storing feed sludge, the thickener feed tank offers operational flexibility, enabling continuous sludge treatment even during periods of fluctuating influent flow.

Typically, the sludge balancing or thickener feed tank receives intermittent flows from sediment basin or clarifier desludging and settled sludge from the filter backwash collection system or direct filter backwash water and returned flows from the dewatering system. The design requirements for the sludge balancing or thickener feed tank are as follows:

a. The tank shall be cylindrical and vertically positioned.

b. The tank shall be sized appropriately to dampen flow variations (or achieve flow equalization) and ensure a constant outflow rate, with the following considerations:

    i. The required tank volume for flow balancing should be determined by plotting cumulative volumetric inflow versus time, alongside an average daily inflow line (or constant outflow rate). The gap between these two plots should be measured to calculate the necessary volume.

    ii. Gaps should be determined by drawing two tangent parallel lines on the cumulative inflow curve (one above and one below the average inflow line). The required volume is calculated from the vertical distance between these tangent lines. If the cumulative inflow curve only lies above or below the average flow line, the required volume equals the vertical distance from the tangent point to the average flow line.

    iii. A safety factor of at least 10%, as well as an appropriate freeboard, should be included in the calculated tank volume when necessary.

    iv. A minimum retention time of 8 hours is recommended based on the average inflow or outflow rate. The higher value between the volumes calculated based on methods (a) through (c) and the retention time should be selected.

    v. An example of the tank sizing calculation is provided in Appendix B.

c. Depending on the tank's shape and size, it shall be equipped with a single mixer, multiple mixers, or a mixing system that meets the following requirements:

    i. Mechanical mixer(s) must provide sufficient energy to homogeneously mix sludge concentrations of up to 2%, preventing settling and ensuring consistent solid concentration feed to the thickener.

    ii. The mixer(s) should be top entry. The externally mounted motor must be supported by suitable frames for easy maintenance and removable using a mobile crane.

    iii. Mixer design must ensure blades provide axial mixing, producing uniform velocity throughout the tank to eliminate dead spots. Blades should be one piece and connected to the shaft via a keyway or welded hub, secured against detachment or loosening due to rotation and vibration.

    iv. The mixer(s) shall operate continuously whenever the tank contains material to avoid stratification and settling of solids.

v. The designer shall assess the need for an adjustable variable speed drive to deliver varying shear forces, as opposed to a fixed-speed motor.

vi. The mixer(s) must include options for remote and local start/stop controls, along with motor current monitoring and alarm systems.

vii. Mixer blades and shaft materials shall withstand the abrasive nature of the solids present in the sludge.

viii. The design must use food grade oil and eliminate any possibility of leakage from the gearbox. Refer *to SPE-00367 M-SPE-STD-001 General Mechanical* for the requirements of food grade oil and any heat transfer fluid required for mixers.

ix. Vertical baffles may be incorporated where necessary to enhance mixing performance. However, their design and placement should be carefully considered to ensure optimal effectiveness.

d. The tank discharge pipe location should be selected with the following considerations:

i. The discharge location should avoid dead zones or areas where solids could settle, ensuring a consistent flow to downstream thickeners.

ii. The discharge pipe should be positioned opposite the sludge inlet to prevent short-circuiting and ensure thorough mixing.

iii. The discharge pipe should be located near the bottom, but not at the lowest point of the tank. Typically, it should be positioned approximately 300 mm above the tank's true bottom. This ensures that settled sludge or debris are not pulled into the discharge line.

e. The design may include a drain valve at the true bottom of the tank to allow for periodic withdrawal of settled sludge.

f. The tank should be located to minimise the length of connecting piping.

g. The tank shall feature a peripheral walkway spanning the entire circumference, equipped with handrails and/or guardrails as appropriate, for cleaning and inspection, while providing protection from falls, in accordance with SPE-00366 *M-SPE-STD-002 Fixed Platforms, Walkways, Stairways, and Ladders*.

h. The tank shall be equipped with a level transmitter, along with backup high- and low-level switches, which include alarms and interlocks to prevent overflow and dry running of pumps, where applicable.

The tank should preferably be constructed from concrete and designed in accordance with *AS 3753 Concrete structures for retaining liquids*, *AS 3600 Concrete structures* and *AS/NZS 1170 Structural design actions*. If steel is used, it must be structurally designed in compliance with relevant standards, including *AS 4100 Steel Structures, AS/NZS 1554 Structural steel welding* and *AS/NZS 1170 Structural design actions*.

The redundancy requirements for the sludge balancing tank and its mixers should be determined in line with the overall sludge system redundancy strategy, considering alternative storage options and eliminating any potential bottlenecks that could impact plant operations.

6.1.1.2. Pipework and Instruments

The design of sludge transfer lines from the sedimentation basin to the sludge balancing tank should consider the following:

a. Line size, length, blockage cleaning, flushing, sampling and relevant components must be designed in accordance with the general requirements specified in Section 9.8.

b. The sludge transfer line should include a flow meter for alarming, monitoring, and optimisation purposes.

c. The design should incorporate an online solid density meter to measure solid concentration and automate basin desludging, provided the reliability of the instrument can be ensured.

6.1.2. Clarifier Sludge Removal

Sludge is periodically removed from the clarifiers, as per the design, to maintain the target settled water turbidity after coagulation and flocculation, as well as to control the sludge banket level. The frequency of desludging typically increases when the raw water has a high solids content or when plant production rises. Sludge removal is usually achieved through gravity transfer, with an automated valve operating at preselected or adjustable time intervals.

The clarifier sludge typically has a solid concentration in the range of 0.2% to 1% (w/v).

The design requirements for pipework and instrumentation for clarifier sludge transfer to the sludge balancing or thickener feed tanks shall comply with the specifications outlined in Section 6.1.1.2.

6.1.3. Filter Backwash

Filters are backwashed using filtered or treated water, combined with air scouring, to maintain the filter media's cleanliness. The backwash water is then removed through a collection channel. The duration and flow rate of each backwash cycle are typically optimised based on the turbidity of the backwash water and other design parameters.

Filter backwash water is typically much more dilute than basin or clarifier desludging water, with solid concentrations usually ranging from 0.01% to 0.05% (w/v). Literature suggests that approximately 10% to 30% of solids are collected from filter backwash in conventional treatment plants. The exact volume of backwash water as a percentage of the total water processed is not fixed, as it can vary depending on factors such as the frequency of backwash cycles and fluctuations in raw water quality. However, backwash water typically accounts for 2% to 5% of the total volume of water treated. It is important to note that this section focuses solely on the design of filter backwash water collection and recovery systems.

Filter backwash collection and recovery systems can be designed and operated as either batch or continuous systems, depending on the preferences of the filter system designers.

- **Batch System**: This system typically uses two tanks that operate in rotation—one for filling and the other for settling and emptying. Both tanks should be identical and equipped with a rake and a decanted water collection system. The design of these tanks should mirror the backwash settling tank specifications outlined in Section 6.1.3.2. The batching process should be controlled automatically, although specific details of the control mechanism are not provided here. Batch systems offer advantages such as simpler control and improved solids settling, making them well-suited to small to medium sized plants or for operations where batch processing fits routine workflows.
- **Continuous System**: A continuous filter backwash collection system requires at least a balancing tank and a settling tank or a clarifier system. This type of system offers advantages when space is limited and there is a need to efficiently handle large volumes. Continuous systems are often favoured in larger, high-capacity treatment plants.

Further details on the design and function of the backwash balancing and settling tanks are provided below.

6.1.3.1. Backwash balancing tank

The filter backwash balance tank is designed to collect, store, and manage the water used during the filter backwash cycle. It ensures the stability of the treatment system by regulating flow fluctuations, prevents environmental contamination, and enables efficient handling of backwash water for further treatment or potential recycling.

The backwash balancing tank will receive intermittent flows from the backwash of filters. In addition, the tank should be designed to receive centrate or filtrate flows from mechanical dewatering and/or other flows, as applicable, according to the plant design. The design requirements for the balancing tank are provided below:

a. The balancing tank shall be cylindrical and should be sized to buffer large instantaneous flows received from filter backwashing. The tank volume required for the flow balancing should be determined following the same guidance provided in Section 6.1.1.1. Alternatively, the tank should be sized at a minimum water volume equivalent to three (3) filter backwashes, plus centrate flows (if applicable), plus at least a 10% safety factor.

b. A slow-moving rake is required for each backwash balancing tank in batch systems. The design specifications for the rake should comply with the guidelines outlined in Section 6.3.6.

c. Mixers are recommended for backwash balance tanks to keep solids in suspension, but only for continuous systems. The mixer design requirements should be followed as described in Section 6.1.1.1 for sludge balancing tanks.

d. Other requirements of flow distribution, connecting piping, instruments, peripheral walkway, handrail and guardrail requirements and tank construction as provided in Section 6.1.1.1 must be followed.

6.1.3.2. Backwash settling tank

Settling of filter backwash water helps reduce the risk of recycling microorganisms, as well as aluminium, manganese, and iron particulates, back into the treatment plant. In continuous systems, this is accomplished using a dedicated settling tank. However, in batch systems, a separate settling tank is not required, as settling occurs within the receiving tank during each cycle. The settled solids (sludge) should be directed to the sludge balancing or thickener feed tank for further thickening before dewatering. Meanwhile, the supernatant water is collected and returned to the plant via the supernatant return system for recycling.

The design requirements for the filter backwash settling tank are similar to those of the sludge thickener, as outlined in Section 6.3, with the following exceptions:

a. Sizing: The following considerations should be made when sizing the settling tank:

    i. The tank should be sized based on a Surface Overflow Rate (SOR) of approximately 2 m/h or a solids loading rate of 4 $kg/m^2{\cdot}h$, whichever is achieved first, across the full hydraulic range. The exact values will depend on upstream processes, particularly whether polymer dosing is used.

    ii. The designer may choose to conduct jar tests to determine the settling rate and corresponding SOR with multiple sludge samples. However, it is important to note that settling rate jar test results cannot be always directly replicated in full-scale plant settings. Therefore, the system should not be designed solely on lab-scale results; literature-reported values should also be considered when determining SOR.

    iii. The typical detention time for sizing the tank depth should be around 2-3 hours.

b. Supernatant Water System: The settling tank should be equipped with either a circumferential v-notch weir and collection trough, or a v-notch weir overflow launder with a collection trough, to transfer supernatant water by gravity into the supernatant return tank. The system must be sized and positioned to ensure the decanted water overflows without overfilling the tank, across the full hydraulic operating range.

c. Flow Distribution: The feed line from the balancing tank to the filter backwash settling tank should be positioned to promote gravity flow, control the water distribution, and avoid short-circuiting, ensuring efficient settling of solids. The exact location of the feed line depends on factors like the elevation difference, tank design, and operational requirements.

d. Water from the balancing tank should typically enter the settling tank from the bottom, at the centre, through a circular well to evenly distribute the flow in all directions. The central well should have a diameter between 15% and 20% of the total tank diameter. The inlet line should be designed with a tangential energy-dissipating mechanism to minimise turbulence.

e. Underflow Transport: If a hydraulic gradient is available, the underflow from the tank should be transported to the sludge balancing tank by gravity. If the hydraulic gradient is insufficient, pumped transfer is recommended. The design may also include a connection to a wet well for pumping thickened sludge to the balancing tank.

f. Sludge Discharge Monitoring: The sludge discharge should be equipped with a flow meter, and optionally a solid density meter, for monitoring, recording, and optimising the sludge flow before it enters the sludge balancing tank.

g. Polymer Dosing: Polymer dosing to the backwash settling tank feed is typically unnecessary if polymer is already dosed in the flocculation basin or pre-filter stage. However, the design may consider polymer dosing for the settling tank, depending on upstream and downstream process needs. Aspects of polymer selection and dosing systems are discussed in Section 6.2.1.

h. Performance Targets: The tank should be designed to remove 90% to 95% of suspended solids, with the following specific targets:

    i. Supernatant Quality: The turbidity of the supernatant water shall be less than 10 NTU, with lower turbidity indicating better solids removal.

    ii. Sludge Concentration: The settled sludge should have a solid concentration targeted between 0.5% and 2% (w/v). The exact concentration will depend on factors such as backwash water turbidity, settling time, and the effectiveness of the tank design.

6.2. Sludge Conditioning

Thickener and centrifuge feed are typically conditioned with polymer to destabilise the surface charge of sludge particles, causing them to flocculate into a matrix that is easier to settle and dewater than discrete particles. Polymer conditioning enhances both the efficiency and cost-effectiveness of the sludge treatment process. Selecting the right polymer is crucial for optimising dewatering performance and, to a lesser extent, thickening.

The primary mechanism by which polymer facilitates sludge conditioning is its bridging effect. However, the interaction between polymer solutions and sludge particles is complex, making the choice of polymer site-specific and reliant on empirical testing.

In addition to polymer, pH adjustment chemicals may be required for liquid sludge streams to achieve optimal settling and thickening results.

6.2.1. Polymer Selection and Dosing System

6.2.1.1. Polymer Selection

Polymer molecular weight, charge density, and charge type are key factors in selecting the appropriate polymer type and determining the optimal polymer dose for a specific sludge. Additionally, sludge properties, feed pH, and mixing conditions influence the choice of polymer and dose rate. Floc strength is a critical characteristic for sludge dewatering, as high shear stress may be necessary during mechanical dewatering to increase the cake solids content. Polymer properties play a significant role in enhancing floc strength under prolonged shear conditions.

Laboratory tests for polymer selection should begin with the sludge dewatering test procedures recommended by polymer vendors. These tests typically involve beaker pouring tests, where different polymers are evaluated at various dose rates to assess free water volume, solids capture rate, and floc strength for a given sludge sample. After selecting a polymer based on empirical lab-scale testing, polymer dose rates must be optimised during centrifuge commissioning and operation to achieve a specified clear centrate and a dry solid cake. It is important to note that laboratory polymer selection tests are generally not directly correlated with the centrifuge rotational speed (rpm) or G-force required for the desired results.

The settling behaviour of sludges during the thickening process should also be evaluated using the selected polymer, following the guidelines in Section 5.3.4. For a cost-effective solution, it is strongly recommended to use the same polymer for both thickening and dewatering processes.

A comprehensive assessment of potential impurities in polymers is essential for polymer selection, following the methodology outlined in *PRO-02564 Drinking Water Treatment Chemicals - Specifications, Monitoring and Assessment Procedure.* For products approved by Seqwater, the manufacturer's specified upper monomer concentration should be utilised instead of the "typical" monomer concentration. This approach ensures that allowable overall dosage and blending requirements are established, preventing monomer levels in drinking water from the water treatment plant (WTP) from exceeding ADWG health guideline values. Additionally, any water quality risks associated with the selected polymer monomer must be addressed, as detailed in Section 8.2.

6.2.1.2. Polymer Dosing System

Polymer batching and dosing systems shall be designed following the requirements stipulated in standard specification *SPE-00481 B-SPE-STD-011 Polymer, PAC, Pot Perm and Soda Ash Systems.* Polymer dosing for thickener and centrifuge feeds shall be flow paced using online sludge flow meter, solid concentration data derived from either laboratory or online analyses, and operator polymer dose set point in kg of polymer/ton of DS.

Proper mixing is crucial when dosing polymer into a settling tank or sludge thickener or mechanical dewatering system. Effective mixing ensures the polymer is fully activated and evenly distributed throughout the sludge, which enhances its ability to condition the sludge. This uniform distribution leads to improved solid settling and greater dewatering efficiency.

The optimal dosing location depends on the system layout, flow dynamics, and desired outcomes. Both the feed line and the feed well are viable options for polymer dosing for the thickener, each offering distinct advantages and considerations. In centrifuge systems, polymer dosing options shall be provided for both the feed line and directly into the equipment to achieve optimal performance across various scenarios.

Polymer vendors should be consulted for service water quality parameters for polymer batching. However, service water system design requirements are covered in *SPE-00481 B-SPE-STD-011*.

6.2.2. pH adjustment

Some plants may need to adjust the pH of the thickener liquid sludge feed to optimise thickening and dewatering processes while ensuring the required supernatant water quality. The need for pH adjustment depends on factors such as upstream processes, site-specific water discharge agreements, and supernatant water quality requirements.

The system pH plays a critical role in the stability of coagulant precipitates, the concentration of soluble coagulant metals in the liquid phase, and the soluble concentrations of other metals, such as manganese and iron, commonly found in source water. While many studies indicate that a neutral or slightly alkaline pH is ideal for sludge systems, the optimal pH can vary depending on site-specific conditions.

For example, if lime saturator sludges are added to the system, a higher pH may be required, provided there are no environmental discharge restrictions. However, experience within Seqwater has shown that higher pH levels can result in slower settling rates for alum sludge, which may necessitate higher polymer dosages. Furthermore, elevated pH levels could exceed the permissible soluble aluminium limits for environmental release, particularly if lime saturator discharges enter the sludge system.

6.3. Sludge Thickener

Sludge thickening, or the process of increasing the solid concentration in liquid sludge, is a critical step in sludge management. Sludge from clarifiers or sedimentation basins, and the filter backwash system is typically thickened by decanting water and allowing solids to settle.

Gravity thickening is the most common method, which is the focus of this standard. Other thickening techniques, such as flotation thickening, gravity belt thickening, and centrifuge thickening, are not covered here as they are not commonly used in drinking water treatment plants.

Gravity thickening is generally performed in a circular tank designed and operated similarly to a clarifier. Mechanical gravity thickeners are equipped with a settling area and an underflow cone or discharge hopper. These thickeners are designed for continuous operation, allowing for simultaneous filling, settling, and desludging.

The sludge thickener is typically above-ground or partially buried, and it is fixed, well-structured, and capable of being filled and discharged in situ. Water extracted from the sludge is collected through overflow launders at the top of the thickener and flows by gravity into the supernatant return system.

A sludge blanket is maintained at the bottom of the thickener to help concentrate the sludge. The depth of the sludge blanket is an operational variable, influenced by conditions such as temperature, with shallower depths typically maintained during warmer months.

The sludge thickener system requirement has been described under the following main components:

- Thickener feed line
- Centre feed well
- Overflow launders
- Sludge rake mechanism
- Discharge cone
- Thickener access
- Thickener instrumentation
- Decanted water outlet line
- Thickened sludge removal
- Thickener performance criteria
- Thickener process control narrative.

The designer shall consider the required elevation level of the thickener to ensure the extracted water can overflow through the weir across the whole hydraulic operating range and flow by gravity into the supernatant return feed tank without intermediate pumping. If the elevation level impacts ground level access to the outlet piping and valves, a suitable work platform shall be provided.

