Farm Dairy Effluent (FDE) Design Standards

Version 2, April 2013

NEW ZEALAND MPTA MILKING & PUMPING TRADE ASSOCIATION
MILKING MACHINERY AND WATER PUMPING SERVICES

IRRIGATION NEW ZEALAND INC

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ABOUT THIS DOCUMENT

Purpose

The purpose of this document is to provide a set of standards against which to assess the design of individual farm dairy effluent (FDE) systems in New Zealand.

It is intended that this document be applicable to all new FDE systems, and to components of FDE systems receiving upgrades, in New Zealand.

This document is intended to be used in conjunction with *FDE Design Code of Practice (2013)*. The code of practice guides designers through the process of developing a FDE system, providing a general design approach aimed at meeting the standards in this document.

Audience

This document is intended for designers of FDE collection, storage, and land application systems, and for those involved in commissioning of FDE systems. This may include engineers, equipment suppliers, and specialist FDE designers.

Background

Rapid development has taken place recently in the New Zealand dairy industry, and DairyNZ has reported a lack of agreed standards in use by designers and suppliers of FDE systems. This lack of standards is leading to inadequate performance in many cases.

Much is written on best practice for FDE management. However, gaps exist because there are few good resources (and even fewer comprehensive resources written specifically for New Zealand) regarding standards for designing and installing FDE systems that allow FDE managers to meet their goals.

This document aims to fill that gap.

The development of this document has been conducted with support from FDE experts and the dairy industry.

Legal Status

This document is not intended to replace any existing regulatory requirements. Rather, it is expected that:

- in addition to any requirements listed in this document, all relevant existing regulatory requirements will also be met, and
- where there is a conflict between the requirements of this document and the regulatory requirement, the most conservative standard should be followed.

FDE DESIGN STANDARDS

1. PURPOSE OF THE FDE SYSTEM

In New Zealand, the purpose of farm dairy effluent (FDE) systems is to capture and apply FDE to land. This is done to maximise the beneficial use of nutrients for plant growth and minimise contamination of groundwater and surface water bodies.

Six main objectives must be considered at the design stage:

- To capture all FDE
- To spread the FDE at a time that allows uptake by plants
- To uniformly spread the FDE to the desired depth, and at the desired intensity
- To control FDE application to within the boundaries of the application area
- To ensure that FDE systems can be operated safely
- To comply with all regulatory requirements, including consent conditions

While system management is ultimately left up the system purchaser, the design must provide a system that will, with appropriate management, achieve a high standard.

2. COLLECTION

A FDE system must collect all of the animal excreta deposited in contained areas, as well as any other material coming into contact with it. In addition to the milking shed, this must include any stand-off areas, feed pads, housing areas and stock underpasses where effluent collects.

FDE collection systems must handle:

- the required volume and consistency of FDE being produced; and
- the peak flow rate of FDE without blocking, overflowing, or leaking.

Collection systems must be capable of removing all FDE from the milking area after each milking.

FDE must not be allowed to pond in the close proximity of the farm dairy and must be directed to a FDE system.

Food Safety Regulations

All requirements of the New Zealand Food Safety Authority in relation to the FDE system must be met (e.g. NZFSA, 2009).

Diversion of Clean Water

Storm-water runoff from areas that do not come into contact with FDE (e.g. the dairy shed roof) should be diverted away from the FDE system, unless the extra water is wanted for a specific reason (e.g. to dilute FDE, or to increase the volume of irrigation water available).

Water Supply

A water source is required for wash-down of the dairy shed, and periodically for washing of other areas such as stand-off areas and feed pads.

Check local regulatory requirements prior to designing systems that use recycled water.

Drains

Drains must handle the peak flow rate of FDE without blocking, overflowing, or leaking.

A minimum operating water velocity of 0.8 m/s should be maintained in all drains so that solids do not settle and cause blockages.

All drains which contain or transport FDE must be sealed to prevent any seepage.

If a venturi or a pump is required for discharging FDE from a milking pit, provide a recess in the floor. The sides and bottom of this recess should be finished to a smooth surface and must be sealed to prevent any seepage.

Slats or Grates

If slats or grates are used, they must hold their own weight plus the weight of animals, humans, and equipment operating within the collection area. The openings should be large enough to prevent undue slat or grate blockages yet small enough to reduce risk of animal injury or application system blockages.