6.3.1. Size and Number

Sludge thickener number and size should include the following requirements:

a. The sludge thickener number shall be determined considering the site's redundancy philosophy, plant production capacity, availability and criticality requirements, site staffing, location and access (e.g. in fair and poor weather), reliability, operability, maintainability, and temporary sludge storage options. Typically, one (1) sludge thickener is considered because of its high capital investment and significant maintenance requirement.

b. Thickener tank diameter should be based on the Surface Overflow Rate (SOR) of a maximum of 1.2 $m^3/h.m^2$ or a solid loading rate of 2.5 $kg/m^2.h$, whichever is reached first. The following should also be considered in sizing the thickener:

   i. In determining the SOR of the thickener, the centre feed well area and support structure must be excluded.

   ii. For solids loading rate, the feed solid concentration should be considered about 0.2% to 2% (w/w).

   iii. Determination of the final thickener size should consider the construction methodology adopted, footprint restrictions, site limitations and ease of manufacturing and transport.

   iv. Where the source water is laden with algae, the SOR should be kept to a maximum of 0.8 $m^3/h.m^2$ or a solid loading rate of 1.6 $kg/m^2.h$, whichever is reached first.

   v. Designers may conduct jar tests to determine the settling rate and SOR. However, since jar test results may not be always replicable in plant conditions, the thickener should not be sized solely on lab results and should consider literature-reported values.

   vi. Pilot studies may be considered to determine the limiting solid loading rate for a particular sludge.

c. The depth of the thickener side wall and centre should be determined either by the thickener's detention time or through segmental depth calculations. According to the literature, typical side wall depths for thickeners range from 3 meters to 5 meters. The following considerations apply when determining thickener depth:

   i. Detention Time: Detention times typically range from 2 to 6 hours and are commonly used to calculate thickener depth, once the area is determined from the surface overflow rate or solid loading rate.

   ii. Verification with Segmental Depth Calculation: The depth calculation based on detention time should be verified using segmental depth calculations. This process includes the following:

      1. Freeboard Length: The length of the freeboard above the surface water.

      2. Clear Water Zone Length: The length of the clear water zone.

      3. Settling Zone Length: The length of the settling zone (note that the clear water and settling zones are often combined in literature).

      4. Thickening Zone Length: The length of the thickening zone or sludge blanket depth, which is typically between 0.5 to 2.5 meters as reported in literature.

      5. Centre Depth: The centre depth, which is calculated based on the cone slope once the tank diameter is determined. The thickener bottom is generally constructed with a floor slope ranging from 1:6 to 1:3 (a ratio of vertical drop to horizonal distance).

An example of the thickener depth calculation is provided in Appendix C.

6.3.2. Thickener Materials

The thickener tank should preferably be made of concrete. However, welded steel tanks may be suitable alternatives for smaller-scale installations. All tank designs must adhere to the applicable standards specified in Sections 6.1.1.1 and 9.5.

The selected materials for the thickener, fittings and attachments shall be chosen to ensure their suitability for use under site conditions and substantially immune to corrosion under all service conditions.

Additional protection should be considered with paint or coating, or other fit for purpose means of ensuring the required design life is achieved.

Refer to Section 9.5 and 9.7 for the materials of construction for the sludge thickener and coatings.

6.3.3. Thickener Feed Line

The thickener feed line starts from the sludge balancing or feed tank and ends directly into the thickener feed well. The sludge feed line comprises of equipment and instruments necessary to accurately feed liquid sludge into the thickener. Where feasible, the system should be designed for gravity transfer of liquid sludge to the thickener.

The design requirements are as follows:

a. The feed line should be appropriately sized to achieve sufficient velocity for effective polymer mixing across the full operating hydraulic range and to prevent sludge settling during operation. Line sizing, length, flushing, and pipe fitting guidelines provided in Section 9.8 should be considered.

b. The line shall also include a suitable mixing system if polymer is dosed directly into it, as this is crucial for ensuring proper mixing and interaction time. The mixing system may include a static mixer or a dosing quill or another alternative mixing mechanism. An alternative location for polymer dosing, specially into feed well, is discussed in Section 6.3.4.

   If a static mixer is used, a bypass line with isolation valves should be installed to allow for maintenance and cleaning in the event of blockages.

c. The feed line should enter the thickener via the feed well, positioned approximately 0.5 to 1 meter below the surface water level and directed tangentially to promote effective mixing.

d. The line shall include a flow meter for polymer dosing with flow pacing.

e. The line should be equipped with an online solid density meter, alternatively, solid content data can be obtained through laboratory analysis.

f. The line shall include an actuated isolation valve for automatic isolation and transfer operation.

g. The line shall be fitted with a service water line connection for flushing upstream of the isolation valve.

6.3.4. Feed well

A feed well, constructed from at least 5 mm steel thick plate with necessary alignment angles, shall be installed at the centre of the sludge thickener. The design requirements of the feed well are outlined as follows:

a. A deflector cone or other suitable mechanism should be installed at the bottom of the feed well to ensure even distribution of the feed across the entire bed at a controlled, slow rate. This will help minimise short-circuiting and reduce the formation of density currents.

b. The feed well shall include appropriately designed baffles to ensure proper mixing, which is especially important when polymer is dosed into the feed well.

c. If polymer dosing occurs in the feed well, the polymer should be introduced through a well-designed injection point, using a dosing quill for uniform distribution. The polymer should be injected tangentially or into the side of the feed well to promote effective mixing with the incoming slurry.

d. The feed well must be designed to dissipate energy and be adequately supported outside the centre cage to ensure smooth diffusion of the liquid sludge into the tank without causing disturbances.

e. The feed well shall be appropriately sized to allow for the de-aeration of the incoming feed, ensuring optimal thickening conditions.

6.3.5. Overflow Launders

The sludge thickener shall be equipped with integral wall overflow launders installed around the perimeter at the top to collect decanted water, which will then be transferred by gravity into the supernatant return tank.

The overflow launder system is required to meet the following requirements:

a. The launder should be designed as a circumferential v-notch weir and include an overflow box for discharge. While radial launders may be considered, they must be accompanied by a suitable walkway and platform to facilitate maintenance and cleaning.

b. It is recommended to install an adjustable weir around the tank's periphery, securely fastened to allow vertical adjustments of approximately 20 mm up or down. The weir must be sealed against the tank wall to prevent leaks.

c. The overflow launders shall be properly sized and positioned to ensure that decanted water can overflow without overfilling the thickener, across the entire hydraulic operating range.

6.3.6. Thickener rake arm mechanism

The thickener shall be equipped with a sludge rake arm and scraper mechanism to create sufficient motion in the settled sludge, ensuring gravity flow towards the underflow cone or collection hopper at the centre of the clarifier. The slow movement of the rake arm also helps prevent bridging of the solids and compacts the material into thicker sludge.

The requirements for sludge rake arm and scrapper mechanism design include the following:

a. The system shall include a drive shaft, trussed rake arms, scrappers, gearbox with electric motor and drive. A series of adjustable angle scrapper blades or curved spiral blades are recommended for the collection of sludge.

b. The thickener rake should consist of two rotating arms with scrapper blades with the rake arms positioned parallel to the thickener bottom. The sludge rake arms should be designed to sweep the entire thickener bottom approximately twice per revolution.

c. The rake mechanism should be designed to operate with a higher torque than a conventional clarifier. This torque should be monitored, as it provides an indication of the sludge bed depth and sludge density. A torque limit should be set to account for the maximum sludge load.

   SCADA should include alarms to alert operators when the torque exceeds 120% of the running torque (operator alert) and when it reaches 140% of the running torque (shut-off limit). Additionally, the peak torque should be advised by the driver supplier, and it is typically set at 200% of the running torque.

d. The drive must be fitted with an integrated overload protection with a soft start feature.

e. The rake drive mechanism must be suitable for operating for site conditions and installed within a sealed conduit box. The motor and gearbox must be direct coupled, utilise food grade oil and include a catchment tray to prevent oil spills into the thickener.

f. Designers should assess the need for vertical pickets on the rake arm to create horizontal flow, aiding in release gas from the sludge blanket and preventing floated sludges from forming without disturbing static conditions needed for settling.

g. The rake should operate as long as a certain liquid level is maintained in the thickener, even if the thickener feed is stopped. The thickener feed must cease if the thickener rake is not operational, or if there is a fault in the rake arm.

h. The sludge scraper blades should be constructed from a sacrificial material, such as polymer or wood, to prevent damage to the concrete floor. The blades should be set to maintain a minimum 10 mm gap beneath them, allowing for floor undulations and reducing the potential for wear on the floor.

i. Designers should evaluate the benefits of equipping the rake drive with a variable speed drive (VSD) to optimise rake speed. Additionally, the benefits of a rake lifting mechanism can be assessed to limit rake torque, thereby enhancing operational flexibility and facilitating maintenance and inspection.

j. The sludge rake arms shall be appropriately coated and galvanically protected to ensure resistance to corrosion and abrasion throughout their design life.

k. The design must prioritise ease of maintenance and maintainability.

6.3.7. Discharge cone

A discharge cone or hopper shall be positioned at the centre of the thickener as an integral part of the design. This cone will collect sludge from the underflow of the rake arm, ensuring controlled and efficient discharge of the thickened sludge. The thickener discharge cone is generally constructed with a floor slope ranging from 1:6 to 1:3 (a ratio of vertical drop to horizonal distance).

The discharge cone shall be equipped with scrapers (also known as centre scrapers) driven by the rake arm mechanism.

6.3.8. Thickener Access

a. Stairway access from the ground level to the top of the sludge thickener shall be provided. The stairway and platforms shall comply with the requirements of SPE-00366 *M-SPE-STD-002 Fixed Platforms, Walkways, Stairways and Ladders.*

b. The sludge thickener must have a full span bridge access walkway to the rake drive and any instrumentation fitted on the top of the thickener for access and maintenance purposes. The bridge structure must be supported by an appropriate mechanism designed to accommodate anticipated load within allowable limits.

c. The sludge thickener shall be provided with a peripheral walkway spanning the complete circumference of the thickener with handrails to allow cleaning and inspection of the launders. When radial launders are used, a suitable walkway and platform shall be provided to allow access for maintenance and cleaning of all radial launders.

d. All bridges and walkways shall be designed to prevent tools falling from heights and to prevent pooling of water in the low points. To facilitate maintenance and cleaning, a safe and reliable means of access to the thickener internals shall be provided.

e. Suitable access to all instruments shall be considered for calibration and maintenance.

f. A fixed davit arm, or an alternative suitable mechanism, should be mounted on the thickener to enable emergency rescue operations.

6.3.9. Thickener Instrumentation

The sludge thickener shall be equipped with instruments to provide monitoring, control and alarming in addition to flow and solid density meters required for inlet and outlet lines as covered in relevant sections.

It should include the instruments for the measurement of:

- Thickener sludge blanket interface level,
- Thickener water level.

The trends of the above instruments shall be recorded in SCADA to optimise the performance of the thickener.

The following shall be considered for the instrument devices:

a. Measurement of sludge blanket interface level: This is an important parameter to monitor and control to achieve the required decanted water turbidity and solid concentration in the thickened sludge. The sludge blanket monitoring device should:

    i. Be either an ultrasonic or an optical level sensor which has proven to be reliable in detecting the sludge blanket interface.

    ii. Be installed with the appropriate mounting method at a suitable location to obtain representative sludge blanket interface level. Typically, the device is mounted from the thickener bridge.

    iii. The operation and measurement must not be inadvertently affected by the presence of other equipment or instrumentation located in the vicinity.

b. Measurement of thickener water level: The device shall be installed to provide the thickener water level for monitoring, control, and alarming. The level device will assist to maintain constant inventory in the thickener, and it should:

    i. Preferably be a radar type level sensor.

    ii. Be installed with an appropriate mounting method, typically the device is mounted on the thickener bridge.

c. Measurement of rake torque and position: Rake torque must be continuously monitored using the method provided by the thickener or rake manufacturer. Any selected instrument must comply with installation, access, materials of construction and other general requirements as covered in standard specification *SPE-00352 E-SPE-STD-02 Instrumentation.*

6.3.10. Thickener supernatant water line

Thickener supernatant water outlet line shall be installed to transfer supernatant water to the supernatant return feed tank by gravity. The outlet line(s) shall be connected from the thickener overflow box.

The thickener supernatant water outlet line shall have the following characteristics:

a. It shall be appropriately sized with minimum flow resistance. The length of the line shall be kept to an absolute minimum, and fittings should be selected to reduce frictional losses.

b. It shall be designed with a continuous downward gradient to enable gravity transfer.

c. It shall be equipped with an online turbidity meter unless the turbidity meter installed in the supernatant return line is deemed sufficient for accurately predicting thickener supernatant turbidity. All turbidity meters shall comply with the requirements of SPE-00503 *I-SPE-STD-016 Turbidity Analysers.* Additionally, provisions should be made for manual sampling to facilitate turbidity measurement.

6.3.11. Thickened Sludge Removal

The removal of thickened liquid sludge from the discharge cone of the thickener requires careful attention to flow dynamics. This can be achieved either through a gravity transfer system with an open valve, provided there is suitable head, or by using progressive cavity pumps. However, potential issues such as line blockages and insufficient velocity must be addressed. To mitigate these risks, an automated flushing system should be incorporated to clear the sludge transfer lines after any stoppage.

Installing an additional wet well next to the thickener for sludge removal is generally not recommended due to the added complexity, equipment, and maintenance requirements.

Maintaining the optimal sludge blanket interface level within the thickener is crucial for consistent and efficient performance. Relying solely on the sludge bed level for removal can be unreliable, as demonstrated by Seqwater's experience with inaccurate sludge blanket interface instruments. Therefore, thickened sludge removal should be primarily controlled based on solid concentration readings from a solid density meter in the sludge removal line. The sludge removal process should automatically stop when the concentration falls below a preset value, as measured by this instrument. Alternatively, sludge removal may be controlled by a timer, based on operational experience.

To optimise thickener performance and ensure stable operation, it is recommended to adopt control strategies that maintain a constant inventory in the thickener. Feedback from the sludge blanket interface level and solid density meter should be used to regulate sludge removal rates and polymer dosing. Further details on these control strategies are provided in Section 6.3.14.

The design of the thickened sludge removal line, instruments, pumps, and flushing system shall generally adhere to the similar requirements as provided in Sections 7.1.3.2 and 7.1.3.3.

6.3.11.1. Sludge transfer line solid density meter

The solid density meter for a sludge thickener should be installed on the discharge side of the pump or actuated valve (as applicable) to provide real-time feedback on the solids concentration, allowing better control of valve or pump speed. Even if the pump or valve operates intermittently on a timer, this location remains optimal for tracking solids concentration during active pumping. When the valve is closed or the pump is off, the solid density meter will either show no flow or low solids concentration, which is acceptable if the meter is designed for low-flow or no-flow conditions.

Installing the solid density meter near the sludge blanket would result in measurement taken before effective thickening occurs, providing data that is less useful for managing thickened sludge removal. Similarly, positioning the meter on the suction side or upstream of the valve may also experience turbulence and pressure fluctuations, leading to unreliable readings.

In timer-based systems, the control system can store data and make operational adjustments during active cycles to optimise sludge removal performance.

To ensure accurate readings and minimise clogging, the solid density meter should be installed at an angle, away from turbulence, and be easily accessible for calibration and maintenance without disrupting normal operations.

6.3.12. Other Requiremetns

a. Sludge Withdrawal Valves: Suitable valves should be installed in the sludge withdrawal line to facilitate the draining of the thickener when maintenance is required.

b. Support Structure for Above-Ground Steel Thickeners: For above-ground steel thickeners, the structure should include sturdy legs and a robust ring beam to support both the tank walls and conical base. This support system must be designed to withstand the full tank contents, including the highest underflow specific gravity. Additionally, the design should ensure that access to underflow equipment beneath the thickener is unobstructed, enabling ease of maintenance.

c. Skimmer and Scum Baffles: The design should assess the need for a skimmer and scum baffles to effectively sweep the surface of the thickener. These should be designed to automatically remove scum and floating materials, which can then be directed to a scum box located at the periphery of the tank.

d. Overflow Management: Overflow from the thickener should be directed to a lagoon for temporary storage, where available, or to other suitable containment systems, based on site-specific conditions and requirements.

e. Thickener Bypass Connection: A bypass connection shall be considered to divert sludge to the centrifuge feed tank during extended periods of thickener downtime or during events of high turbidity in the raw water. This can be achieved through an offtake from the thickener sludge feed line and/or the basin desludging feed, fitted with appropriate manual isolation valves.

f. Polymer Dosing: Polymer dosing in a sludge thickener is crucial for optimising the solid-liquid separation process. Sections 6.2.1, 6.3.3, and 6.3.4 provide more detailed information on polymer selection, mixing, and dosing to ensure effective performance.

6.3.13. Thickener performance critiera

The following performance criteria for a gravity sludge thickener should be considered for the design and project documentation:

a. Thickener underflow solid concentration shall be at least double in comparison to feed solid concentration and therefore thickener sludge volumetric rate shall be reduced at least by 50% from that of thickener feed.

b. Solid concentration in thickened sludge should be in between 2 % to 5 % (w/v).

c. Thickener decanted water turbidity shall be less than 10 NTU under all operating conditions. Standard jar tests may be considered with or without polymer at various dosing rates to determine the limit of supernatant water turbidity.

6.3.14. Thickener Process Control Narrative

This process control narrative outlines the typical operation of a sludge thickener system, where the primary objective is to maintain a consistent solid inventory. Feedback is provided by the sludge blanket level and the underflow solid density meter (if included), which guide adjustments to sludge removal and polymer dosing as needed. This narrative should be read in conjunction with Sections 6.3.1 to 6.3.13. Additionally, the general control system requirements and control modes for the design of the sludge thickener system must adhere to the standards specified in Section 9.13.

Normal Operation

This control narrative covers typical start-up, steady-state, and shutdown operations when equipment and group controls are set to "Remote Automatic" mode.

Start-Up

The gravity sludge thickener system automatically starts when the feed tank level rises above the designated start/operation level. This triggers the following systems to operate simultaneously:

- Activation of the thickener feed pump and/or opening of the actuated valve (as applicable).
- Start of the polymer dosing pump and batching system (if applicable).

Thickener Feed Line

Upon activation, the thickener feed line actuated valve (for the gravity system) or feed pump checks the following conditions:

- The liquid level in the feed tank is above the operational low level.
- The liquid level in the thickener is not too high.

Once these conditions are met, the outlet valve opens for the gravity system, or the feed pump starts, along with the opening of the corresponding actuated valves to allow liquid sludge to flow into the thickener.

The feed pump transfers the liquid sludge at the commissioning-determined flow rate. The operator can adjust the pump speed within allowable limits based on the design flow rate used for sizing the sludge balancing or feed tank.

Polymer Dosing and Batching System

Polymer dosing control follows the information provided in standard specification SPE-00481 *B-SPE-STD-011 Polymer, PAC, Pot Perm, and Soda Ash Systems*. For the sludge thickener, the polymer dosing flowrate setpoint (in L/h) is calculated based on the liquid sludge flow rate (in L/s), solid concentration (in %), polymer batch concentration (in %), and the polymer dose rate (in kg polymer/ton of dry solids). The controller adjusts the polymer dosing pump speed to match the setpoint, with feedback from the polymer dosing flowmeter.

Thickener Sludge Blanket Interface Level

The thickener should operate at an optimised sludge interface level, as determined during commissioning. This level may be adjusted seasonally (e.g., higher during summer or winter). If the sludge blanket interface level rises, operators may need to adjust the polymer dosing or increase the sludge removal time or pump speed (as applicable), especially if the underflow density is high.

Thickener Rake Mechanism

The thickener rake should operate whenever the liquid level in the thickener is above the operational level, regardless of the feed line or thickener status. Operators can adjust the rake speed via SCADA to optimise thickener performance (if this feature is incorporated). The rake arm can also be manually stopped through SCADA if necessary.

Thickener Supernatant (Overflow) Water Transfer Line

Thickener supernatant water overflows from the thickener through the launders. When the thickener is in operation, the transfer line allows supernatant water to flow through the overflow weir drain and into the supernatant return tank via gravity. The system continues to operate until the supernatant return tank reaches a high-high level.

Thickened Sludge Removal

The thickened sludge removal pump starts, or the actuated valve opens either on a timer or based on the sludge blanket interface level when feed line remains open. The set sludge removal flow rate, as determined during commissioning, is adjusted within specified limits using feedback from the underflow solid density meter (if present). A high solid concentration signal will indicate high solids, triggering an increase in removal time or pump speed (as applicable) within allowable limits, and vice versa.

At the end of each operational cycle or during stoppage, the design should consider provisions of automatic water flushing of the sludge transfer line into the centrifuge feed tank to remove retained thickened sludge.

Steady State

Once started, the thickener and polymer dosing system will operate automatically and continuously. Operators will monitor the feed solids concentration, thickened sludge concentration, rake torque and supernatant turbidity, using either online instruments, laboratory data (as applicable), or visual inspection. The sludge removal pump speed or timer period will be automatically adjusted based on the solid concentration as outlined above.

Shut down

A normal shutdown sequence will be initiated when low-level or high-level signals are received from the respective tanks. Upon activation, the thickener feed pump will stop, or the actuated valve will close, and the polymer dosing system will shut down. The feed and thickened sludge transfer lines will then be flushed according to the design specifications. After the flushing cycle is complete, the thickener feed pump and sludge transfer line will be stopped (if they haven't already been), and the flushing valves will be closed. However, the rake is not connected to the shutdown system and will continue to operate until the thickener level drops below the operational low level.

Abnormal Operation

When installed, the turbidity meter on the supernatant line and the solid density meters on the sludge removal line will trigger alarms if the supernatant turbidity exceeds the set point or if the underflow solid concentration falls below the allowable limit. If turbidity reaches a high-high level, the thickener feed will be stopped. Stopping the feed pump or closing the valve will also shut down the polymer dosing system.

If the underflow solid concentration reaches a low-low level (detected by the solid density meter, if used), or if the sludge blanket interface or thickener water level drops to a low-low point, the sludge removal pump will be tripped or the removal line valve will be closed.

If the solid concentration in the thickened sludge removal line reaches a high-high level, automatic actions should include stopping or reducing the sludge feed, triggering alarms, initiating line flushing, stopping polymer dosing, and adjusting rake speed, depending on the design. If these actions are ineffective, the system may be shut down to prevent damage and ensure safe operation.

The thickener water level transmitter will trigger alarms if the water level falls outside allowable limits. A high-high water level will trip the feed pump or close the gravity feed valve. The same actions will apply to high-high levels in the centrifuge feed tank or supernatant return tank.

High rake torque will trigger an alarm if it exceeds the operational range. A high-high torque condition will stop the rake, which will also trip both the feed and sludge removal pumps.

7. Dewatering Processes

The general objective of dewatering is to separate liquid wet sludge into solids and liquids and thus reduce the sludge volume with the aim of waste minimisation. In other words, dewatering is defined as a process to increase the solids concentration of residuals (by weight) typically in the 15% to 25 % range for alum sludge.

Dewatering processes can be broadly classified under the following two categories:

- Mechanical dewatering
- Non-mechanical dewatering

There are several processes available under each of the above broader categories which are discussed in the following sections.

The selection of a dewatering process cannot be made in isolation, as it is influenced by both upstream processes and subsequent disposal practices. Choosing an appropriate dewatering method requires a comprehensive evaluation of the entire solids handling system, which may involve a complex assessment of various combinations of unit processes for thickening, conditioning, dewatering, and final disposal.

Factors such as field testing, laboratory analysis, initial cost estimates, organisational technology preferences, site-specific disposal arrangements, and the location and layout of the site must all be considered when selecting a dewatering process. This specification does not provide a specific preference or recommendation for any particular dewatering process.

It is recommended that the project team determine the most suitable dewatering process for the specific site or application through the required assessments.

The following sections detail the design requirements for mechanical dewatering via centrifugation and provide high-level design considerations for key non-mechanical dewatering processes.

7.1. Mechanical Dewatering

A wide variety of mechanical dewatering processes are available such as:

- Centrifugation
- Belt Filter Press
- Plate and Frame Filter Press
- Vacuum Filtration
- Screw Press.

At Seqwater, all mechanical dewatering devices currently utilised are centrifuges, and they are expected to remain the preferred choice for mechanical dewatering in future projects. As a result, this standard specification focuses solely on the requirements for centrifuges, specifically decanter centrifuges.

However, this specification does not restrict capital projects from assessing and selecting alternative mechanical dewatering methods if they offer a more optimal solution for a specific application.

7.1.1. Decanter Centrifuges

In general, a centrifuge is a mechanical device that uses rapid rotation to apply centrifugal force to its contents, separating components with different densities. The rate of separation is governed by principles such as Stoke's Law. For more detailed theoretical information, including explanations of Stoke's Law and other relevant concepts, please refer to Appendix D.

Centrifuges can be classified based on rotor design or intended use, with the decanter centrifuge being one of the most common types. A decanter centrifuge continuously separates solids from liquids in slurry or liquid sludge. When the slurry is introduced into the decanter, centrifugal force generated by the high-speed rotation of a horizontal cylindrical bowl separates the solids from the liquids. The difference in densities causes the sludge solids and liquids to form two distinct layers. The solids, known as the "cake", and the clarified liquid, or "centrate", are continuously discharged separately from the unit.

In addition to the rotating horizontal bowl, a decanter centrifuge also incorporates a screw conveyor or scroll. This scroll rotates at either a slightly lower (lagging scroll) or higher (leading scroll) speed than the bowl, depending on the design. Decanter centrifuges are sometimes referred to as scroll centrifuges. At Seqwater, the majority of centrifuges use a leading scroll design, although many decanter centrifuges in the industry utilise the lagging scroll design.

The differential speed between the bowl and the scroll, measured in Revolutions per Minute (RPM), is one of the key parameters that control centrifuge performance. For more details on this, refer to Section 7.1.4.

Typically, liquid sludge enters the decanter centrifuge through a stationary feed pipe that extends to the centre of the rotating conveyor's hollow shaft. The feed is then distributed through ports in the shaft into a pool within the rotating bowl. The bowl is supported by bearings at both ends and tapers into a conical section that serves as the dewatering beach.

As the bowl rotates, the settled solids are conveyed by the scroll towards the conical section, where they are discharged through 360° outlet ports. These solids are then directed downward into a sludge cake discharge hopper. Meanwhile, the centrate (clarified liquid) moves in the opposite direction, exiting the unit through an adjustable collection port. The position of this port determines the liquid depth in the bowl.

The main components of a decanter centrifuges include:

- Bowl
- Scroll or conveyor – with various flight and pitch designs.
- Main motor
- Scroll motor (or back drive motor)
- Feed pipe
- Solid cake outlet ports
- Liquid dischare ports
- Solids diversion valve
- Gearbox
- Enclosure
- Instruments and control.

The minimum requirements for the design, selection, and installation of a decanter centrifuge system are outlined under the following key items:

- Cetrifuge design specification
- Centrifuge feed system
- Automatic flushing system
- Polymer dosing system
- Centrate collection system
- Solid cake collection system
- Process contol and monitoring.

7.1.2. Centrifuge Design Specification

When designing a new facility or retrofitting an existing facility that incorporates centrifuges, consideration should be given to the plant's size, availability requirements, criticality and level of resourcing dedicated to operation (e.g. 24 hour servicing, vs 24 hour monitoring, vs remote sites etc.). These factors may influence control strategies, redundancy requirements, and equipment selection.

Appendix E includes details of the Template *TEM-00410 B-TMP-STD-014 Centrifuge Datasheet* which is available for specifying key centrifuge design parameters.

7.1.2.1. Key Design Parameters

The key design parameters which affect the sizing and selection of the decanter centrifuges for sludge dewatering and associated support facilities are listed below:

a. Hydraulic Loading Rate (HLR) in m^3/hr,

b. Solids Loading Rate (SLR) in kg/hr,

c. Feed solids concentration range % (w/v) or % (w/w),

d. Sludge characteristes (type, % ash content, feed temperature, pH and other physical/chemial properties),

e. Desirable hours of opration per day (batch or continuous and operational requirements),

f. Target centrate quality (NTU),

g. Target cake solids % (w/w),

h. Target solid capturing capability %,

i. Space and operational environment (internal/external location, atmospheric conditions (e.g. marine environment),

j. Site power availability/constraints.

7.1.2.2. Centrifuge size and number

When sizing centrifuges, the following factors should be considered:

a. Ensure the system can consistently dewater and treat the maximum daily design hydraulic and solids loading rates, as determined by the following criteria:

   i. HLR and SLR should be determined based on the criteria as outlined in Section 3.2, including thickened sludge discharge rate and solid concentration from the thickener.

   ii. The selected centrifuges should typically be operated up to 80% of nameplate capacity to obtain the driest cake and cleanest centrate under maximum HLR or SLR conditions. However, this percentage should be confirmed with the centrifuge vendor.

   iii. Any expected growth in treated water demand not addressed in Section 3.2 should be considered.

   iv. If the daily operating hours are unknown, plan for 20 hours per day to handle future load requirements per centrifuge.

b. Provide redundancy by arranging duty and standby centrifuges for typical water quality and treatment processes. However, the final number of centrifuges should be determined based on the site's availability and criticality requirements, its size, operating hours, alternative sludge storage options during peak events, staffing levels, site location (including accessibility in varying weather conditions), and the overall reliability, operability, and maintainability of the system.

c. One (1) standby centrifuge should be maintained during normal operations. However, it is acceptable for the standby centrifuge(s) to be used in duty/assist operation during peak water quality events, provided this mode of operation has been incorporated into the design and assessed during the design phase.

7.1.2.3. Safety Requirements

The following safety requirements must be followed for the selection and design of centrifuge equipment:

a. The selected centrifuge must comply with all safety requirements as specified in standard *EN 12547 Centrifuges – Common Safety Requirements*.

b. Centrifuges must be of the closed vessel system type so that moving parts are not accessible during operation, and all danger zones must be inaccessible.

c. Vibration monitoring devices must be provided to monitor vibration of different rotating components including bearings.

d. In addition to the PLC program, an additional speed monitoring device must be included to prevent the bowl exceeding the set point speed. The differential speed between the bowl and the scroll must not be allowed to exceed the defined boundary limit.

e. The rotor of the selected centrifuge must be designed with a safety margin against fatigue and cyclic load failure.

f. Nosie level should be ≤85 dB at 1 m distance when the centrifuge is at full load.

g. Bowl bearing temperature must not exceed the limit and be protected with appropriate instruments.

h. Scroll torque must be monitored and prevented from exceeding the limit.

i. The centrifuge lube oil system must include suitable protection against low oil level, low flow, and high differential pressure across the lube oil filter.

j. Centrifuges must be programmed by the vendor preventing the centrifuges operating outside the specified torque, speed, vibration, temperature range and the ranges must be un-changeable.

k. All electrical and control devices which may be subjected to wet, outdoor or chemical exposure shall be protected to a minimum of IP56 as per standard specification SPE-00352 *E-SPE-STD-001 Electrical Design and Construction*.

7.1.2.4. Materials of Construction

a. Centrifuge bowl, scroll, feed pipe, scroll flights, and weir plates must be of 316 Stainless Steel (SS).

b. Regardless of the point above, superior materials of Duplex SS shall be considered for bowl and scroll if pitting corrosion is evident or likely for new centrifuges.

c. To achieve abrasion wear protection, solids discharge ports and scroll flight tips shall be coated with tungsten carbide or equivalent.

d. Diverter gate at cake discharge to drain liquid during start up must be of 316 SS.

e. Centrifuge frames shall meet material, structural and coating requirements of standard specification SPE-00367 *M-SPE-STD-001 General Mechanical* and SPE-00348 *M-SPE-STD-004 Protective Coatings*.

7.1.2.5. Other Instllation and Mechanical Requirement

a. Centrifuges must be supplied as a complete unit, including all ancillary equipment such as a local control panel, programmable logic controllers, frequency controllers for both motors, vibration monitoring, solids line diversion valves, lubrication system, polymer dosing connections, and discharge chutes for both cake and centrate.

b. The centrifuge must be supplied as a fully assembled unit, securely mounted on a base frame with vibration isolators to minimise vibrations and ensure proper balance during operation.

c. The centrifuge unit must include flanged connections for all pipework, along with vibration-damping joiners to absorb and mitigate operational vibrations.

d. The decanter centrifuge should be installed indoors in an elevated position, allowing the solids cake to fall by gravity into the collection system or conveyor belt, while the liquid phase is directed by gravity to the receiving tank.

e. Both the cake and centrate chutes must be equipped with air vents that maintain the same pressure and include provisions for flushing the vents to prevent blockages.

f. The solids discharge line must be fitted with an automated flow diversion valve to facilitate liquid discharge during start-up, shutdown, and flushing procedures.

g. The centrifuge must be equipped with a suitable lifting point to allow for crane lifting and ensure safe and efficient maintenance operations.

7.1.3. Centrifuge Feed System

The centrifuge feed system shall be fully automated and be capable of supplying sludge feed to the centrifuges within the design HLR and SLR.

The centrifuge feed system includes the following key items:

- Centrifuge feed tank
- Centrifuge feed pump
- Centrifuge feed line
- Flushing system.

7.1.3.1. Centrifuge Feed Tank

Here the centrifuge feed tank is essential for maintaining consistent, stable operation by buffering fluctuations in the feed flow and solid concentration, enabling continuous operation, optimizing centrifuge performance, and protecting equipment. Its use leads to more efficient separation, reduced wear on machinery, and better overall system control.

The centrifuge feed tank will typically receive flows from the thickener and occasionally from sedimentation basins or clarifiers and supply feed to the centrifuges.

The requirements for the design of the centrifuge feed tank will be similar to sludge balancing tank or thickener feed tank as mentioned in Section 6.1.1.1 with the following exceptions:

a. The tank should be sized appropriately considering the following information:

   i. Damping of Flow Variations: The tank should be large enough to buffer fluctuations in feed flow, ensuring a consistent solid concentration for the centrifuge, which is critical for efficient operation.

ii. Suitable Tank Level Margins: The tank should be sized to accommodate the necessary level margins that allow for the centrifuge to start and stop without issues, whether operating in duty/standby or duty/assist mode. This ensures that there is always enough feed available to the centrifuge during transitions.

iii. Extra Capacity for Unforeseen Variations: The tank should include additional capacity to handle unexpected variations in feed rate, process upsets, or maintenance activities, preventing interruptions in centrifuge operation.

iv. Minimum Residence Time: The tank should provide a minimum residence time of 4 to 8 hours under average inflow conditions. This allows for effective buffering of flow fluctuations, promotes proper mixing, prevents solids from settling, and supports a consistent feed to the centrifuge. The exact residence time should be determined based on factors such as the variability of the feed rate, the operating schedule and the centrifuge's design capacity. The primary goal is to maintain a uniform solid concentration and optimise the overall centrifuge performance.

b. The feed tank should be fitted with a level transmitter to control the start and stop of the centrifuge at different tank levels. In addition, a redundant level transmitter is recommended, as the centrifuge operation is dependent on the feed tank level. If a second level transmitter is not provided, back-up high-high and low-low level switches must be included to prevent overflow and ensure proper pump and centrifuge protection.

c. The tank must be equipped with one or more mixers to maintain uniform sludge consistency. In the event of mixer failure, as identified by current monitoring or other means, an interlock should be in place with the centrifuge feed pumps to prevent inconsistent or irregular feed, particularly with higher solid concentrations, from being directed to the centrifuges.

7.1.3.2. Centrifuge Feed pump

Duty/standby centrifuge feed pumps must be provided to draw liquid sludge from the centrifuge feed tank and feed to the centrifuges. Normally, where centrifuges are designed to operate in duty/standby or duty/assist modes, one dedicated pump shall be included for each centrifuge train. If a common standby feed pump is selected, appropriate automation and control logic must be implemented to enable seamless and reliable changeover between pumps as needed.

The pumps should be supplied via a common suction header with a single header manual isolation valve from the centrifuge feed tank.

The pumps shall be progressive cavity types to feed to the centrifuges. The progressive cavity pumps shall be selected and designed with the requirements as stipulated in *SPE-00506* *M-SPE-STD-016 Progressive Cavity Pumps*.

A VSD controlled motor must be included to provide the flexibility to achieve the required variable HLR and SLR.

Each pump suction line shall incorporate an actuated isolation valve and a service water connection for automatic flushing, which shall also include a separate actuated isolation valve. Refer to Section 7.1.3.4 for additional details on the flushing system.

A pressure relief valve must be installed immediately downstream of the pump discharge. The relief vale shall be sized for a full flow relief. Ideally, the relief line should return to the top of the centrifuge feed tank. Alternatively, it may discharge within the pump bunded area, provided that appropriate level indication is installed.

Bunding is recommended to contain any potential leaks or spills from the centrifuge feed pumps and to prevent uncontrolled discharges into the environment,

7.1.3.3. Centrifuge Feed Line

The centrifuge feed line or pump discharge pipework shall incorporate the following:

a. Feed Line size, length, blockage cleaning, flushing, sampling, and other relevant components should be designed in accordance with the general requirements specified in Section 9.8.

b. Each pump shall have its own actuated valve, manual valve, flow meter and solid density meter at discharge end to make an independent centrifuge feed line or train.

c. Each actuated valve shall be fitted with position switches for feedback and pump start and stop.

d. Flowmeters shall be used to measure the sludge HLR for each centrifuge. A solid density meter should be considered to measure the SLR, provided the reliability of the instrument can be ensured. This data should be used to automatically determine the appropriate polymer dosing.

e. A flexible hose connection must be included to the centrifuge to accommodate movement in the centrifuge and avoid the transmission of vibration.

f. A pressure switch should be included to permit the shut-down of the pump should the discharge line become blocked, or the isolation valve be closed.

g. Pressure relief valve inlet line shall be kept as short as possible and needs to be designed for flushing of the inlet line when the feed line is flushed.

h. A polymer dosing point must be included at an appropriate location on each pump discharge line to ensure effective mixing. An additional polymer dosing point must be included directly to the centrifuges. Refer to Section 6.2.1 for guidance on selecting the appropriate polymer. The polymer dosing system must comply with the requirements outlined in *SPE-00481* *B-SPE-STD-011 Polymer, PAC, Pot Perm and Soda Ash Systems*.