All sealed Areas

All sealed areas within 45 m of the farm dairy that may be contaminated by faeces or urine, and all other sealed areas (regardless of the distance from the farm dairy) where animals are contained (including feed pads, standoff areas and underpasses) must be directed to a FDE system.

3. STORAGE

FDE storage must be designed according to the standards in Section 3.1 and 3.2, so that the FDE storage can:

- hold the FDE until it can be applied to land when it is most beneficial to the plant, and least likely to cause environmental contamination, and
- be placed in an appropriate location that minimises its effect on human health and wellbeing and is least likely to cause environmental contamination.

All storage units must be adequately sized, and must not leak.

All storage units must comply with all regulatory requirements and accepted civil construction standards.

3.1 Liquid Storage

Storage Volume

The required storage volume must be the greater of:

A: Regulatory requirements, OR

B: the calculated storage requirement determined taking all of the following into account (see Figure 1 for an illustration of these requirements):

- FDE Volume
  This is the accumulated volume of FDE that will be added to the storage during the storage period.
- Storage Period
  This is the length of time that FDE is stored between emptying events. This must account for local climate, the potential for periods of saturated soil conditions and periods of limited staff availability (e.g. calving) and meet the criteria in Table 1 in at least 9 out of every 10 years, based on a statistical analysis.
- Precipitation Minus Evaporation
  This is the accumulated volume of water that will be added directly onto the storage surface during the storage period.
- Volume of Runoff
  This is the average expected runoff from rainfall onto all areas that drain into the storage during the storage period.
- Contingency for Large Storm Events
  This is the volume of rainfall and runoff from a 25-year, 24 hour storm event directly onto the storage, and onto all areas that drain into the storage.
- Expected Leachate and Runoff Volume from Solids Storage.
- Expected Solids Accumulation

  Take into account the diminishing effective liquid storage volume that results from the accumulation of solids.

- Minimum Freeboard
  Maintain a minimum freeboard of 0.3 m.
- Climatic Conditions and Soil Temperature
  Take into account periods when conditions may reduce or prevent nutrient attenuation or uptake by plants.
- Contingency for Breakdowns and Maintenance
  Take into account the occurrence of occasional breakdowns and routine maintenance of land application equipment. This will depend on location and access to necessary services.
- Future Stocking Rates
  Account for potential future increases in stocking rate.

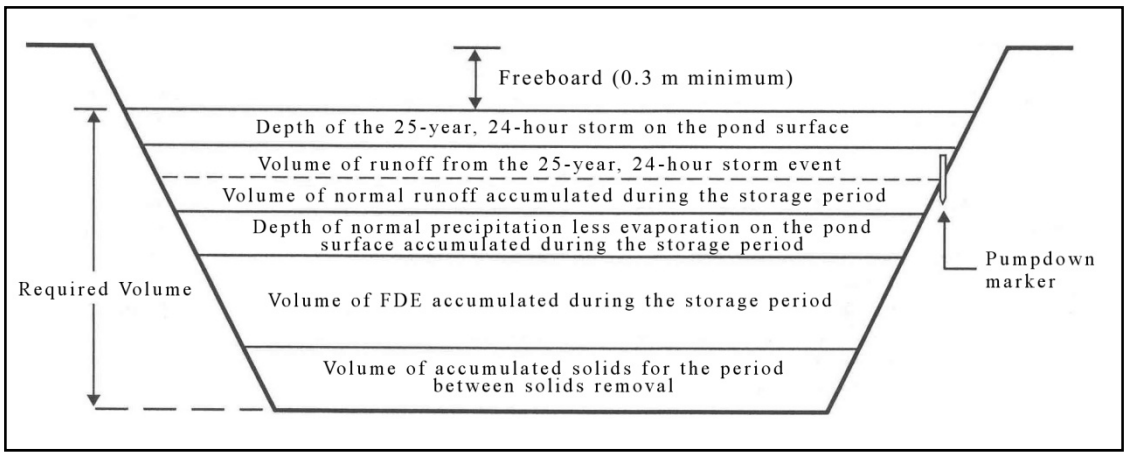

Figure 1: Cross section of liquid FDE storage pond with a watershed (modified from: USDA, 1997, Figure 10-15)

Table 1: Application depth and storage requirements for different soil and landscape features (modified from: Houlbrooke & Monaghan, 2009)

FDE risk category	**A**	**B**	**C**	**D**	**E**
Soil and landscape feature	**Artificial drainage or coarse soil structure**	**Impeded drainage or low infiltration rate**	**Sloping land (> 7°) and Hump and Hollow drained land**	**Well drained flat land (< 7°)**	**Other well drained but very stony [(a)] flat land (< 7°)**
Application depth of FDE to land (mm)	< Soil water deficit	< Soil water deficit	< Soil water deficit	< 50% of PAW_{30} (b)	≤ 10 mm & < 50% of PAW_{30} (b)
Storage requirement	Apply FDE only when soil water deficit exists	Apply FDE only when soil water deficit exists	Apply FDE only when soil water deficit exists	Do not apply within 24-hours of soil saturation	Do not apply within 24-hours of soil saturation

(a) Very stony = soils with > 35% stone content in the top 20 cm of soil.