7.1.3.4. Centrifuge Flushing system

An automatic system for the flushing of the pump, pipework and centrifuge must be provided before shutting down or starting a centrifuge, or for periodic flushing after the defined hours of operation. This will be achieved by incorporating appropriate isolation valves and line connections using the site service water. The flushing system shall be designed with the following requirements:

a. Flushing water connections must be provided on the suction and discharge of each pump, and directly on each centrifuge following the centrifuge supplier requirements.

b. Service water lines for each connection point must be fitted with solenoid or actuated valves, check valves and manual V-notch ball or diaphragm valves for manual flow control.

c. Service water supply pressure and flow requirements must be assessed and designed with a suitable pressure regulator (if needed), flow meter and pressure gauge.

d. Where the source water does not have sufficient pressure or flow for flushing, include a booster pump and the operation of the booster pump shall be interlocked with the centrifuge feed pump operation.

e. In addition to the above requirements, where a potable water system is used for flushing, it shall be protected using a reduced pressure zone (RPZ) backflow prevention device – only proprietary back flow prevention devices shall be used. Double check valves are not considered adequate double layer protection. Arrangement must comply with the *AS / NZS 3500 – Plumbing and Drainage* and the *Queensland Plumbing and Wastewater Code*.

7.1.4. Cake Conveying & Disposal

The dewatered sludge cake conveying system shall transport sludge from the centrifuges to the stockpile area or skip bins. The cake should be discharged directly onto a horizontal conveyor for efficient transfer. If elevation is required to reach a higher storage level, the design may incorporate a vertical conveyor or an alternative lifting mechanism to facilitate this transfer.

Depending on site disposal arrangements, the cake receiving or transfer conveyor may connect to a second discharge conveyor for stacking or for discharge into skip bins. However, the design should prioritise the use of a single conveyor wherever possible.

The conveyor system design includes the following requirements:

a. The cake conveyor system should preferably use a belt type for longer distances and a screw type for shorter distances.

b. If a screw conveyor is selected, it must be enclosed along its entire length with suitable covers.

c. All discharge chutes from conveyors (where applicable) must be vertical to prevent material build-up; inverted pyramid chutes are not acceptable.

d. The conveying distance should be minimised by adopting an optimal layout for centrifuge installation. Installing the centrifuge at an elevated level, with the collection system at ground level, can significantly reduce issues related to cake blockage in the belt system.

e. The conveyor inclination angle must prevent the cake from flowing under its own weight.

f. Proximity motion detectors should be installed to alert when driven elements are not rotating.

g. For storage or skip bins, the design should consider multiple discharge chutes per transfer conveyor, each equipped with automated slide gate valves and dedicated level sensors. The system should enable automated bin filling – either based on level detection or timed operation - by sequentially filling individual bin compartments.

h. For skip bin design, internal systems should be incorporated to evenly distribute sludge cake throughout the bin, preventing heaping. Additionally, drainage arrangements should be included to facilitate the removal of liquid from the bins without requiring the tailgate to be opened. If floor drains are present beneath the bins that connect to the supernatant return system, these bins shall be exclusively designated for water treatment plant (WTP) use.

i. The use of shared bins with other customers shall not be permitted due to contamination risks; such bins may contain sewage cake or industrial waste, which could compromise the WTP process train in the event of leakage or overflow.

j. For the skip bin option, an emergency stockpile location should be included in the design. Stormwater must be diverted away from all sludge stockpile areas to prevent contamination and ensure environmental compliance.

k. For the skip bin option, the design should incorporate a covered collection area to prevent rainwater ingress, particularly during the wet season. The area should also be bunded to minimise the risk of unintentional spills to the environment.

l. The design must provide operational flexibility (i.e., interconnections) to ensure that the failure of a single piece of equipment in the cake conveying and disposal area does not lead to a complete shutdown of the dewatering process.

m. Conveyors must have pull wires or similar safety switches to stop them in an emergency.

n. The design must specify an effective and maintainable belt cleaning system for belt conveyors.

o. Permanent access platforms, ladders and walkways must be provided for the operation and maintenance of the conveyors as per SPE-00366 *M-SPE-STD-002 Fixed Platforms, Walkways, Stairways and Ladders*.

p. General Safety requirements for conveyors must comply with *AS 1755 Conveyors - Safety requirements* and *AS/NZS 4024.3610 Safety of machinery Conveyors - General requirements*.

q. Belt conveyors must meet additional safety requirements of *AS/NZS 4024.3611 Safety of machinery Conveyors - Belt conveyors for bulk materials handling*.

r. Belt conveyors must adhere to elastomeric material requirements for belts in accordance with *AS 1332 Conveyor belting—Textile reinforced and AS 1333 Conveyor belting of elastomeric and steel cord construction*.

Detailed design requirements and equipment for the movement and handling of cake skip bins or for collection and spreading of stockpiled sludge by trucks for ultimate disposal are not included in this specification document.

7.1.5. Centrate line

Centrate or clear water collected from the centrifuges should generally flow to the receiving tank by gravity as per the design.

If the system is designed to run more than one centrifuge at the same time, centrate discharge must be connected to a common header for gravity flow to the receiving tank which is commonly a thickener feed tank, or in some cases, a filter backwash balancing tank, as applicable.

Each centrifuge discharge connection line and the combined header should be sized considering the maximum HLR and minimum cake moisture content. Line sizing must rule out any possibility of centrate overspill at the collection point under all operation conditions.

The centrate line and header shall have connection points to flush deposited solids with service water if centrifuges yield centrate with high solid content during commissioning or in other periods.

The centrate line for each centrifuge must be installed with an online turbidity meter and associated alarms for continuous monitoring of centrate quality. The turbidity meter serves an early warning system, alerting operators to any decline of dewatering performance.

In addition, a suitable manual sample collection point must be provided on each centrifuge's centrate line.

7.1.6. Process Control and Monitoring

General requirements for the design, procurement and installation of control systems have been provided in Section 9.13. A Functional Description for centrifuge systems shall be developed to cover control requirements in detail following the standards and templates as provided in Section 9.13.

The vendor shall deliver the centrifuge system as a package unit. The package system must include the vendor PLC to control and monitor the centrifuge. Package system controllers are typically changed in/out by Seqwater and Seqwater does not maintain the controller and its configurations.

If the vendor intends to use already developed proprietary control blocks, then prior permission shall be obtained following the requirements in SPE-00361 *I-SPE-STD-013 Control Systems Design and Construction*, see further requirements of equipment specification and maintenance in Section 7.1.6.2.

7.1.6.1. Functional Requirements

a. Each centrifuge shall have its own locally mounted Local Control Panel (LCP).

b. Each LCP shall enable an operator to toggle equipment between the following equipment modes via a hardwired switch located on the LCP (See Section 7.1.6.3 for more detail regarding equipment control modes):

- Off
- Local
- Remote.

c. The control system shall permit centrifuges to automatically start-up or shut-down as required by the system demand - based on the level of centrifuge feed tank, see Section 7.1.6.4 for details.

d. The start-up sequence for centrifuges shall be developed considering the overall sludge system control and operation philosophy.

e. Where multiple centrifuges are installed, the start-up sequence of each centrifuge shall be clearly defined.

f. Decanter centrifuge systems shall be automated with control measures suitable to enable continuous operation with the assumption that plants will be unmanned. Manual intervention will be available in the event of system failures; however, it may not be immediate.

7.1.6.2. PLC & HMI Functionality

a. Centrifuge systems shall be controlled by a dedicated vendor package PLC including centrifuge start up and shut down. However, the plant or main PLC will initiate centrifuge start up and shut down sequence.

b. The layout and functionality of Human and Machine Interface (HMI) screen shall be determined by the centrifuge manufacturer.

c. The centrifuge supplier shall obtain Seqwater agreement for the communication protocol among vendor PLC, plant PLC and SCADA. Communications to the plant PLC should be routed through an approved network segregation device, ensuring a robust firewall that protects Seqwater control systems from cybersecurity threats.

d. The control system and HMI screen equipment shall be as per the requirements of *SPE-00342 I-LST-STD-001 Control Systems Prescribed Equipment*. Where the prescribed equipment requirements cannot be met for the third-party control package, advice from Seqwater must be sought before proceeding.

e. If control equipment is selected outside of the list of *SPE-00342 I-LST-STD-001 Control Systems Prescribed Equipment*, spare process controllers, that can be readily swapped in/out, shall be provided as part of the project. Seqwater generally does not maintain such control equipment and its configurations, and it shall be agreed and documented as part of the project.

f. Where multiple centrifuges are installed, there shall be a dedicated vendor PLC and HMI for each centrifuge.

g. Table 2 summarises the minimum signal requirements from the centrifuge system to the SCADA.

7.1.6.3. Control Modes

Centrifuge system shall support the following equipment control modes as defined *in* SPE-00361 I-SPE-STD-013 Control Systems Design and Construction:

a. Local Mode – In Local Mode the centrifuge system is controlled at the LCP. This mode shall only be used during centrifuge system commissioning and maintenance.

b. Remote Mode – When the locally mounted mode switch is selected to "Remote", control of the centrifuge system shall be selectable remotely. Remote Mode shall support remote selection of the following group modes:

   i. Remote Manual – operators select which centrifuges or dewatering trains to operate, and the setpoints at which they operate. In this mode, hardwired and trip interlocks remain functional.

   ii. Remote Automatic – the centrifuges or dewatering trains will start and stop automatically with the operator setpoints at which they operate. The plant PLC determines which and how many centrifuges or centrifuge trains operate. In this mode, hardwired and trip interlocks remain functional including process and start permissives.

c. Switching equipment control modes and group modes of individual centrifuges or dewatering trains shall be available independently of all other installed centrifuges.

d. Equipment and devices shall be programmed to include Disable and Maintenance Functions as described in SPE-00361 I-SPE-STD-013 Control Systems Design and Construction.

7.1.6.4. Typical Process Control Narrative

This section outlines a typical process control philosophy for the operation of a centrifuge or a centrifuge train. It does not cover the operation of cake conveying and disposal to skip bins or stockpiling. For a complete understanding, this section must be read in conjunction with Sections 7.1.1 through 7.1.4.

The control narrative is described based on:

- Automatic sludge feed control from solid loading.
- Automatic sludge feed control based on hydraulic loading.
- Automatic sludge feed control based on centrifuge feed tank level (if necessary).
- Differential speed control based on scroll torque set point. Alternatively, adjustment of scroll torque set point or pool depth based on centrate and cake quality.

Normal Operation

This process control narrative includes start-up, steady state and shut down operation when the equipment and group control are in "Remote Automatic" mode.

Start up

A dewatering sequence will start when the centrifuge feed tank level reaches the centrifuge train start level and the plant PLC sends a signal to the centrifuge package PLC to start the centrifuge. This will initiate the automated start sequence of the centrifuge as designed by the vendor. The centrifuge will begin its lubrication and water flushing at a certain sequence which may take approximately 10 to 20 minutes depending on the design requirements, which are not detailed here.

The solid cake conveyors will start prior to the centrifuge starts. Prior to the drive motor start up, an audible siren sounds for a defined time together with a flashing light.

The sludge feed pumps and polymer dosing pumps cannot start until the centrifuge has completed its startup sequence. Once the centrifuge PLC sends 'ready for feed' signal to the Plant PLC, the centrifuge is ready for production. To start the centrifuge train, the following additional conditions need to be met under "Remote Automatic" Mode:

- Centrifuge feed pump(s) and feed tank mixers are healthy.
- Feed line flow meter and solid density meter are healthy.
- Polymer dosing, flushing water and conveyor systems are healthy.
- No high-high level alarm from centrate receiving tank.
- Where used, dry cake receiving skip bins are not full.

Once all start permissive signals are met and the Plant PLC receives “feed on” signal from the centrifuge PLC, the actuated valves in the sludge line, sludge feed pump and polymer dosing pump will start in a defined sequence, each operating at its calculated speed. The feed sludge pumps shall be provided with VSDs to allow the feed sludge flow rate to be controlled by the plant PLC based on the sludge feed flow meter and solid density meters and the nominated maximum operating HLR and SLR for each centrifuge train. The polymer dosing pumps shall be flow paced with real time HLR and SLR and be fitted with VSDs to maintain the operator input dose rate (kg polymer/ton of DS).

Where more than one centrifuge or centrifuge train is designed to run at the same time, they will start and stop automatically in the same way, one by one as the set level in the centrifuge feed tank increases or decreases.

Where needed, an automated process can be included in the design to have separate HLR and SLR set points for power peak and off-peak periods. Different “Start” levels form the centrifuge feed tank that are intended to allow for lower centrifuge run time, lower pumping and lower power usage during the peak period and higher usage at off-peak period can included. These set points may need to be adjusted to suit varying seasonal and operational conditions.

Steady State

Once started, the centrifuge and centrifuge train will operate automatically and continuously adjust the differential speed (or scroll speed) to meet the scroll torque set point as set by the operator. The scroll torque set point provides indication of optimum solid loading on the scroll conveyor. The differential speed cannot exceed the boundary limit as programmed in the Centrifuge PLC.

The operators will monitor the solid cake quality through manual sampling unless dry solid cake sensors are installed. The operators will monitor centrate quality from online turbidity instruments. If incorporated in the vendor package design, a multivariable model predictive control system or an Artificial Intelligent (AI) system will adjust the torque set point automatically to achieve the target solid cake percentage and/or centrate quality (in NTU) based on real-time instrument feedback.

Shutdown

The centrifuge train will continue to operate unless an interlock becomes active, or the centrifuge feed tank goes to “Stop” or low level.

A normal centrifuge shut down sequence will be initiated when the low-level signal is received from the centrifuge feed tank. When this occurs, the sludge feed pumps, and polymer dosing systems will shut down. The main plant PLC will automatically send a ‘feed off’ pulse to the centrifuge PLC, and the centrifuge PLC will drop ‘feed on’ confirmation. The centrifuge PLC will then automatically call the flushing system, the service water supply line will be opened after the feed sludge diverter gate is closed. The centrifuge will be flushed with all waste being diverted through the Centrate line. Once the flushing sequence is complete, the centrifuge will shut down.

When the plant PLC raises a ‘feed off’ pulse the sludge pump will do a staged ramp down to a nominated minimum flow rate for flushing of the feed line pipework and the pump. Suction side sludge feed valve will be closed, and pump suction and discharge side service water line will be opened for flushing. After completion of the flushing cycle, the sludge feed pump will be stopped (if not stopped already) and flushing valves will be closed.

The conveyor system will continue to run for a preset time before stopping after the last centrifuge has shut down.

Abnormal Operation

Centrifuges or centrifuge trains will stop by interlocking the sludge feed pump and polymer dosing pump, and raise alarms in SCADA to alert the operator when any of the following conditions are met:

Centrifuge package:

- High and High-high torque on scroll drive.
- High differential speed between Bowl and Scroll drives.
- Bowl speed exceeding the overspeed set point.
- High temperature on bearings.
- High vibration of rotating components from the measurement of RMS (root mean square value).
- Low flow on lube oil cooling circuit.
- Low level on the lube oil tank.
- High and high-high differential pressure on the lube oil filter.
- Common fault including main drive scroll drive faults.
- Activation of an Emergency stop button.

Other interlocking conditions will include:

- Centrifuge feed tank registers low-low level signal.
- Cake conveyor fails or stops, belt out of alignment signal from belt conveyor tracking, pull wire switches and usage of local E-stop.
- High pressure from pressure switch (or pressure transmitter) in the sludge pump discharge line. Pump suction/discharge actuated valve fails to open. These will direct to start the standby centrifuge train (if available).
- Fault in polymer dosing system.

In addition, key alarms from a centrifuge train are set out below:

- Sludge flow rate outside minimum/maximum constraints.
- Sludge feed line flow meter or solid density meter fault.
- High-high level alarm from centrate receiving tank.
- High-high and low-low level alarms from centrifuge feed tank.
- Centrifuge feed tank mixer stops or register fault signal or shows high or low current.
- Polymer dosing deviation alarms from polymer dosing flow meters.

7.1.6.5. Vendor package and SCADA Interfacing Parameters

Designers shall refer *to* SPE-00361 *I-SPE-STD-013 Control System Design and Construction* for general details on SCADA monitoring and trending requirements. Table 2 provides minimum parameters and signals associated with centrifuge systems that must be required to interface/output to on-site SCADA.

Table 2 Summary of Centrifuge Parameters and Signals (to be fed to SCADA) for Monitoring, Control and Trending Requirements.

Parameter	Measure	Function	Signals
Date & Time	dd/mm/yyyy hr:mm:ss		

Parameter	Measure	Function	Signals
Instantaneous sludge flow to each centrifuge (Sludge feed line flowmeter)	L/s	Monitoring only	1 signal per centrifuge
Total instantaneous flow to the centrifuge system	L/s	Monitoring only	None (sum of individual flow meters)
Feed solid concentration	%	Monitoring only	1 signal per centrifuge
Solid loading rate	kg/hr	Monitoring only	None (Calculated)
Bowl speed	rpm	Adjustable & Monitoring	1 signal per centrifuge
Differential speed	rpm	Monitoring only	1 signal per centrifuge
Scroll torque	N.m	Monitoring only	1 signal per centrifuge
Scroll torque set point	N.m	Adjustable & Monitoring	None
Vibration	Hz or others	Monitoring only	At least 1 signal per centrifuge
Bearing temperature	ºC	Monitoring only	At least 1 signal per centrifuge
Power consumption	kW	Monitoring only	1 signal per centrifuge
Total power consumption	kWh	Monitoring only	None (totalised from active centrifuges)
Hours run per centrifuge	h	Monitoring only	None (calculation), Re-settable after maintenance
Centrate quality	NTU	Monitoring only	1 signal per centrifuge
Cake dryness (if applicable)	% solid	Monitoring only	1 signal per centrifuge
Pool depth or weir size (if applicable)	cm	Monitoring only. Adjustable (if applicable)	1 signal per centrifuge
Polymer batch concentration	%	Adjustable & Monitoring	None
Polymer dose rate	kg/t of DS	Adjustable & Monitoring	None
Polymer flow rate	L/h	Monitoring only	1 signal per centrifuge
Centrifuge fault	Alarm	Monitoring only	No of signals per centrifuge decided by the design

In addition, signals from centrifuge feed pumps, positions of actuated valves for feed and flushing lines, pressure instruments, cake conveying system instruments, centrifuge feed tank instruments must be included to on-site SCADA.

7.1.6.6. Interlock, Trip and Alarm Mangement

All interlocks shall be defined in the Functional Descriptions following the requirements provided in Section 9.13. Conditions and failures in each centrifuge (and interfacing systems) shall trigger appropriate responses in all affected systems including control systems of other plant areas, overarching control systems, and external control systems.

Before the centrifuge system is tripped as an action, the following should be considered:

- Are there alternate control parameters that can be applied?
- Can the last known operating parameter be held safely?
- Can the centrifuge or associated system shut down to a safe state immediately, or is a ramp down necessary?
- Could an alternate design prevent the need for a trip in the first place and its impact to plant operation?

Seqwater Standard Specifications SPE-00361 *I-SPE-STD-013 Control System Design and Construction*, SPE-00356 *I-SPE-STD-005 High Priority Alarms & Interlocks Management*, and SPE-00357 *I-SPE-STD-006 Alarm and Event Management* outline the philosophy that should be applied to the assessment of alarm priority and management of interlocks and alarms.

7.1.7. Testing and commissioning requirement

In addition to vendor specific requirements, centrifuges shall be tested and commissioned in accordance with the general requirements provided in Section 9.16.

The contractor shall be responsible for validating all test results and demonstrating system-wide performance. Comprehensive training must be provided by the centrifuge supplier to Seqwater's key operations and contracting personnel prior to process commissioning.

All centrifuges shall undergo a continuous operational testing and commissioning period following installation to demonstrate their performance. In addition to the requirements specified in the aforementioned standards, testing activities shall include the following:

a. Installation, machine internals, mechanical, electrical, utilities etc.

b. Hydraulic testing:

   i. Flow to individual centrifuges not exceeding maximum HLR allowed.

   ii. Flow to all centrifuges at the same time not exceeding each centrifuge maximum HLR allowed.

c. Flushing system testing with the design service water flow and pressure.

d. The performance testing shall include recording the following parameters as a minimum:

- Maximum HLR and SLR,
- Bowl speed range,
- Differential speed range,
- Scroll torque range and control gradient,
- Solid content in the feed, cake and centrate,
- Inlet and outlet pressure,
- Vibration in solid and liquid side under nominal condition,
- Motor current for main motor and back drive motor,
- Bearing temperature at oil and liquid side,

- Gearbox oil temperature,
- Power consumption,
- Saving the commissioning parameter in the control unit (as applicable) including HLR, SLR and polymer type and dosing.

e. Functional testing following SPE-00360 I-SPE-STD-011 Control System Testing including start/stop, changeover from duty/standby to duty/assist operation (if incorporated), design hydraulic and solid concentration ranges.

f. Upon completion of the proof of performance tests, the contractor must provide a comprehensive proof of performance report. This report should include process optimisation details and comply with all requirements outlined in SPE-00346 B-SPE-STD-003 Commissioning Requirements.

7.1.8. Performance Guarantee

The centrifuges shall meet the performance requirements as stated in this standard and project documentations for a period identified by the project.

The following performance criteria shall be included in project documentation:

a. Solid capture capacity shall be above 98% for all conditions including the design maximum HLR and SLR.

b. Centrate water quality ranges in NTU, should target to achieve maximum around 50 NTU.

c. Dry solid percentage in cake shall be above 16% (w/w).

d. Estimated power consumption at the design operating conditions.

e. Equipment sensitivities to variations in voltage and current.

f. The performance of automated flushing system under the design and operating conditions.

7.2. Non-mechanical dewatering

Non-mechanical, or natural, dewatering is one of the simplest methods for reducing the water content in liquid sludges generated by water treatment plants. This approach primarily relies on evaporation and drainage to remove moisture. Evaporation is mainly driven by solar radiation, air temperature, humidity, and wind. Drainage, or gravity dewatering, takes place as water is drawn downward through gravity and capillary action. Common non-mechanical dewatering methods include the use of sludge lagoons, sand drying beds, wedge wire filters, and geotextile dewatering tubes (geotubes).

Design aspects of sludge lagoons, drying beds and geo-tubes have been included in this section.

7.2.1. Lagoons

Lagoons are the most common and oldest method to manage liquid sludges in drinking water treatment plants. Where lands are readily available and inexpensive, the use of lagoons may be a cost-effective means of storage, thickening, dewatering, and drying particularly for small treatment plants.

In sludge lagoons, sludge is deposited into large, shallow basins where water is gradually removed through a combination of settling, drainage and evaporation, resulting in a concentrated sludge layer that can be more easily handled or disposed of. Solids settle at the bottom of the lagoons and liquid can be drawn at various levels depending on the design.

Lagoons can be classified by their mode of operations. Lagoons used as a final disposal site for settled solids are classified as permanent lagoons. Lagoons which are cleaned periodically are categorised as dewatering lagoons.

Lagoons can be also used for temporary storage of liquid sludge particularly when the normal plant operation cannot manage additional liquid sludges produced from occasional high turbidity source water, equipment breakdowns and process upsets.

The effectiveness of lagoons depends on the method of operation. Alum coagulant sludges are reported to achieve up to 10-15% of dry solids when operating the lagoon at full water depth for 1 to 3 months.

Lagoons must be designed to prevent the release of contaminants into the environment, including surrounding land and groundwater, as well as to prevent overflow and infiltration.

The following factors apply for the design of lagoons, regardless of the operation mode or method:

a. Lagoon sizing should be based on a design assumption of an average three-month filling period followed by a three-month drying period.

b. An approximate dry solid loading rate of 40 kg/m^2 for an average 100 days of filling should be considered for the determination of lagoon area. A higher loading rate of up to 80 kg /m^2 for an average 100 days filling should be considered for dry regions. Additional area required for access roads and berms should be added to determine the final lagoon area.

c. Lagoons typically have shallow structures with a depth of up to 1.5 m and earth embankments no steeper than 1 in 2.5. Lagoon embankments must be properly constructed with impermeable liners to prevent seepage and erosion, ensuring appropriate slope stability and drainage.

d. A complete installation should be provided with several small lagoons operated in staggered cycles for filling, drying and emptying.

e. Lagoons must be lined to limit the risk of ground water contamination. The designers should select suitable impermeable lining materials preferably bituminous based geomembrane, polyethylene, and geosynthetic layer. Additionally, measures to identify damage to the lagoon liner during maintenance or operational activities should be provided.

f. Lagoons should be equipped with weir boards or penstocks at multiple locations to manage decanted water and rainfall. The collected water should then be directed to the supernatant return tank or other designated locations, as per site-specific requirements.

g. It is recommended to fence off the lagoons as the sludge at the surface may form a crust which may appeared to be dry but may not withstand the weight of a person or livestock. Fencing is also necessary to deter large wild animals and, where applicable, to prevent access by cane toads.

h. Fauna egress ramps and poles should be installed to provide wildlife with an escape route if they enter the lagoon area.

i. Where lagoons are used for temporary storage of liquid sludge, algal bloom and breeding of cane toads must be monitored and avoided due to the potential risk of toxin presence where decanted water is returned to the head of the plant.

j. Where cane toads may be anticipated, the installation of a suitably sized screen should be considered in the liquid sludge return line to capture tadpoles, toadlets and eggs as they may contain toxin which is poisonous to human.

k. A freeboard of 0.5m is generally recommended from the invert of the outlet to the top of bank.

l. Level instruments with alarms should be considered to prevent overflows into the environment.

m. Emergency overflow connections should be provided preferably at least 0.2 m from the top of the bank where there is a risk of flooding.

n. Provisions should be made to safely collect the samples of the lagoon contents.

o. Sludge removal methods should be assessed, and the lagoon should be designed accordingly.

p. Egress ladders are generally recommended for lined lagoons.

q. Site storm water drains shall not be connected to lagoons.

7.2.2. Drying Beds

Drying beds are rectangular areas with a perforated false floor made of sand and gravel which allows liquids to drain into an underdrain collection system. These beds feature a simple design and operation, enabling water to drain through the bed and evaporate, leaving behind a relatively dry solid sludge that can be disposed of or undergo further treatment. In some cases, adjustable decanting facilities are necessary to discharge the supernatant water and/or rainwater.

The process used in drying beds is known as gravity dewatering, where the extent of dewatering achieved depends on factors such as the drying duration and weather conditions.

Drying beds can handle sludge from sedimentation basins, clarifiers, or thickened liquid sludge from a thickener. They are typically most effective in small treatment plants and in regions with low to moderate rainfall.

The following should be considered for the design of drying beds:

a. Drying beds should have a perforated false floor, consisting of approximately 100-200 mm of sand with an effective size of 0.3-0.75 mm, supported by about 250 mm of gravel and an underdrain system. Alternatively, a porous concrete floor may also be considered.

b. A minimum of four drying beds should be provided to allow for the discharge of sludge to one bed while the others are draining, drying, and being cleaned.

c. The design must include an efficient system for transporting liquid sludge from various sources to the drying beds, using appropriately sized gravity or pumped pipelines. At the drying beds, the sludge must be evenly distributed through a network of inlet manifolds, gated outlets, or spreading arms. The layout should ensure uniform sludge loading, operational flexibility, and ease of maintenance.

d. The underdrain system should include slotted plastic pipes , covered with coarse gravel and/or perforated clay.

e. The underdrain system should be designed accordingly with pumps, valves, and turbidity meter to return the collected water to the head of the plant, release to the environment or to the sewage system following the site requirement.

f. An impermeable liner, such as a plastic geomembrane, should be installed at the base of the bed to seal it and prevent any potential environmental leaching.

g. Coagulant sludges should be applied in a thin layer, typically between 150-300 mm, and spread across multiple drying beds. Sufficient time should be allowed between spreading cycles to permit proper draining, drying, and removal of the sludge.

h. The drying bed area for coagulant sludge should be estimated at approximately 25 kg of dry solids/ m^2. year with additional space allocated for access roads. If the sludge is conditioned with polymer before being applied to the drying beds, performance can improve by up to 50%. For a conservative design, the net evaporation rate (i.e. evaporation minus precipitation) should also be factored in when sizing the drying beds.

i. Liquid sludge should generally be conditioned with polymer before being spread onto the drying beds. Proper mixing of the polymer with the liquid sludge should be ensured through appropriate provisions and assessments. Further information for the type of polymer and polymer dosing are provided in Section 6.2.1 and potential risk to water quality from polymer monomer are discussed in Section 8.2 which must be taken in considerations.

j. A suitable mechanical means, such as a front-end loader or another method acceptable to the site, should be incorporated into the design for the removal and final disposal of dry sludge. An access road should also be provided to facilitate sludge removal without causing damage to the bed. Additionally, some sand may be lost during the sludge removal process, so periodic replenishment of sand will be necessary.

k. An overflow system should be included in the system considering wet weather periods.

7.2.3. Geotubes

Geotextile tubes or bags offer a natural physical separation between the solid and liquid fractions of sludge. The captured solid sludge can be transferred for disposal, while the liquid permeate can be returned to the supernatant return system or discharged into the local sewage system. Geotubes must be replaced when full, and the materials used are typically not recyclable and are disposed of in landfills.

Geotubes present an attractive alternative for sludge dewatering, especially for small treatment plants or during high turbidity raw water events to manage peak flows. However, dewatering with geotubes can be slow, depending on the volume and characteristics of the sludge, making them unsuitable for applications requiring rapid, continuous dewatering.

Key design considerations for a geotube system include:

a. The site should have a minimum of three geotubes to ensure continuous availability, with one reserved for drying or replacement when full. The final number of geotubes should be determined based on factors such as size, available space, filling and draining periods, feed rates, staffing, operability, and maintenance requirements.

b. Each geotube should be sized to accommodate solid loading for 3–6 months, based on average hydraulic and solids loading rates. The supplier's recommendations should also be considered when determining the size and number of geotubes.

c. Polymer should be dosed to the liquid sludge feeding the geotube to enhance dewatering performance, ensuring proper mixing as per Section 6.2.1 and 8.2 for polymer selection, dosing rates, and potential water quality risks.

d. Geotubes must be placed in an impermeable bunded area, with the bund capacity equal to 110% of the total capacity of the geotubes under fully stretched conditions.

e. The bund must have a sump to collect permeate water, which should be returned to the plant's head via pumps, equipped with level instruments for automatic operation.

f. A concrete bund with a suitable coating is recommended. If impermeable liners are used, precautions must be taken to prevent damage from machinery during solid cake collection and geotube replacement. The bund should also be designed with appropriate slopes to direct permeate to the sump.

g. Geotubes must not be filled above the safe fill height recommended by the supplier. A visual monitoring string line may be installed to track the height.

h. A cutoff pressure switch should be considered in the feed line to prevent overstretching or overfilling the geotubes.

i. If permeate is returned to the plant, the return line must be equipped with both a flow meter and a turbidity meter.

j. Hard stand or equivalent access roads should be provided for machinery to access the bunded area for the removal of solids and geotubes.

k. Provisions must be made for safe access to the geotubes at multiple locations to enable cutting and facilitate effective drying of the solid cake prior to removal.

l. Stormwater runoff into the geotube bunded area must be prevented.

m. For very small systems, geotubes may be placed in skip bins for easy solid transportation, provided that a permeate return or discharge system is designed accordingly.

n. Geotube materials must be inert to biological degradation and non-reactive with liquid sludge properties. Key physical, mechanical, and hydraulic properties should be tested according to recognised standards, with results readily available.

o. The geotube feed line must meet the same requirements outlined in Section 6.3.11 for thickened sludge removal lines, branching to each geotube with isolation valves for changeover during draining, drying, or solid removal.

p. Consider placing geotubes on plinths or raised platforms to facilitate free drainage into the geotube bund. If the geotube is placed directly on the bund floor, the separation rate may be affected by the liquid contained in the bund.

q. The design should account for high turbidity water management during the ripening or early operational phases, which are typical of new geotubes.

8. Supernatant Return System

Without adequate management, the return of spent filter backwash water and/or supernatant from the sludge thickening and dewatering system increases the risk of pathogens bypassing the treatment plant. Additionally, the return water may introduce high levels of polymer monomer, toxins from potential algae blooms, high organic loading, metals, and solids into the main treatment processes, potentially impacting plant performance.

If anaerobic conditions develop in the return system, they may release iron, manganese, colour, and organics, which can impart undesirable tastes and odours to the supernatant. If recycled, this could adversely affect treatment plant performance. Therefore, return water must be carefully managed with an appropriate design.

The supernatant return system should, at a minimum, include the following main equipment, instruments, components, and fittings:

- Supernatant return or holding tank,
- Level instruments for the return tank,
- Supernatant return water pump,
- Flow meter,
- Online turbidity meter,
- Return line pipework and valves.

The following typical features are to be incorporated for the design of a supernatant return system:

a. Supernatant return tanks should be sized and designed using criteria similar to those for the sludge balancing tank, as outlined in Section 6.1.1.1 with the exception that mixers are generally not recommended for these tanks. Tanks must be equipped with a suitable level transmitter to prevent overflow, pump dry run, and to control pump start/stop, as well as ramp-up of pump speed, if applicable.

b. Centrifugal pumps should generally be considered for the supernatant water return lines, with a duty/standby arrangement. The pump system design should include VSD-controlled motors to provide flexibility in achieving the required flow rates.

c. Supernatant water return pumps must have an interlock to run only when raw water pumps run or when raw water flowmeters register certain flows.

d. The return line size should be optimised considering pumping energy requirement and available pump size, frictional head loss, back pressure from the head of the plant and other minor head losses.

e. The return line must include an actuated valve for automatic isolation of the system when pump stopped. The line should also include a check valve with several manual isolation valves for the isolation of pumps, tanks and the line at suitable locations.

f. Any water returned to the head of the plant shall be upstream of any raw water inlet of clarifiers or sedimentation basins, and upstream of coagulation and any other processes designed to remove solids and dissolved organics from raw water.

g. Supernatant return water system shall be designed to be well mixed with the raw water.

h. Return flows should be designed to be continuous, as intermittent flows can hinder the optimisation of coagulation. The target return flow should generally be less than 5% of the raw water flow and should not exceed 10%. However, in exceptional cases, as outlined in SPE-00320 *Water Treatment Plant (WTP) and*

Supply System – Process Validation Standard, a return flow greater than 10% of the raw water flow may be acceptable for a period, provided a suitable risk assessment is conducted and supervision is ensured.

i. Flow-paced coagulation dosing must account for the return water flow rate to ensure optimised coagulation.

j. The supernatant water return line shall include a flow meter and a turbidity meter, located immediately downstream of the supernatant return pumps.

k. The online supernatant return flow meter and turbidity analyser shall trigger a shutdown of the supernatant pump station via an interlock, activated by critical limits associated with either of these instruments.

l. Waste from the turbidity analyser should be returned to the supernatant water feed tank. However, insertion-type instruments should also be considered for the return line.

In addition, depending on the specific process units of the water treatment plant, additional treatment steps - along with necessary equipment and instrumentation may be necessary to further polish the supernatant water before it is recirculated to the head of the plant. These steps may include advanced filtration, pH adjustment or other conditioning processes to ensure compatibility with upstream processes and to maintain overall treatment performance and efficiency.

8.1. Supernatant Return Water Quality

Supernatant return flow and water quality are identified as Critical Control Points, as inadequate management of these factors can increase the risk to the main treatment processes and compromise the quality of the treated water.

Seqwater document SPE-00320 *Water Treatment Plant (WTP) and Supply System – Process Validation Standard,* provides the default values for online flow and turbidity parameters for operational target, action and critical limits. These values shall be incorporated into the system design.

Furthermore, the design shall typically incorporate strategies to maintain optimal pH levels, manage soluble iron and manganese content, and address the seasonal occurrence of algal blooms. It is also essential to monitor and control the levels of acrylamide monomer and DADMAC monomer. The following section provides detailed information regarding acrylamide monomer content.

8.2. Acrylamide Monomer Risk

Polyacrylamide polymer is typically dosed as a flocculation aid, filtration aid, sludge thickening agent, and sludge dewatering agent. The monomer acrylamide is known to have adverse health impacts when present in drinking water above the allowable limit. Note that the monomer remains in commercially available polyacrylamide products in small quantities as an unreacted substance after the polymerisation process.

Polyacrylamide products used at a water treatment plant (WTP) must not cause any exceedance of the Australian Drinking Water Guidelines (ADWG) health limit for acrylamide monomer, which is 0.2 µg/L. Exposure of drinking water to acrylamide monomer should be minimised to the lowest level technically achievable. It is essential that the acrylamide monomer content in the supplied polyacrylamide remains as low as possible, and the polymer should never be overdosed in an attempt to shortcut process performance improvement.

The overarching document PRO-02564 *Drinking Water Treatment Chemicals - Specifications, Monitoring and Assessment Procedure* includes Seqwater's tendering and operational chemical quality requirements for polyacrylamide.

The polyacrylamide dosing required for sludge treatment is generally directly proportional to the solid content in the feed water of the sludge thickening and dewatering system, or the mass of dry solids per unit volume of treated water. High turbidity in raw water, along with increased coagulant dosing for turbidity or organics removal, will result in higher solid production from the treatment plant. This, in turn, increases the risk of elevated acrylamide monomer levels in drinking water if the polyacrylamide dosing is not properly managed.

At a water treatment plant (WTP), a monomer mass balance should be established based on actual polymer dosing, flow rates, and solid concentrations. During the design phase, a theoretical monomer mass balance should also be calculated, considering raw water flow, theoretical solid production, estimated polyacrylamide dose rate, supernatant return flow, and the acrylamide monomer content in the supplied polyacrylamide. This ensures that the polymer dose rates for the sludge handling process and the supernatant return water flow can be appropriately managed during operation, without exceeding the maximum allowable monomer concentration in the treated water.