(b) Soil water holding capacity in upper 30 cm of soil.

Separation Distances

In addition to any minimum separation distances required by other regulations including NZCP1 (NZ Food Safety Authority), liquid FDE should not be stored within:

- 45 m of the milking area, milk receiving area, milk storage area, and milk collection point
- 90 m of any water supply used for human consumption, and
- 45 m of the dairy shed water supply.

It is strongly recommended that liquid effluent is not stored within 300 m of off-site dwellings or public use areas, including public roads. If a FDE storage is to be sited less than 300 m, and it meets local regulations, then odour and human health risks must be considered and mitigated.

Leakage and Runoff

Liquid storage facilities must be constructed from materials that prevent FDE from contaminating surface or ground water.

3.2 Solids Storage

Storage Sizing

The required solids storage area must be the greater of:

A: Regulatory requirements, OR

B: the calculated storage requirement, taking all of the following into account:

- Solids volume accumulated during the storage period.
- Storage Period
  This must account for local climate. Ensure that land application does not have to occur on frozen ground or saturated soils in at least 9 out of every 10 years, based on a statistical analysis.
- Potential for future increase in stocking rates.
- The storage method (i.e. open stockpile or bunker).
- Angle of repose of material and height of stockpile.

Separation Distances

In addition to any minimum separation distances required by other regulations, including NZCP1 (NZ Food Safety Authority), solid FDE should not be stored within:

- 45 m of the milking area, milk receiving area, milk storage area, and milk collection point (with the exception of stone trap cleanings stored on a sealed surface in volumes less than 5 m^3)
- 90 m of any water supply used for human consumption, and
- 45 m of the dairy shed water supply.

It is strongly recommended that effluent solids are not stored within 300 m of off-site dwellings or public use areas, including public roads. If solids storage is to be sited less than 300 m, and it meets local regulations, then odour and human health risks must be considered and mitigated.

The following should also be observed:

- Do not store solids in areas with more than a 1 in 50 year flood risk.
- Do not store solids on steep slopes running toward surface water bodies or boreholes.

Leakage and Runoff

Solid storage areas must be constructed from materials that prevent FDE from contaminating surface or ground water.

All leachate and runoff from the solids storage area must be directed back into the FDE collection system.

4.0 LAND APPLICATION

All land application systems must be designed to uniformly spread the FDE to the desired depth, and at the desired intensity, according to the standards in Sections 4.1-4.8, so that:

- contamination of groundwater and surface water bodies is minimised, and
- the beneficial use of nutrients for plant growth is maximised.

4.1 Application Area(s)

Land application systems must control FDE application to within the boundaries of a defined application area.

The minimum area of land to be used for the application of FDE must be based on:

- local regulatory requirements for nutrient loading (i.e. kg N/ha), and
- a nutrient budget.

The most stringent of these (i.e. the one requiring the largest area) must be used as a minimum size for the application area.

If solids separation is used, both the liquid and solid components of FDE must be considered separately when calculating land application area.

FDE solids should not be applied to areas with a ground slope of >7 degrees

4.2 Separation Distances

The design must ensure minimum separation distances required by local regulations are met.

In addition, all practicable steps should be taken to ensure FDE does not move outside the target application area or otherwise impact sensitive areas.

The following guidelines may be used. FDE should not be applied to land within:

- 45 m of the milking area, milk receiving area, milk storage area, and milk collection point
- 20 m of any surface water body for ground slope <3 degrees
- 30 m of surface water body for ground slopes of 3-5 degrees
- 90 m of any surface water body for ground slopes of 5-6 degrees
- 90 m of any water supply used for human consumption
- 90 m of public roads
- 90 m of property boundaries, and
- 90 m of dwellings or public use areas.