The design should incorporate dynamic monomer mass balance calculations into the SCADA system, utilising data from online instruments. This will allow operators to be alerted when the theoretical acrylamide monomer concentration approaches the allowable limit. An example of the theoretical monomer mass balance calculation, which can be used during the design phase, is provided in Appendix A.

8.2.1. Removal of acrylamide

Acrylamide monomer risk in drinking water becomes a concern during periods of high solid production per unit volume of treated water. If alternative sludge management options to minimise acrylamide risk are not feasible, removing acrylamide from the supernatant return water or centrate can be considered as a last resort.

Granular activated carbon has been reported as effective for removing acrylamide from drinking water, as stipulated in the *Australian Drinking Water Guidelines (ADWG), NHMRC 2011*. However, its efficiency in removing acrylamide from water is not well established in the literature.

Although limited, chemical oxidation for the degradation of acrylamide in water has been explored. Among common oxidants used in water treatment, ozone shows good potential for acrylamide degradation without generating undesirable by-products. In Seqwater's WTPs, ozonation in the main treatment process has been shown not to result in detectable acrylamide in the final produced water, even when the supernatant return water contains acrylamide. Laboratory tests using a prototype ozone reactor at Seqwater demonstrated effective breakdown of acrylamide monomer.

Chlorine is also capable of degrading acrylamide but should not be used for supernatant water treatment due to the risk of producing disinfection by-products (DBPs) from reactions with organic matter. However, the potential for acrylamide monomer degradation from chlorine used in pre-filtration or primary disinfection processes requires further evaluation.

Potassium permanganate ($KMnO_4$) has been found effective in removing acrylamide. The primary by-product of this oxidation process is manganese oxide, along with small amounts of fatty acids and ammonia. The concentrations of these by-products are generally low and do not impact drinking water quality. However, before selecting potassium permanganate as an oxidant, jar tests should be conducted to assess its effectiveness in reducing acrylamide levels. These tests should identify the optimal dose rate, evaluate the influence of other chemicals on oxidation rates, and analyse the type and concentration of by-products in relation to the specific quality of the supernatant water. It is also essential to assess how these factors might impact drinking water quality. Special attention should be given to the concentration of unreacted potassium permanganate, as it could result in pink water, which may not be suitable for recycling back to the head of the plant.

If potassium permanganate is selected, the batching and dosing system shall be designed following the requirements stipulated in SPE-00481 *B-SPE-STD-011 Polymer, PAC, Pot Perm and Soda Ash Systems.*

9. General Requirements

This section provides a number of general requirements for the design and installation of the sludge management system with reference to other applicable standards.

9.1. Safety in Design

In order to incorporate safety in design, Seqwater has a number of Engineering Standards that shall be used in the design and review of new assets and installations and modifications to existing systems:

- *PRO-01617* X-PRO-STD-009 Engineering Design, Construction, Operation and Maintenance
- *PRO-02140* X-PRO-STD-013 Engineering Technical Hazard Study

These standards include discussion of the various risk assessments/reviews, studies, and management systems that must be in place/demonstrated and used to satisfy legislative and Seqwater requirements.

All designs and installations shall ensure due consideration is given to reliability, accessibility, maintainability, constructability, operability and mitigation strategies. This shall be demonstrated through auditable design documentation, reviews, communication, meetings and established processes/procedures.

Design decisions and residual risks in design shall be supported, reviewed and accepted in accordance with FRA 00014 *Enterprise Risk Management Framework*.

9.2. Engineering Units

Where not specified in this document, equipment and instrument units shall be in accordance with the requirements of *AS 1000 International System of Units (S.I) and its Applications* and *SPE-00361 I-SPE-STD-013 Control Systems Design and Construction.*

9.3. Design Life

Seqwater relevant *Asset Class Plans* and standard specification *SPE-00367 M-SPE-STD-001 General Mechanical* shall be referred for the design life of valves, pumps, flow meters, pipework, protective coatings, tanks and other equipment. For the design life of electrical equipment refer to *SPE-00352 E-SPE-STD-001 Electrical Design and Construction.*

9.4. Site Conditions

The term Site Conditions is intended to mean any of the ambient conditions, process conditions, ground conditions and operating conditions that may be reasonably expected to occur during normal operation.

Ambient conditions for mechanical, electrical and control equipment shall be specified from the following documents:

- *SPE-00352 E-SPE-STD-001 Electrical Design and Construction*
- SPE-00361 I-SPE-STD-013 C*ontrol System Design and Construction*

Design and construction shall allow all assets to operate continuously and uninterrupted between the minimum and maximum Site Conditions specified.

If not defined by Seqwater, Site Conditions for design and construction of process equipment shall be determined by the Designer or Contractor and submitted to Seqwater for approval.

9.5. Materials

Materials selected for tanks, thickener, rakes, mixers, piping and equipment shall be appropriate for their intended applications and compatible to site conditions. When the sludge is thickened, it may become more abrasive; and this shall be considered when specifying mechanical equipment.

If stainless steel is used for any equipment, passivation and pickling must be carried out correctly in accordance with *ASTM A380* to protect fabricated welded areas.

Where not specified in the specific section of this document, material requirements shall be sought from the following sources as a minimum:

a. Relevant Australian and industry standards and specifications for the material(s) selected.

b. Vendor and supplier recommendations and experience.

c. Safety Data Sheet (SDS).

d. *SPE-00367 M-SPE-STD-001 General Mechanical.*

e. *SPE-00366 M-SPE-STD-002 Fixed Platforms, Walkways, Stairways and Ladders.*

f. *SPE-00348 M-SPE-STD-004 Protective Coating.*

g. *SPE-00395 D-SPE-STD-001 Water Supply Networks Planning, Design and Construction.*

Materials used in equipment, piping, coatings, joints, and other components that may come into contact with supernatant return water must have appropriate certification to *AS/NZS 4020*. For further details, refer to the potable water compatibility section of *SPE-00367 M-SPE-STD-001 General Mechanical*.

Additionally, SPE-00367 M-SPE-STD-001 G*eneral Mechanical* shall also be referenced for H1-certified food-grade oils, greases, and HT-1-certified heat transfer oil applications.

9.6. Equipment Selection

In general, this standard specification does not specify the type and manufacturer of equipment (pumps, valves, mixers, instruments etc.) for a design. Where not specified, requirements shall be sought from the followings as a minimum:

a. *REG-01074 X-LST-STD-001 Seqwater Preferred Equipment*

b. *SPE-00367 M-SPE-STD-001 General Mechanical*

c. *SPE-00434 M-SPE-STD-009 Flow Meters*

d. *SPE-00430 M-SPE-STD-012 Chemical Dosing Pumps*

e. *SPE-00355 M-SPE-STD-013 Chemical Dosing Piping*

f. *SPE-00506 M-SPE-STD-016 Progressive Cavity Pumps*

g. *SPE-00342 I-LST-STD-001 Control System Prescribed Equipment*

Only circular vessels or tanks shall be selected for the sludge system. Rectangular or square vessels or tanks shall not be selected, as they create dead zones that hinder mixing and reduce system performance.

Improved energy performance of new equipment shall be considered in the equipment selection process as specified in the following documents:

- *PLN-00393* Seqwater Energy Management System and Plan

- PLN-00452 Corporate Energy Strategy

9.7. Colour and Coatings

Where needed, buildings, enclosures and shelters, pipes, tanks, fittings, fixtures, equipment and surfaces shall be coloured / coated in accordance with:

a. *SPE-00367 M-SPE-STD-001 General Mechanical..*

b. *SPE-00348 M-SPE-STD-004 Protective Coatings*

c. *WSA 201- Manual for Selection and Application of Protective Coatings.*

d. *AS 2312.1 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coating, Part 1: Paint coatings..*

e. *AS 2312.2 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings, Part 2: Hot dip galvanizing*

f. Other relevant legislation and Australian Standards, especially those referenced in the above documents.

9.8. Pipe Size, Fittings, Valves and Isolation

The following general considerations should be taken into account in the design for pipework, line sizing, blockage prevention and cleaning, valve selection, and related components for the sludge system:

a. Line Size and Blockage Prevention: Suitable line velocities should be considered in all pipework to manage sludge settlement, minimise head loss, and maintain asset integrity. The sludge system line size should not be smaller than DN 100 mm to reduce blockage risks, based on Seqwater's successful operational experience. However, some literature recommends a minimum line size of DN 150 mm for pumped systems and DN 200 mm for gravity systems.

   Excessively large pipe diameters should be avoided, as they can lead to lower velocities, promoting settling. To balance preventing settling and minimising pipeline wear, a line velocity of around 1.5 m/s is recommended.

b. Pipe Length and Elbows: Pipe length should be minimised wherever possible. Long-radius elbows should be used to reduce flow resistance and the potential for blockages.

c. Valves for Sludge Transfer: Manual or actuated valves for the sludge transfer line should be full-bore types, preferably plug or pinch valves, to ensure proper flow and minimise the risk of clogging.

d. Line Cleaning and Blockage Removal: The pipework should be designed to allow for blockage removal via high-pressure water or jet rodding. Cleanouts such as plugged tees or crosses should be installed for easy access and maintenance.

e. Flushing: The design should incorporate appropriate isolation valves, fittings, and line connections to enable flushing after each stoppage, as required.

f. Drainage, Air Relief, and Sampling: Manual drain valves should be installed at low points, and air relief valves should be installed to prevent air buildup and facilitate drainage. Regular maintenance of air relief valves is necessary to ensure proper function and prevent debris or solids from affecting their performance.

g. Sampling: A sample line should be provided, equipped with appropriate valves, and located in an accessible area for the collection of liquid sludge samples for analysis.

h. Coarse Screening: Where necessary, a coarse screen (approximately 25 mm aperture) should be included in the line to capture large objects. Provisions should be made for easy cleaning and inspection of the screen.

i. Service water pressure, flow and backflow prevention: The system design must ensure adequate pressure and flow for flushing and pressure cleaning (e.g., Jet rodding). If potable water is used, any service water connections must include a Reduced Pressure Zone (RPZ) backflow prevention device.

j. Pipework and Fittings: All pipework and fittings shall comply with the relevant standards, including:

   i. SPE-00367 M-SPE-STD-001 General Mechanical

   ii. SPE-00323 M-SPE-STD-003 Valves for Water Applications

   iii. Additionally, compliance with applicable industry and Australian Standards is required.

k. Flexible Connections: Flexible connecting sleeves should be designed and installed as best as practical to avoid large losses of liquid in the case of a failure.

l. Isolation: Mechanical isolation of piping and pump system shall conform to the requirements of *SPE-00367* M-SPE-STD-001 *General Mechanical*.

9.9. Civil Works

Civil works shall comply with the requirements of WSA 03 *Water Supply Code of Australia*, *SPE-00395 D-SPE-STD-001 Water Supply Network Planning, Design and Construction*, and relevant Seqwater, Australian and industry Standards, Specifications and Codes.

All concrete shall be suitably finished and coated for the application and in accordance with SPE-00348 M-SPE-STD-004 *Protective Coatings*.

9.10. Mechanical and Structural Works

The mechanical and metal structural design and construction shall comply with Seqwater's specifications, relevant legislation, and applicable Australian and industry codes and standards.

Refer to *SPE-00367 M-SPE-STD-001 General Mechanical Specification* for further guidance.

9.11. Electrical Works

All electrical works shall comply with the requirements of:

a. E-SPE-STD-001 Electrical Design and Construction

b. E-SPE-STD-009 Low voltage switchboards, Distribution Boards and Control Panels

Standards noted above are the key standards relevant to this standard and the standards referred within these key standards shall also be considered as part of the design.

9.12. Instrumentation Works

Instrumentation shall conform with the requirements of this standard specification, *SPE-00352 E-SPE-STD-001 Electrical Design and* Construction, *SPE-00353 I-SPE-STD-015 Instrumentation,* Australian and industry Codes, Specifications. Instrumentation shall also comply the following requirements:

a. Transmitters and control circuits shall comply with the voltage requirements of *SPE-00352 E-SPE-STD-001 Electrical Design and Construction*.

b. Safety devices or switches used for equipment protection or critical process safety or protection against environment release or personal safety shall be hardwired and fail-safe with the requirements of SPE-00361 I-SPE-STD-013 *Control Systems Design and Construction*.

c. Flow meters shall comply with the requirements of *SPE-00434 M-SPE-STD-009 Flow Meters and REG-01074 X-LST-STD-001 Seqwater Preferred Equipment* for the selection and installation.

d. Microwave or optical sensors should be considered for solids density/concentration meters.

e. Radar-type level transmitters are generally recommended to use in liquid sludge tanks.

f. Vibrating fork level switches are recommended for use in liquid sludge tanks.

g. Ultrasonic or optical level sensors should be considered for detecting the sludge blanket interface.

h. Turbidity meters shall comply with the requirements of *SPE-00503 I-SPE-STD-016 Turbidity Analysers*. Where practical, direct insertion-type turbidity meters should also be considered for sludge applications, in addition to panel-mounted installations with sample lines. For the design of turbidity analyser panels, refer to the standard P&ID Drawings *B-DWG-STD-041 to B-DWG-STD-045*.

i. A trial should be carried out for a reasonable duration before the final selection of any new type of instrument for sludge applications to assess its reliability and maintenance requirements.

j. Displays shall be digital and suitably weatherproof to the site conditions and shielded to prevent glare.

9.13. Control System Requirements

Control systems shall comply with the requirements of the standards listed below, the requirements of this standard, and relevant Australian and industry Standards, Specifications and Codes:

a. *SPE-00356* I-SPE-STD-005 High Priority Alarms & Interlocks Management

b. *SPE-00358* I-SPE-STD-009 Control Systems Architecture

c. *SPE-00361* I-SPE-STD-013 Control Systems Design and Construction

Standards noted above are the key standards relevant to this standard, but the standards noted within these key standards shall also apply and must be considered as part of the design.

A Functional Description (FD) for each process unit of a sludge system shall be developed to cover control requirements in *detail. Functional descriptions shall use the following standards and templates as necessary:*

d. SPE-00349 B-SPE-STD-005 Functional Description Documentation

e. TEM-00221 I-TMP-STD-001 Functional Description Part A Template

f. TEM-00222 I-TMP-STD-005 Functional Description Part B Template

g. TEM-00327 I-TMP-STD-013 Cause and Effect Matrix (C&E) Template

Some specific details of centrifuge and thickener control requirements, process control narrative and interface requirement between SCADA and vendor package are provided in Section 7.1.5 and Section 6.3.14.

9.14. Cyber Security

For all units associated with sludge system design particularly centrifuge system or any other unit supplied as a package unit or not, the vendor shall comply with Seqwater cyber security requirements as specified in the SPE-00502 *Control Systems Cyber Security Standard.*

The vendor shall provide sufficient information as requested by Seqwater to allow the assessment of cyber security risks.

9.15. Signage, Tagging, Marking and Labelling

All equipment, instrumentation, and pipework shall be numbered and labelled, and include nameplates in accordance with:

a. *SPE-00367 M-SPE-STD-001 General Mechanical*

b. *SPE-00352 E-SPE-STD-001 Electrical Design and Construction*

c. *SPE-00359 I-SPE-STD-010 Control System Tag Naming*

d. *PRO-02190 X-PRO-STD-006 Equipment Numbering and Naming Conventions*.

9.16. Testing and Commissioing

All systems shall be tested and commissioned in accordance with the requirements of

a. *SPE-00346 B-SPE-STD-003 Commissioning Requirements*

b. *SPE-00352 E-SPE-STD-001 Electrical Design and Construction*

c. *SPE-00367 M-SPE-STD-001 General Mechanical Specification.*

d. *SPE-00360 I-SPE-STD-011 Control System Testing*

At a minimum, the following tests shall be conducted:

e. Tanks:

   i. Tanks shall undergo hydrostatic testing using water, conducted by the supplier or manufacturer, prior to installation. The test method shall comply with the appropriate hydrostatic testing standards. The test report must be provided to Seqwater.

   ii. Tanks shall also undergo leak testing using water to full volume, on-site, after installation and before commissioning any ancillary systems. This test must be successfully maintained and demonstrated over a 24-hour period.

f. Pipework:

   i. Pipework shall be tested in accordance with the relevant material standards and codes.

g. Pumps:

   i. Pumps shall be performance-tested by the supplier or manufacturer prior to delivery to site. On-site testing shall be carried out after installation to verify correct operation, including flow rate, pressure, and power consumption, in accordance with the design specifications.

h. Centrifuge Testing and Commissioning:

   i. Specific requirements for centrifuge testing and commissioning are included in Section 7.1.7.

10. Definitions and Abbreviations

Table 3 Definitions

Term	Definitions
Advanced treatment of water	The treatment of water that has been treated in a sewage treatment plant by removing dissolved salts so that the water is potable or suitable for agricultural or industrial use.
Appropriate treatment of wastewater or contaminants	Refers to (a) for release to a sewerage service provider's waste facility or sewer—treatment that meets the service provider's requirements for the release to the waste facility or sewer; or (b) for release to land—treatment that ensures the release to land is ecologically sustainable; or (c) for release to surface waters or groundwaters—treatment that ensures, or the taking of other steps to ensure, that the release— (i) will not affect the environmental values for the waters; or (ii) is offset by undertaking an activity to counterbalance the impacts of releasing wastewater or contaminants to waters, other than an offset to which the Environmental Offsets Act 2014 applies.
Centrate	Refers to relatively clear water collected from the centrifuge after separation of solid as a cake.
Contractor	An entity engaged by Seqwater to undertake work in accordance with an agreed contract and defined scope of work.
Decantation	A process for drawing off liquid from a tank without stirring up the sediment in the bottom.
Design Life	The design life of equipment is the period of time during which the item is expected by its designers to provide the required functionality and availability, for the specific operating conditions.
Designer	An entity engaged by Seqwater to produce or modify a design for a project (including the design of temporary works); or who provides instructions to another party to complete works in a described manner. May also be the Contractor.
Dry Solid	Dry solids refer to the sludge solids measured by weight in the laboratory after being dried at 105°C, following the approved method
Engineering Standard	Includes Seqwater Engineering Standard Procedures and Standard Specifications and associated supporting documents such as Standard Drawings, Guidelines, Lists, Manuals, Registers, and Templates.
Fit for purpose	Suitable for the intended purpose and meets the performance requirements set out in this standard and other project documents.
HAZOP	A method of study for identifying hazards and operability considerations within chemicals and fuels processing through to electrical and machinery systems.