4.3 Application Depth

The maximum FDE application depth is determined by soil hydraulic properties and nutrient loading calculations, and must:

- account for local climate, the potential for periods of high soil moisture levels and periods of limited staff availability (e.g. calving)
- meet the criteria in Table 1 in at least 9 out of every 10 years, based on a statistical analysis
- account for the application uniformity of the chosen land application method, and
- comply with all local regulations.

4.4 Application Uniformity

All liquid FDE land application systems must achieve a DU_{uq} (as defined in the accompanying *FDE Design Code of Practice 2013*) of no greater than 1.25.

If DU_{uq} information is not available, a design may use the low quartile equivalent, in which case DU_{lq} must be no less than 0.80.

4.5 Application Intensity

For sloping land (>7°) or other areas identified as high risk, the instantaneous application intensity of the land application system must not exceed the expected infiltration rate of the soil based on the best available information.

For all other situations, the average application intensity of the land application system must not exceed the expected infiltration rate of the soil based on the best available information.

4.6 General Hydraulic Design

The hydraulic design of FDE systems must take into consideration the physical and chemical properties of FDE, which may differ from clean water. The hydraulic design standards presented in this section apply broadly to all components of the FDE system, including drains, pipes, pumps, storage, and land applicators.

Material Selection

All inlet and conveyance structures must be constructed of corrosion resistant materials, as they may spend long periods of time submerged in potentially corrosive material.

Pipe Friction

Friction losses must be accounted for when designing a FDE system. Appropriate pipe sizes, for mainline and lateral pipes, should be selected that do not result in a friction loss of more than 2.0 m per 100 m of pipe.

Maximum Water Velocity

The maximum pipe water velocity should not result in a friction loss that exceeds the pipe friction standard.

Minimum Water Velocity

All pipes and open channels should achieve an average operating water velocity of ≥0.8 m/s, to ensure that solids do not settle and cause blockages.

Pressure Variation

The FDE land application system must be designed to apply within +/- 10% of target applied depth with acceptable uniformity and application intensity in any location. In general the total pressure at the applicator(s) should not vary by more than 20% of the design operating pressure at any point in the system.

Provision must be made for pressure measurement at both the pump and the applicator (ie either at the effluent irrigator or at the sprinklers depending on the applicator used).

Flow Control

All flow through the system must stop when the system is shut down for any reason. For systems with mainline running downhill from the liquid FDE storage facility, measures must be put in place to prevent the unintended:

- siphoning of the storage, and
- drainage of the main pipeline.

Flushing

Consider facility to allow the FDE conveyance system to be flushed with clean water. This will include collection as well as distribution infrastructure. Note when connecting to a fresh water supply that back flow prevention must be accommodated (see section 4.8).

4.7 Pump Motor Efficiency

Minimum Energy Performance Standards (MEPS) are included in AS/NZS 1359.5:2004, which sets out minimum energy performance and labelling of motors in Australia and New Zealand.

4.8 Back-Flow Prevention

The design must ensure that FDE cannot contaminate any fresh water source. Local regulations will dictate the type of back-flow prevention necessary.

In the absence of local regulation, an effective back-flow prevention device must be used if the FDE system is to be hydraulically connected to a freshwater source. This includes systems where FDE is injected into freshwater irrigation systems connected to a groundwater supply or surface water source.

5.0 MONITORING AND CONTROL

It is strongly recommended that all systems are designed with appropriate monitoring and control devices as described below.

Liquid Storage

A marker or water level measuring device should be installed in the FDE storage that clearly indicates stored volume and/or storage capacity remaining.

A marker or other measuring device should be installed to indicate the level of solids accumulation on the bottom of the storage. This should be visible after the liquid has been removed so the need for solids to be removed may be determined.

Flow Rates

A flow measuring device, or provision for a flow measuring device, must be installed on the delivery side of the FDE pump to measure the volume and flow rate of liquid FDE applied to land. Flow measurement is necessary for calculating how much nutrient has been applied to specific land areas.

Pump and Applicator Pressure

Pressure gauges or pressure test points must be installed at the pump outlet and at the inlet to the applicator to enable regular checking of performance.

The distance from a pressure gauge or test point to any valves must be at least three times the diameter of the pipe.

All pressure gauges should be fitted with an air-bell (or similar) to protect the gauge from corrosion and blocking. All pressure gauges should be fitted with isolating stopcocks (or similar) so they can be turned off to prevent damage when not in use.

Automatic Cut-offs

The following “Fail-safe” devices should be installed to protect the system and the environment.