Term	Definitions
Manufacturer / Supplier / Vendor / Original Equipment Manufacturer (OEM)	The entity that manufacturers or supplies equipment to meet the specifications of the Contractor.
Mixed water	Water that has undergone advanced water treatment and has been mixed with raw water.
Owner / Principal / Seqwater	The entity that engages the Contractor to undertake the work and takes custody of the outcome. The Owner may delegate responsibilities to other entities to act on its behalf (e.g. a consultant).
Process Conditions	Refers to the conditions that assets may be subject to as a result of operating plant and equipment.
Raw water	Refers to (a) water derived (i) directly from surface water; or (ii) from groundwater; or (b) mixed water.
REX	Seqwater Electronic Document and Records Management System.
SCADA	The system which acquires data from remote devices such as valves, pumps, instruments, transmitters etc. and provides overall control remotely from a host software platform. The host platform also provides functions for graphical displays, alarming, trending and historical storage of data.
Seawater	Refers to tidal waters, other than tidal waters between the banks of a river or stream.
Seqwater Approval / Acceptance	Written sign-off gained via the deviation process, as detailed in X-PRO-STD-008 Asset Standards Management and Application Procedure.
Sewerage Service provider	See the Water Supply (Safety and Reliability) Act 2008, schedule 3.
shall / must	Indicates a mandatory requirement.
should	Indicates a recommendation.
Sludge	Refers to the solid or liquid-solid or underflow residuals from clarifiers or sedimentation basins or filter wash water tanks or fluid feeding to centrifuge.
Supernatant	Refers to relatively clear water collected from sludge thickener overflow and/or filter backwash water settling tank overflow.
Waste facility	Means a facility for the recycling, reprocessing, treatment, storage, incineration, conversion to energy or disposal of waste.
Waste prevention	Means the adoption of practices or processes that avoid generating waste or reduce the quantity of waste requiring subsequent treatment, recycling or disposal.
Worker(s)	Includes all permanent, temporary, and casual employees of Seqwater, and: • vocational and work experience placements • volunteers contractors and consultants employed by another entity but temporarily assigned to do work for or on behalf of Seqwater.

Table 4 – Abbreviations

Abbreviation	Description
ADWG	Australian Drinking Water Guidelines
AS	Australian Standards
DS	Dry Solid
DN	Nominal Diameter
EA	Environment Authority
ERA	Environmental Relevant Activity
HAZOP	Hazard and Operability Study
HMI	Human-Machine Interface
LCP	Local Control Panel
PLC	Programmable Logic Controller
SCADA	Supervisory Control and Data Acquisition
SEMM	Site Environment Management Manual
SME	Subject Matter Expert
SS	Stainless Steel
VSD	Variable Speed Drive
WSAA	Water Services Association of Australia
WTP	Water Treatment Plant
WQMF	Water Quality Management Facility

11. References and Related Materials

The documents listed in Table 5 and Table 6 below, and the requirements therein, are relevant to this Standard Specification. In their latest editions, these documents form a part of this document. Note that this is not an exhaustive list of documents relevant to the works.

Seqwater undertakes regular updates of its Engineering Standards. Before utilising this document, the complete list of Seqwater Engineering Standards should be reviewed to ensure currency and applicability for the proposed works.

Table 5 References of Seqwater Documentation

Description	Location
B-DWG-STD-041 to B-DWG-STD-045, Analyser Panel Standard P&ID Drawings	REX (INO/DRA/507)
FRA-00014 Enterprise Risk Management Framework.	REX
PLN-00004 Drinking Water Quality Management Plan (DWQMP)	REX
PLN-00296 Environment Management Manual	REX
PLN-00393 Seqwater Energy Management System and Plan	REX
PLN-00452 Corporate Energy Strategy	REX
POL-00012 Water Quality Policy Statement	REX
POL-00027 Environment Policy Statement	REX
PRO-01617 X-PRO-STD-009 Engineering Design, Construction, Operation and Maintenance	REX
PRO-02140 X-PRO-STD-013 Engineering Technical Hazard Study	REX
PRO-02190 X-PRO-STD-006 Equipment Numbering and Naming Convention	REX
PRO-02205 X-PRO-STD-008 Asset Standards Management and Application	REX
PRO-02564 Drinking Water Treatment Chemicals - Specifications, Monitoring and Assessment	REX
REG-01074 X-LST-STD-001 Seqwater Preferred Equipment List	REX
SPE-00320 WTP and Supply System - Process Validation	REX
SPE-00323 M-SPE-STD-003 Valves for Water Applications	REX
SPE-00342 I-LST-SPE-001 Control System Prescribed Equipment	REX
SPE-00346 B-SPE-STD-003 Commissioning Requirements	REX
SPE-00348 M-SPE-STD-004 Protective Coatings	REX
SPE-00349 B-SPE-STD-005 Functional Description Documentation	REX
SPE-00352 E-SPE-STD-001 Electrical Design and Construction	REX
SPE-00353 I-SPE-STD-015 Instrumentation	REX
SPE-00355 M-SPE-STD-013 Chemical Dosing Piping	REX
SPE-00356 I-SPE-STD-005 High Priority Alarm & Interlock Management	REX

Description	Location
SPE-00357 I-SPE-STD-006 Monitoring and Control System Alarm and Event Management	REX
SPE-00358 I-SPE-STD-009 Control Systems Architecture	REX
SPE-00359 I-SPE-STD-010 Control System Tag Naming	REX
SPE-00360 I-SPE-STD-011 Control System Testing	REX
SPE-00361 I-SPE-STD-013 Control Systems Design and Construction	REX
SPE-00366 M-SPE-STD-002 Fixed Platforms, Walkways, Stairways and Ladders	REX
SPE-00367 M-SPE-STD-001 General Mechanical Specification	REX
SPE-00395 D-SPE-STD-001 Water Supply Networks Planning, Design and Construction	
SPE-00430 M-SPE-STD-012 Chemical Dosing Pumps	REX
SPE-00434 M-SPE-STD-009 Flow Meters	REX
SPE-00445 B-SPE-STD-009 Liquid Chemical Storage and Dosing Systems	REX
SPE-00481 B-SPE-STD-011 Polymer, PAC, Pot Perm and Soda Ash Systems	REX
SPE-00502 Control Systems Cyber Security	REX
SPE-00503 I-SPE-STD-016 Turbidity Analysers	REX
SPE-00506 Progressive Cavity Pumps	REX
TEM-00221 I-TMP-STD-001 Functional Description Part A Template	REX
TEM-00222 I-TMP-STD-005 Functional Description Part B Template	REX
TEM-00224 X-TMP-STD-022 Asset Standards Deviation Request Form	REX
TEM-00327 I-TMP-STD-013 Cause and Effect Matrix (C&E) Template	REX
TEM-00410 X-TMP-STD-014 Centrifuge Datasheet	REX

Table 6 – Reference External Standards, Specifications and Documents

Standard/Specification/Document Name or Number or Type	Document Title
AS 1000	International System of Units (S.I.) and its Applications
AS 1332	Conveyor belting—Textile reinforced
AS 1333	Conveyor belting of elastomeric and steel cord construction
AS 1628	Water supply - Metallic gate, globe and non-return valves
AS 1755	Conveyors - Safety requirements
AS 2129	Flanges for Pipes, Valve and Fittings
AS 2312.1	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coating, Part 1: Paint coatings
AS 2312.2	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings, Part 2: Hot dip galvanizing
AS/NZS 3500 Set	Plumbing and Drainage Set
AS 3600	Concrete structures

Standard/Specification/Document Name or Number or Type	Document Title
AS 3735	Concrete structures retaining liquids
AS 3996	Access Covers and Grates
AS/NZS 4020	Testing of products for use in contact with drinking water
AS/NZS 4024 - Series	Safety of Machinery
AS 4041	Pressure Piping
ASTM A380	Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
EN 12547	Centrifuges – Common Safety Requirements
QLD Act	Environmental Protection Act 1994
QLD Act	Waste Reduction and Recycling Act 2011
QLD Regulation	Environmental Protection Regulation 2019
QLD Code	End of Waste Code for Water Treatment Residuals (ENEW07503318)
Handbook	Management of Water Treatment Plant Residuals in New Zealand, New Zealand Water & Wastes Association
Handbook	Technology Transfer Handbook, Management of Water Treatment Plant Residuals – EPA, ASCE, AWWA.
Sydney Water Specification D001932	Design Specification – Dewatering Equipment
Sydney Water Specification BMIS0209	Technical Specification - Mechanical
WHS Act 2011	Work Health and Safety Act 2011
WSA 201-2017	Manual for Selection and Application of Protective Coatings
WSAA Guidance Manual	Water Services Association of Australia *Manual for the application of Health-Based Target's for Drinking Water Safety, September 2015.*
Textbook	MWH's Water Treatment, Principles and Design – Third Edition – John Willy & Sons, Inc.
Textbook	Twort's Water Supply – Seventh Edition – Butterworth-Heinemann Publications
Textbook	Basic Water Treatment – Sixth Edition - ICE Publishing
Textbook	Water Quality and Treatment – A Handbook on Drinking Water - AWWA
Textbook	Wastewater Engineering Treatment and Reuse – Metcalf & Eddy – Fourth Edition – McGraw-Hill
Textbook	Biosolids Treatment Processes – Volume 6 – 2007, Totowa, Nj Humana Press.
Study Report	Understanding the Risk of Acrylamide Monomer in Drinking Water Treatment – School of Engineering – RMIT University

12. Changes from previous version

This Standard Specification will be regularly reviewed in accordance with the requirements of the Seqwater Controlled Document Management Procedure. Reviews will include consideration of suggestions for alteration or improvement made in accordance with Seqwater Procedure *X-PRO-STD-004 Development and Review of Asset Standards*. Changes made from the previous version are summarised in Table 7 below.

Table 7 Changes from previous version

Section Number	Change
Not applicable	Not applicable

Appendix A: Sample Calculation - Sludge Mass and Volume, Monomer Balance

A.1 Sample Calculation – Sludge Mass and Volume

Sample calculation

Assumptions

Raw water flow rate = 1000 L/sec

Alum dose rate (as Al_2O_3) = 9 mg/L

Raw water turbidity = 14 NTU (100% removed), Ratio of total suspended solid in mg/L/ NTU removed = 1.5

Raw water colour = 16 HU (80% removed), Ratio of production of mg solid/L/HU removed = 0.15

Powder Activated Carbon (PAC) addition = 10 mg/L

Raw water manganese = 0.4 mg/L (Manganese removal by potassium permanganate oxidation).

Flocculation Polymer addition = 0.05 mg/L

Thickener polymer addition = 1 kg polymer/ton of dry solid

Dewatering polymer addition = 5 kg polymer/ton of dry solid

Specific gravity of solids in sludge = 2.5, water density = 1000 kg/m^3

Solid concentration in liquid sludge for dewatering = 2%

a. Sludge from alum addition

Sludge produced from alum addition (kg/day) = alum dose rate (mg/L) x 2.59 kg dry solid/kg of Al_2O_3 x raw water flow rate (L/sec) x (86,400 sec/day) x (1 kg/10^6mg)

= 9 x 2.59 x 1000 x 86,400 x 1/10^6

= 2,014 kg DS/day

b. Sludge from turbidity removal

Sludge produced from turbidity removal (kg/day) = 1.5 mg solid/L/NTU removed x 14 NTU removed x raw water flow rate (L/sec) x (86,400 sec/day) x (1 kg/10^6mg)

= 1.5 x 14 x 1000 x 86,400 x 1/10^6

= 1,814 kg DS/day

c. Sludge from colour/organics removal

Sludge produced from colour removal (kg/day) = 0.15 mg solid/L/HU removed x 0.8 x 16 HU x raw water flow rate (L/sec) x (86,400 sec/day) x (1 kg/10^6mg)

= 0.15 x 0.8 x 16 x 1000 x 86,400 x 1/10^6

= 166 kg DS/day (this is equivalent to approximately 2 mg/L of dissolved organics removal)

d. Sludge from PAC addition

Sludge produced from PAC addition (kg/day) = 1 kg solid/kg of PAC x 10 mg/L x raw water flow rate (L/sec) x (86,400 sec/day) x (1 kg/10^6mg)

= 10 x 1000 x 86,400 x 1/10^6

= 864 kg DS/day

e. Sludge from dissolved manganese removal (by potassium permanganate)

Sludge produced from polymer (kg/day) = 2.58 kg solid/kg of polymer x 0.4 mg/L x raw water flow rate (L/sec) x (86,400 sec/day) x (1 kg/10^6mg)

= 2.58 x 0.4 x 1000 x 86,400 x 1/10^6

= 89 kg DS/day

f. Sludge from floc polymer addition

Sludge produced from polymer (kg/day) = 1 kg solid/kg of polymer x 0.05 mg/L x raw water flow rate (L/sec) x (86,400 sec/day) x (1 kg/10^6mg)

= 0.05 x 1000 x 86,400 x 1/10^6

= 4.3 kg DS/day

g. Sludge production before polymer addition for thickening and dewatering

Sludge production (kg/day) = (Sludge from alum dosing + sludge from turbidity removal + sludge from colour removal + sludge from PAC addition + sludge from manganese removal + sludge from floc polymer addition kg/day

Sludge production (kg/day) = (2,014 + 1,814 + 166 + 864 + 89 + 4.3) kg/day

= 4,952kg of DS/day

h. Additional sludge due to addition of polymer in thickening and dewatering

Sludge from polymer addition in thickening + Sludge from polymer addition in dewatering

= (1 kg/ton of dry solid x 4.952 ton dry solid /day) + (5 kg/ton of dry solid x 4.952 ton dry solid/day)

= 29.7 kg DS/day

i. Total sludge production = 4.952kg/day + 29.7 kg/day

Total sludge production = 4,981 kg of kg of dry solid/day

= 4.98 ton of DS/day

j. Liquid sludge volume production for dewatering

Assume solid concentration in liquid sludge = 2%, specific gravity of liquid sludge = 1.02

$$Liquid\ sludge\ volume\ \left(\frac{m^3}{day}\right) = \frac{Estimated\ dry\ solid\ feed\ \left(\frac{kg}{day}\right)}{Water\ density\ \left(\frac{kg}{m^3}\right) \times solid\ conc.\ (\%)\ \times\ specific\ gravity\ of\ liquid\ sludge\ \left(\frac{kg}{m^3}\right)}$$

$$= \frac{4{,}981 \left(\frac{kg}{day}\right)}{1000 \left(\frac{kg}{m^3}\right) \times 0.02 \times \; 1.02 \left(\frac{kg}{m^3}\right)}$$

= 244.2m³/day

k. Volume of dewatering liquid sludge as percentage of total flow

$$Dewatering\ liquid\ sludge\ volume\ as\ (\%) of\ total\ flow = \frac{Sludge\ volume\ production \left(\frac{m^3}{day}\right) \times 1000 \left(\frac{L}{m^3}\right)}{Raw\ water\ flow\ rate \left(\frac{L}{S}\right) \times\ 86400 \left(\frac{sec}{day}\right)} \times 100$$

$$Liquid\ sludge\ volume\ as\ (\%) of\ total\ flow = \frac{244.2 \left(\frac{m3}{day}\right) \times 1000 \left(\frac{L}{m3}\right)}{1000 \left(\frac{L}{S}\right) \times 86400 \left(\frac{sec}{day}\right)} \times 100$$

= 0.28%

l. Liquid sludge volume from basin de-sludging

Assume solid concentration in liquid sludge (including PAC) = 0.5%, specific gravity of liquid sludge = 1.01, 90% of sludge collection from sedimentation basin

$$Liquid\ sludge\ volume \left(\frac{m^3}{day}\right) = \frac{Estimated\ dry\ soild \left(\frac{kg}{day}\right) \times \%\ sludge\ collection\ from\ basin}{Water\ density \left(\frac{kg}{m^3}\right) \times solid\ conc.\ (\%)\ \times\ specific\ gravity\ of\ liquid\ sludge \left(\frac{kg}{m^3}\right)}$$

$$= \frac{4{,}981 \left(\frac{kg}{day}\right) \times 0.9}{1000 \left(\frac{kg}{m^3}\right) \times 0.005 \times \; 1.01 \left(\frac{kg}{m^3}\right)}$$

= 888 m³/day

m. Volume of basin desludging liquid as percentage of total flow

$$Basin\ desludging\ volume\ as\ (\%) of\ total\ flow = \frac{Liquid\ sludge\ volume\ production \left(\frac{m^3}{day}\right) \times 1000 \left(\frac{L}{m^3}\right)}{Raw\ water\ flow\ rate \left(\frac{L}{S}\right) \times\ 86400 \left(\frac{sec}{day}\right)} \times 100$$

$$Liquid\ sludge\ volume\ as\ (\%) of\ total\ flow = \frac{888 \left(\frac{m^3}{day}\right) \times 1000 \left(\frac{L}{m^3}\right)}{1000 \left(\frac{L}{S}\right) \times\ 86400 \left(\frac{sec}{day}\right)} \times 100$$

= 1 % (v/v)

A.2 Sample Calculation - Polyacrylamide Monomer Balance

Sample calculations summary for theoretical polyacrylamide monomer mass balance for several scenarios

Table 8 Several scenarios for theoretical polyacrylamide monomer level in treated water

Items/Scenarios	1	2	3	4	Comment
Raw water flow rate (ML/D)	50	50	50	50	Assumption
Raw water Turbidity (NTU)	10	125	125	200	Assumption
Solid production per NTU removal (mg/L)	1.5	1.5	1.5	1.5	Assumption
Coagulant alum dosing as Al_2O_3 (mg/L)	8	20	20	30	Assumption
Solid production from alum dosing (kg DS/kg of Al_2O_3)	2.59	2.59	2.59	2.59	Assumption
Total theoretical dry solid production (kg DS/day)	1,832	11,988	11,988	18,895	Calculated
Polymer dosing for flocculation and pre-filter (mg/L)	0.15	0.15	0.15	0.15	Assumption
Polymer addition for thickening and dewatering (kg/ton of DS)	6	5	6	5	Assumption
Acrylamide monomer in polymer (mg/kg)	100	200	100	200	Assumption
Acrylamide mass per day (g/day)	1.87	13.54	7.97	20.45	Calculated
Clarifier de-sludge water volume (% of raw water)	0.7	1.0	1.0	1.2	Assumption
Clarifier de-sludge water volume (ML/D)	0.35	0.5	0.5	0.6	Calculated
Backwash water volume (% of raw water)	2	3	3	3	Assumption
Backwash water volume (ML/D)	1	1.5	1.5	1.5	Calculated
Supernatant return flow (ML/D)	1.34	1.95	1.95	2.05	Calculated
Supernatant return (% of raw water)	2.69	3.91	3.91	4.1	Calculated
Acrylamide concentration in supernatant return (µg/L)	0.80	6.03	3.61	8.58	Calculated
Acrylamide concentration in treated water (µg/L)	**0.04**	**0.26**	**0.15**	**0.37**	Calculated