- Automatic system shut-down that prevents damage to the system in case of high pressure failure (e.g. high pressure from pipe blockage or valve failure).
- Automatic system shut-down that avoids continuous pumping in case of low pressure failure (e.g. burst pipes, empty sump).

- For systems with travelling FDE irrigators, it is highly recommended an automatic shut off be installed that turns the system off when the irrigator stops moving for more than 5 minutes.
- It is highly recommended that fixed (stationary) land application systems be fitted with timers, or other means of automatically limiting the depth of application.

Alarms

Alarms should be installed on all liquid FDE storage units (including sumps) to indicate:

- when the normal pumping level has been exceeded, and
- just prior to the "emergency storage" capacity being exceeded, i.e., stormwater allowance and/or freeboard is used up.

6.0 TESTING AND COMMISSIONING

The commissioning process must demonstrate that all components of the system are operating properly and according to the system specification over the range of on-site conditions expected.

Appropriate manuals and training must be provided with every FDE system.

Evaluation Process

The installed system must be tested to determine that the performance standards have been met.

Table 1 lists the acceptable level of deviation from the system specification.

Table 1: Acceptable deviation from system specification.

Parameter	Acceptable Performance
Storage volume	Must not be less than that specified.
Pump flow rate	Must be within ±5% of the system specification.
Pressure at the applicator	Average pressure must be within ±10% of the system specification. Pressure variation at the applicator(s) must be according to the limits in Section 4.6.
Application depth (adjusted for uniformity)	Must be within 10% of that specified.

Commissioning Report

A commissioning report must be provided to the purchaser after carrying out the testing and commissioning of the system. This report will describe the system as it was installed, including the evaluation of its performance.

If actual performance is significantly different from the system specification, an explanation must be made, and the consequences of the differences between assessed need and proposed system performance explained to the purchaser.

The commissioning report must include:

- Date of commissioning
- Procedures followed during commissioning
- Results of performance testing
- An as-built plan

As-Built Plan

A final clear and concise readable plan, drawn to scale, with all key items located on the plan must be provided after commissioning. A revised as-built plan must be provided following any significant changes to the FDE system.

The plan must provide accurate locations, dimensions and sizes of all key components in the system and indicate areas where effluent can and cannot be applied.

Operation Manual

A system operation manual must be provided, and must include:

- protocols for operating the system safely
- methods for monitoring system performance (e.g. how to read flow rate or operating pressure)
- optimal operating range(s) and how to achieve them
- guidance regarding the scheduling of FDE applications
- a system plan, indicating the prevailing wind direction relative to North
- how the system handles extreme natural events such as large rainfall events
- how environmental impacts will be monitored, and
- emergency procedures.

Maintenance Manual

A system maintenance manual must be provided, and must include:

- a service manual and parts list, and
- a schedule of maintenance and replacement that specifies the frequency of inspection and service for all elements of the system.

Training

Training that covers all of the main items in the operation and maintenance manuals must be made available for the purchaser and system operator.

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DEFINITIONS

For the purposes of this document, the following definitions shall apply:

Application Area The area (hectares) to which FDE will actually be applied, excluding those parts of paddocks that are not reached by the irrigator.

Application Depth The mean depth (mm) of liquid FDE applied to the soil surface during a single application event.

Application Intensity The rate (mm/hr) at which FDE is applied to land.

- Instantaneous Application Intensity (R_i)
  The rate (mm/hr) at which FDE is applied by an individual stream, from an individual outlet or nozzle, to a very small area. For example, for a rotating boom it is the flow from a single outlet divided by the area being wetted at any instant by that outlet.
- Average Application Intensity (R_a)
  The rate of application (mm/hr), averaged over the individual applicator's wetted footprint. For example, for a rotating boom it is the applicator's flow rate divided by the area wetted by one full rotation of the boom.

Application Rate The commonly used alternative term for application intensity.
Note: It does not mean applied depth per event (see Application Depth) or applied depth per day.

Application Uniformity The spatial variability (measure of the evenness of coverage) of application. This can be defined in a variety of ways. Common examples are:

- Distribution Uniformity (DU)
- Coefficient of Uniformity (CU)
- Coefficient of Variation (CV)

Back Flow Preventer A device designed to prevent water from flowing in reverse through the system. For FDE systems, these are generally used to prevent FDE from mixing with clean water sources.

Capital Cost The overall system purchase and installation cost ($), expressed as a total or annualised cost.