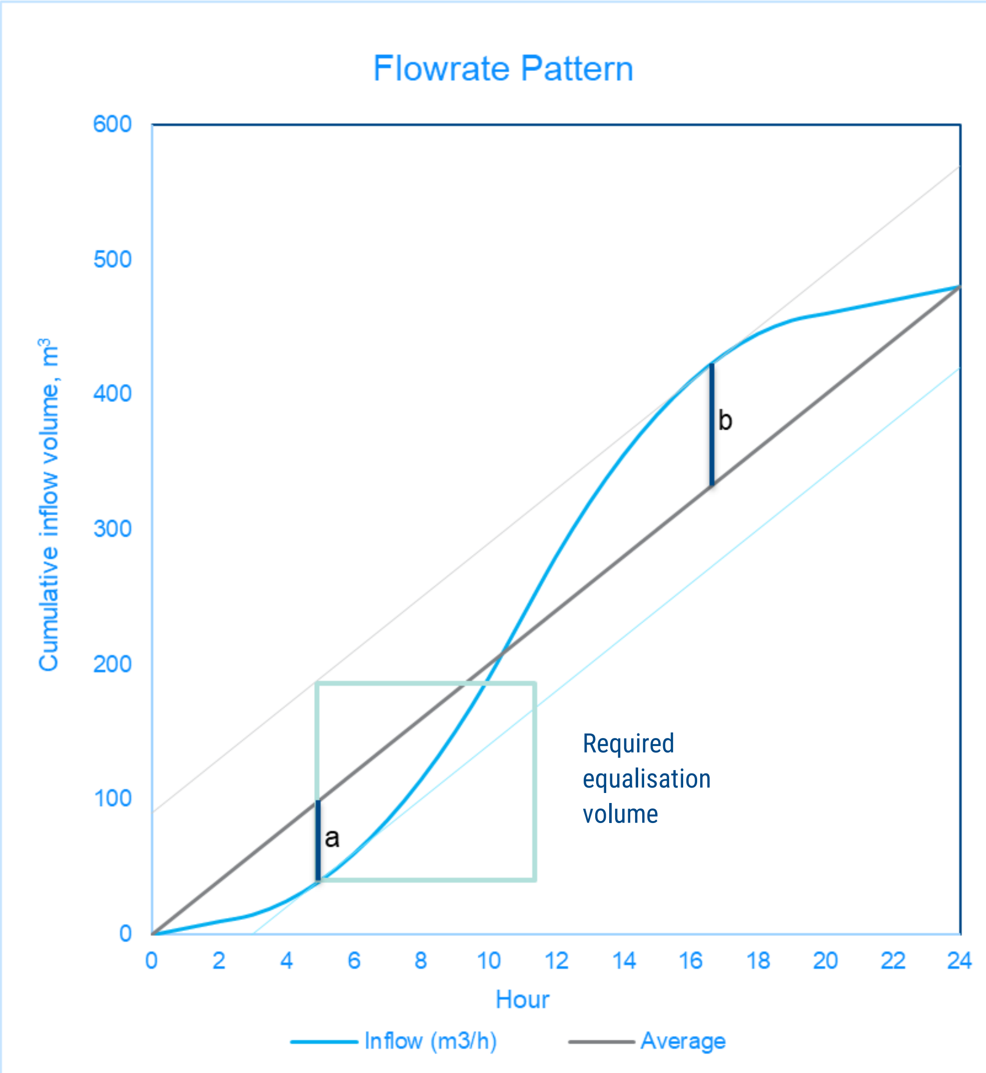
Appendix B: Balance Tank Sizing Sample Calculation

1. Calculation Method A (Based on gap in cumulative flow from average inflow)

Assumption: Flow data over 24 hr period (average flow)

Time (hour)	0	2	4	6	8	10	12	14	16	18	20	22	24
Cumulative inflow (m^3/hour)	0	10	25	60	115	190	280	355	410	445	460	470	480

The above data is used to draw the following graph:



From the graph, the vertical distance between the tangent lines is calcualted which is a+b, where a = 60 m^3 and b = 90 m^3. Therefore, the required volume is:

$a + b = 60 + 90 = 150m^3$

After adding a safety factor of 10%, as per Method A, the required tank volume becomes

150 m^3 X 10% = 165m^3.

2. Calculation Method B (Based on Detention Time)

Assumptions:

Detention Time = 8 hr

Average Inflow / Outflow = 20 m^3/hr

Required Tank volume = 8 X 20 = 160 m^3

Since the tank volume calculated using Method B is less than the 165 m^3 determined by Method A, the tank volume of 165 m^3 should be chosen.

An appropriate freeboard should be added in the total calculated volume.

Appendix C: Thickener Sizing Sample Calculation

1. **Method A: (Total Thickener Depth based on Detention Time)**

Assumptions:

Thickener Inlet Flow rate = 100 m^3/hr

Design surface overflow rate = 1.2 m/hr , Solid Loading Rate = 2.5 kg/m^2.hr

Inler solid concentration = 0.2 % (w/v)

Detention Time = 3 hr

Calculation:

Calculated Tank Volume = Inflow rate x Detention Time = 100 x 3 = 300 m^3

Thickener surface area = Inlet flow rate / surface overflow rate = 100/1.2 = 83.3 m^2 (note that based on solid loading rate area becomes 80 m^2, therefore 83.3 m^2 is chosen)

Nominal Calculated Tank Side Wall Depth = Volume/Area = 300/83.3 = 3.6 m (excluding bottom cone section)

Tank Diameter = 10.3 m (calculated from area)

2. **Method B: (Thickener Depth based on Segmental Depth Calculations, an alternative method)**

Assumptions:

Density of thickened sludge $\rho_{SL(out)} = 1050\frac{kg}{m^3}$

Density of inlet sludge $\rho_{SL(in)} = 1000\frac{kg}{m^3}$

Sludge volume going into the thickener $V_{SL} = 100\frac{m^3}{h}$

Thickened solid residence time $t = 12\ h$ (assume the thickened zone volume can store thickened solid for 12 hr)

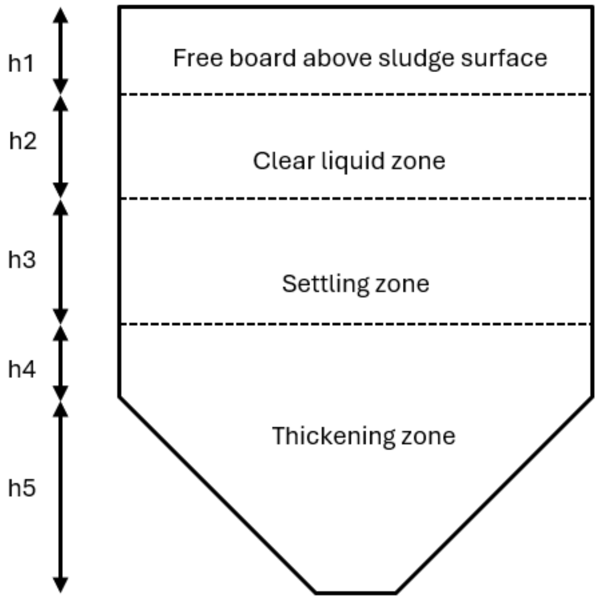
Concentration of solid in the thickened sludge $C_{SL(out)} = 1\%\frac{w}{w}$

Concentration of solid in the thickener inlet $C_{SL(in)} = 0.2\%\frac{w}{w}$

Thickener Inlet Flow rate, V_{sL} = 100 m^3/hr

Slope of bottom cone section = 1:6

The diagram below shows the typical segments / layers of a thickener along the depth:



Here, only h_4 will be calculated based on the sludge volume and density, while other segment values are assumed based on the typical values used in literature.

Layer	Value (m)	Comments
h_1 (free board above water surface)	0.6 (assumed)	Assumption
h_2 (clear liquid zone)	0.8	Assumption, literature reports this area up to 1 m
h_3 (settling zone)	1.2	Assumption, literature often reports the clear liquid and settling zones together as a combined entity.
h_4 (thickening zone, side wall depth)	To be calculated	From thickening zone volume calculation
h_5 (bottom cone height)	Slope 1:6	Assumption

Solid flux coming in the thickener,

$$X_{SL(in)} = \rho_{SL} \times C_{SL(in)} = 1000 \frac{kg}{m^3} \times 0.2\% = 2 \frac{kg}{m^3}$$

Solid flux coming out of the thickener,

$$X_{SL(out)} = \rho_{SL} \times C_{SL(out)} = 1050 \frac{kg}{m^3} \times 2\% = 21 \frac{kg}{m^3}$$

Mass of sludge dry solids accumulated in the thickening zone

$$m_{SL(in)} = V_{SL} \times X_{SL(in)} \times t = 100 \frac{m^3}{h} \times 2 \frac{kg}{m^3} \times 12\ h = 2400\ kg$$

Determine the diameter:

- Using the surface loading rate limit of 1.2m/hr, Tank Diameter = 10.3 m
- Using the solid lading rate limit of 2.5 kg/m^2.hr, Tank Diameter = 10.09m
- The tank diameter is 10.3m

Depth of the centre (h_5):

$$h_5 = r \times \frac{1}{6} = \frac{5.15}{6} = 0.86\, m$$

Volume of Thickened Zone Circular Section (Cone) =

$$V_{cone} = \frac{1}{3} \times \pi \times\ R^2 \times\ h_5 = \frac{1}{3} \times \pi \times\ 5.15^2 \times 0.86 = 23.84 m^3$$

Mass of solid in the cone zone =

$$m_{SL(cone)} = V_{cone} \times\ X_{SL(out)} = 23.84 m^3\ \times 21 \frac{kg}{m^3} = 500.73 kg$$

Side wall depth of the thickening zone (h_4):

$$h_4 = \frac{m_{SL(in)} - m_{SL(cone)}}{A_T \times\ X_{SL(out)}} = \frac{2400 kg -\ \ 500.73 kg}{83.3\ m^2 \times 21 \frac{kg}{m^3}} = 1.09 m$$

Total side Wall depth of the thickener:

$$H = h_1\ +\ h_2 +\ h_3 + h_4 =\ 0.6 + 0.8 + 1.2 + 1.09 = 3.69 m$$

Total depth of the thickener:

$$H_c = H +\ h_5 = 3.69 + 0.85 = 4.54\, m$$

Therefore, a detention time of 3 hours results in a tank side wall depth of 3.6 meters, which is slightly lower than the 3.69 meters calculated using the segmental depth method, assuming all assumptions are correct. Based on this, for this example, a side wall depth of 3.69 meters and a centre depth of 4.54 meters should be used for the thickener.

Appendix D: Stoke's Law

The rate of separation in a centrifuge mainly depends on the particle size and density by way of gravitational force as explained by Stoke's law.

$$v = \frac{d^2\,(\rho_2 - \rho_1)}{18\,\mu} \times g \qquad (10)$$

Where,

v is the sedimentation or settling velocity or rate (m/sec)

d is diameter of the particle (m)

ρ_2 is particle density (kg/m^3)

ρ_1 is medium density (kg/m^3)

μ is dynamic viscosity of medium (kg/m.sec)

g is gravitational force (m/sec^2).

Centrifuges create additional artificial gravity from spinning and thus increase 'g' factor in the above equation and therefore massively speed up the settling process.

In addition to bowl speed, gravitational force or "G" force is the more appropriate method for describing decanter centrifuges as explained above by the Stoke's law. "G" force takes into account both bowl speed and diameter which is also called Relative Centrifugal Force (RCF) as it is expressed relative to the earth's gravitation force. "G" force acting on particles is exponentioal to the speed of the bowl in RPM and can be represented by the following equation:

$$\text{"G"}\ force\ or\ RCF = 1.118 \times 10^{-5} \times r \times (RPM)^2 \qquad (11)$$

Where,

"G" force or RCF is unitless as it is a relative value or ratio of gravitational force.

RPM the speed of bowl, minute.

r is the radius of the bowl, cm.

1.118×10^{-5} is the conversion factor, as dervied from force, mass and angular veolcity equation and considering relative gravitational acceleration constant of 981 cm/s^2.

Appendix E: TEM-00410 X-TMP-STD-014 Centrifuge Datasheet Template

seqwater WATER FOR LIFE	**LOCATION: e.g. MT CROSBY EASTBANK WTP**	CONTRACTOR LOGO	
	SUBLOCATION: e.g. Centrifuge Room		
	Equipment Datasheet **Decanter Centrifuge**	**EQUIPMENT TAG(s):**	
Rex ID:	**Template may be updated and should be accessed from official location prior to each use. Uncontrolled copy valid only at time of printing.**	**Current Revision number:**	Rev XX
Date Printed: 11-Jun-25			

Document Number:	**M-DSH-XXX-XXX**
Usage:	e.g. Tender Specification / Issued for Construction / As Built
Project Number:	XXXXXXXXX
Project Description:	e.g. New Centrifuge Installation
Equipment Description:	Decanter Centrifuge

REV	DATE	DESCRIPTION	AUTHOR	APPROVED	DATE	SIGNATURE
X	XXXX	e.g. Issued for Tender / Construction/ As Built	XX	XX	XXXX	XX

BACKGROUND						
IDENTITY	1	Equipment Number(s)	Text	XXXXX		
	2	P&ID Number(s)	Text			
	3	Service Description	Text			
	4	Hazardous Area Classification	Text			
	5	Installation Detail	Text	e.g. DWG Number		
	6	Line Number and Stream Number	Text			
	7	Reference Specification	Text	SPE-00525 *B-SPE-STD-017 Sludge Management System s*		
ENVIRONMENT	8	Operating Environment	Dropdown	Inland / Coastal / Rural / Urban		
	9	Equipment Location	Dropdown	Inside / Outside		
	10	Special Environmental Hazards	Text			
	11	Criteria:		**MIN**	**MED**	**MAX**
	12	Ambient air temperature - Min / Ave / Max	°C	X	Y	Z
	13	Humidity (relative)	%	X	Y	Z
PROCESS CONDITIONS / DESIGN PARAMETERS						
FEED SLUDGE CHARACTERISTICS AND PROCESS CONDITIONS	14	Criteria (Note 1)		**MIN**	**MED**	**MAX**
	15	Sludge Type / Characteristics	Text			
	16	Hydraulic Loading Rate	m^3/h	X	Y	Z
	17	Solids Loading Rate	kg/h	X	Y	Z
	18	Feed Solids Concentration	% (w/v) or % (w/w)	X	Y	Z
	19	Sludge Feed Temperature	°C	X	Y	Z
	20	Fluid pH		X	Y	Z
	21	Wet Sludge Specific Gravity		X	Y	Z
	22	Sludge Ash Content (if known)	%			
	23	Hours of Operation per Day	hr			
	24	Mode of Operation	Dropdown	Batch / Continuous		
	24	Redundancy Required	No	Duty/Standby, (N+1) required		
PERFORMANCE SPECIFICATION						
	25	Service Life	Years			
	26	Hydraulic Loading Rate (Maximum)	m^3/h			
	27	Hydraulic Loading Rate (Minimum)	m^3/h			
	28	Solid Loading Rate (Maximum)	kg/h			
	29	Solid Loading Rate (Minimum)	kg/h			
	30	Centrate Turbidity (Maximum)	NTU			
	31	Solid Capture Rate	% w/w	>98 %, Vendor to Confirm		
	32	Dry Cake Solid Concentration Range	% w/w	>16% for Alum Sludge, Vendor to Confirm		
	33	Polymer Dosage Range	kg/Ton of dry solid			
	34	Daily Operation	hr/day			
	35	Weekly Operation	day/week			
	36	Excess Capacity Factor				
	37	Noise level @ 1m	db	<85, Vendor to Confirm		
	38	Vibration Level at Maximum Speed	mm/s			
	39	Bowl Bearing Temperature	°C			
	40	Failsafe Mode in the Event of Power Loss	Text			
	41	Warranty Period	Years			

DESIGN SPECIFICATION						
	42	Centrifuge Manufacturer	Text			
	43	Centrifuge Model & Serial Number	Text			
	44	Country of manufacture	Text			
	45	Flow Configuration	Dropdown	Counter Current / Co Current		
	46	Sludge Inlet Pressure (Minimum)	kPag			
	47	Sludge Inlet Pressure (Maximum)	kPag			
	48	Total no. of Centrifuges	No.			
	49	DIMENSIONS / SIZES / WEIGHTS				
	50	Centrifuge Dimensions - L x W x H	mm	L	W	H
	51	Bowl Diameter	mm			
	52	Bowl Length	mm			
	53	Inlet Flange Size	mm			
	54	Centrate Flange Size	mm			
	55	Cake Discharge Connection Size	mm			
	56	Polymer Dosing Connection Size	mm			
	57	Overall Weight (Dry)	kg			
	58	Overall weight (Full Load)	kg			
	59	Beach Angle	degree			
	60	MATERIALS				
	61	Bowl	Text	SS 316 minimum		
	62	Scroll	Text	SS 316 minimum		
	63	Scroll Flights	Text	SS 316 minimum		
	64	Scroll Flight Tips	Text	Tungsten Carbide, Vendor to Confirm		
	65	Feed Pipe	Text	SS 316 minimum		
	66	Weir Plates	Text	SS 316 minimum		
	67	Frame	Text	per M-SPE-STD-001 General Mechanical/ M-SPE-STD-004 Protective Coating		
	68	Cover	Text			
	69	Solid discharge port	Text	Tungsten Carbide, Vendor to Confirm		
	70	Weir Plates	Text			
	71	Vibrate Joiner	Text			
	72	SPEED INFORMATION				
	73	Bowl Speed (maximum)	rpm			
	74	Scroll Speed (maximum)	rpm			
	75	Differential Speed (maximum)	rpm			
	76	Torque per Unit (maximum)	% or kNm			
	77	POWER Supply / MOTOR				
	78	Power Supply	V/Hz			
	79	Power Consumption (at full load)	kW			
	80	Bowl Motor Datasheet	Text	Refer Separate Datasheet		
	81	Scroll Motor Datasheet	Text	Refer Separate Datasheet		
	82	SOLIDS DIVERSION VALVE				
	83	Valve Actuation Type	Dropdown	Pneumatic / Electrical		
	84	Actuation Time Required	Sec			
	85	Valve Fail Position	Text			
	86	Valve Limit Switches (Open / Close)	Dropdown	Yes / No		
	87	Valve Flushing Medium	Text	Service Water		
	88	Pressure Required For Flushing	kPag			
	89	Flushing Instantaneous Flow	L/s			
	90	Valve and Limit switch Power Supply	V			
	91	INLET FLUSHING SYSTEM				
	92	Flushing Medium	Text			
	93	Required Flushing Pressure	kPag			
	94	Instantaneous Flow (maximum)	L/s			
	95	Bowl Speed for Flushing Cycle	rpm			
	96	Control System				
	97	Control Cabinet Datasheet	Text	Refer Separate Datasheet / Document		
	98	PLC Hardware Datasheet	Text	Refer Separate Datasheet / Document		
	99	Variable Frequency Drive (VFD) Datasheet	Text	Refer Separate Datasheet / Document		
TESTING AND COMMISSIONING						
TESTING AND COMMISSIONING (SUPPLIER TO PROVIDE DOCUMENTATION)	100	General Criteria	Text	Vendor to Provide Documentation as per B-SPE-STD-003		
	101	Hydraulic Testing Required / Performed	Dropdown	Yes / No		
	102	Flushing Testing Required / Performed	Dropdown	Yes / No		
	103	Performance Testing Required / Performed	Dropdown	Yes-as per B-SPE-STD-017 / No		
	104	Functional Testing Required / Performed	Dropdown	Yes-as per B-SPE-STD-017 / No		
	105	Operator Training Required / Provided	Dropdown	Yes / No		
NOTES						
NOTES	106	Note 1: Should be specified from project Basis of Design document.				
	107					
	108					
	109					