Design Specification A document that defines site-specific performance targets that a proposed FDE system must be able to achieve. A designer prepares the final design to meet these requirements.

Distribution Uniformity (DU) One measure of application uniformity. With FDE application it is usual to use upper quartile distribution uniformity (DU_{uq}), which compares the average of the highest quarter of (measured) applied depths with the average depth of all (measured) applied depths. DU_{uq} puts higher emphasis on over-watering.

Evapotranspiration Rate (ET) The rate of water loss from the combined vegetation and soil surfaces (mm/day). It includes evaporation of water from the soil surface and the surface of plants, and transpiration by plants.

Farm Dairy Effluent (FDE) All material (solid or liquid) that has been in contact with animal manure, and is destined for storage or application to land. This includes the manure itself (i.e. faeces and urine) as well as any wash-water, bedding material, feed, milk, etc. that is mixed with it.

FDE Characterisation Determination of the make-up and expected variation over time of FDE including:

- Quantity
- Total solids content
- Nutrient content especially Total Nitrogen, Total Phosphorous and Total Potassium.

FDE Production Rate The amount of FDE being produced in a given time period (e.g. m^3/day, l/cow/day).

Field Capacity The water content of a soil after drainage from an initially saturated condition. At field capacity, the macro-pores of the soil are filled with air and the micro-pores hold water by capillary action. This generally occurs at a soil suction of approximately 0.1 bar.

Hydraulic Design The process of determining system operating pressures and flows and selecting componentry to achieve the specified performance requirements

Infiltration Rate The rate at which the soil can absorb water (mm/hour). Infiltration rate changes according to the wetness of the soil.

Leaching Deep percolation of dissolved salts, nutrients, or biological contaminants beyond the root zone of plants.

Limiting Nutrient The nutrient in FDE (e.g. N, P, or K) with the highest concentration relative to the annual demand for that nutrient. As FDE is applied, the limiting nutrient will be the first to reach its annual limit.

Nutrient Budget A calculated balance of nutrient additions and removals from an area of interest, such as an effluent application field.

Pumping Rate The volume of FDE per unit time that a pump is designed to pump at the design pressure (ℓ/s or m^3/hr).

Profile Available Water (PAW) The maximum amount of water that can be held in the soil that is extractable by plants. This is equal to the difference in the volume of water in the top 90 cm of soil at a suction of 0.1 bar and the volume of water in the soil at a suction of 15 bar. The fraction of this that is held in the soil at suction less than approximately 5 bar is considered “readily available”.

Soil Water Deficit The amount of water (mm) required to restore a soil to field capacity from its current moisture status.

Solids Material present in FDE that is not in the liquid state. Solids may be separated from liquids by a number of methods, including screens, filters, and settling basins.

Stress Point The soil moisture content below which plant growth will be limited by the rate at which it can extract water from the soil. This point is different for different plants, but generally occurs at soil suctions below approximately 5 bar.

Surface Ponding Liquid that does not immediately infiltrate into the soil, and collects on the lowest points in the micro-topography of the soil surface.

Surface Runoff Liquid that does not immediately infiltrate into the soil, and runs across the soil surface by gravity.

Surface Water Body Any significant accumulation of fresh water that is visible on the surface of the earth. Surface water bodies include lakes, rivers, streams, wetlands, water races, watercourses, and drains.

System Specification A document that describes what the final FDE system will comprise of, and what it will be capable of achieving. A system specification:

- lists components of the system, e.g., pipes and pumps
- shows their locations, and
- describes their key specifications, e.g., diameters, speeds, pressures.

Total Solids (TS) The residue remaining after FDE has been evaporated and dried at a specified temperature (103 to 105°C) (Metcalf & Eddy, 2003)

Appendix A: Summary of Standards

Summary of Standards

Parameter	Unit(s)	Standard
Land application area	ha	No less than the design specification (see Section 4.1)
Minimum achievable application depth	mm	No greater than the system specification (see Section 4.3)
Application intensity	mm/hr	< design soil infiltration rate, according to Section 4.5
Application uniformity	% ratio	DU_{uq} < 1.25 Or DU_{lq}>0.80
Pumping rate	ℓ/s	±5% of the system specification
Pressure at the applicator	m bar kPa	Average pressure must be within ±10% of the system specification. Pressure variations at the applicator(s) must be according to the limits in Section 4.6.
Effective liquid storage volume	days m^3	Not less than the system specification (see Section 3.1)
Effective solids storage volume	days m^3	Not less than the system specification (see Section 3.2)

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